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ELECTROSTATIC PRECIPITATOR FOR INCINERATOR

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Abstract: Air pollution and waste management are some of the major concerns in the modern era. One of the common methods used for waste management and is growing in popularity is incineration. Incineration generates flue gas which contain harmful particulate matter and acid gases which if not treated are harmful pollutants. Decreasing the concentration of aerosol particles helps reduce the incidence of respiratory tract infections that can lead to disease and even death. Industries use electrostatic precipitator to treat the exhaust, whereas in domestic application, minimal effort is taken to do the same. A compact, low-cost electrostatic precipitator that requires low input voltages is designed to solve the need for air pollution control in domestic incinerators. Generation of high voltage in the electrostatic precipitator can be achieved by using a Cockcroft - Walton Multiplier and Flyback Transformer. High voltage generated cause a high voltage arc between the electrodes of an electrostatic precipitator that produce an electrostatic charge on the particulate matter. These charged particulate matter are then collected using oppositely charged collector plate.

Keyword: Electrostatic precipitator (ESP),Cockroft-Walton Multiplier(CW)

I. INTRODUCTION

Incinerator wastes are deliberately dispersed or released to the environment, carrying with them the diversity of pollutants formed or redistributed during the incineration process. Through this project the emissions from the incinerator can be controlled to an extent. Airborne particulate matter can be effectively removed using electrostatic precipitators (ESPs). The precipitator functions by applying energy only to the particulate matter being collected, without significantly impeding the flow gases. Precipitators function by electrostatically charging particles in the gas stream. The charged particles are attracted to and deposited on plates or other collection devices. The energy to be supplied to the plates are supplied from Cockcroft-Walton Multiplier. A multiplier is an electric circuit that generates high DC voltage from a low voltage input. It is made up of a voltage multiplier ladder network of capacitors and diodes to generate high voltages. Unlike transformers, this method eliminates the requirement for the heavy core and the bulk of insulation/potting required.

II. CONSTRUCTION DETAILS

The Driver Circuit mainly uses an IR2110 IC. It is a 14 pin IC and is used to drive a high side and low side MOSFET simultaneously. The pin description of the IR2110 is shown in the table 4.1. In the circuit, the IR2110 is used to generate a square wave of frequency 50kHz which is supplied to an AC flyback transformer. V_{DD} is the supply Voltage to the Logic Circuit in the IR2110 and is 5V.

ATMEGA328P – PU Microcontroller is used to supply 2 square pulses of 50kHz, inverted to each other, simultaneously to H_{IN} and L_{IN} pins of the IR2110 (Fig 3.2), these are the logic inputs to the IC. A High Signal to H_{IN} indicates the High Side MOSFET, U1 needs to be driven and vice versa. Similarly, a High Signal to L_{IN} indicates the Low Side MOSFET, U2 needs to be driven and vice versa. D1, C4 form the Bootstrap Circuit (Fig 3.2). It provides a floating supply for the High side gate of U1. When a high signal is supplied to LIN, U2 turns ON and the capacitors C4 gets charged to a voltage level of V_{CC} minus the voltage drops across diode D1, which is the voltage at V_B. When a high signal is applied to H_{IN}, V_B adds an extra voltage greater than the source voltage of U1 to the output of H_O. L_O and H_O are outputs to the gate of MOSFET's U1 and U2, to drive it simultaneously and complementary to each other at 50kHz. These MOSFET's are part of a Half Bridge circuit, consisting of capacitors C6 and C7. The Half Bridge is supplied by a dedicated power supply of 24V and the voltage across C6 and C7 is 12V. The primary of the flyback transformer is placed at the load of the Half Bridge. When U1 turns ON, current flows from U1 to the primary and through the Capacitor C7 to ground. After U1 turns OFF, U2 turns ON and the direction of current reverses from C6 to the primary and through U2 to ground. The bidirectional current flowing through the primary creates a square wave across the primary at 50kHz.

The Cockcroft-Walton multiplier is an electronic circuit that can multiply an AC voltage by a factor of two or more. It is also known as a voltage multiplier, ladder circuit, or Greinacher circuit. The basic principle behind the Cockcroft-Walton multiplier is the use of diodes and capacitors to store and transfer charge between successive stages of the circuit. The circuit consists of a ladder-like structure of diodes and capacitors, with each stage of the ladder doubling the voltage of the previous stage. In the circuit the secondary of the flyback transformer (AC voltage of 5kV, 50kHz) is then connected onto a Cockroft Walton Multiplier Circuit. During the positive half cycle, capacitor C1 gets charged up to 5kV (Fig 3.3). In the next half cycle, the diode D1 gets forward biased along with the discharge of capacitor C1, which then charges the capacitor C2 to double the supply voltage, which is 10kV. This is the 1st stage. During the next positive half cycle, C2 discharges through diode D3 and C3 gets charged to voltage 10kV. In the next negative half cycle C3 gets discharged through D4 along with the addition of 5kV to charge capacitor C4 to 15kV. This is the 2nd stage. This process goes on till the 8th stage. The output is taken from points A and B which is 60kV (as per the design given in Chapter 4) and is then connected onto the electrodes of the Electrostatic Precipitator.

Electrostatic Precipitator's are effective devices used for the removal of particulate matter in gas stream. It consists of a discharge electrode and a collector electrode which are oppositely charged. The air stream when passing through the ESP will first encounter the discharge electrode which is negatively charged. The discharge electrode would discharge electrons into the gas stream. The gas molecules with the electrons attached to it would be negatively charged. Particulate matter in the gas gets charged based on the surface of the matter. For sizes greater than 2um in diameter, the particles get charged by collision with the negatively charged gas molecules. As particle size decreases, charging takes place by diffusion, where a negative charged gas molecules induces charge on nearby flowing particulate matter. The charged particulate matter would then be collected on collector electrodes which are oppositely charged plates. This would free the air stream from particulate matter

III. HARDWARE IMPLEMENTATION

The driver circuits, AC Flyback transformer, Cockroft- Walton voltage multiplier, and precipitator electrodes are assembled as part of the electrostatic precipitator's hardware implementation. The Driver circuit was designed onto a Printed Circuit Board (PCB) as shown in Fig 5.8 and Fig 5.9.

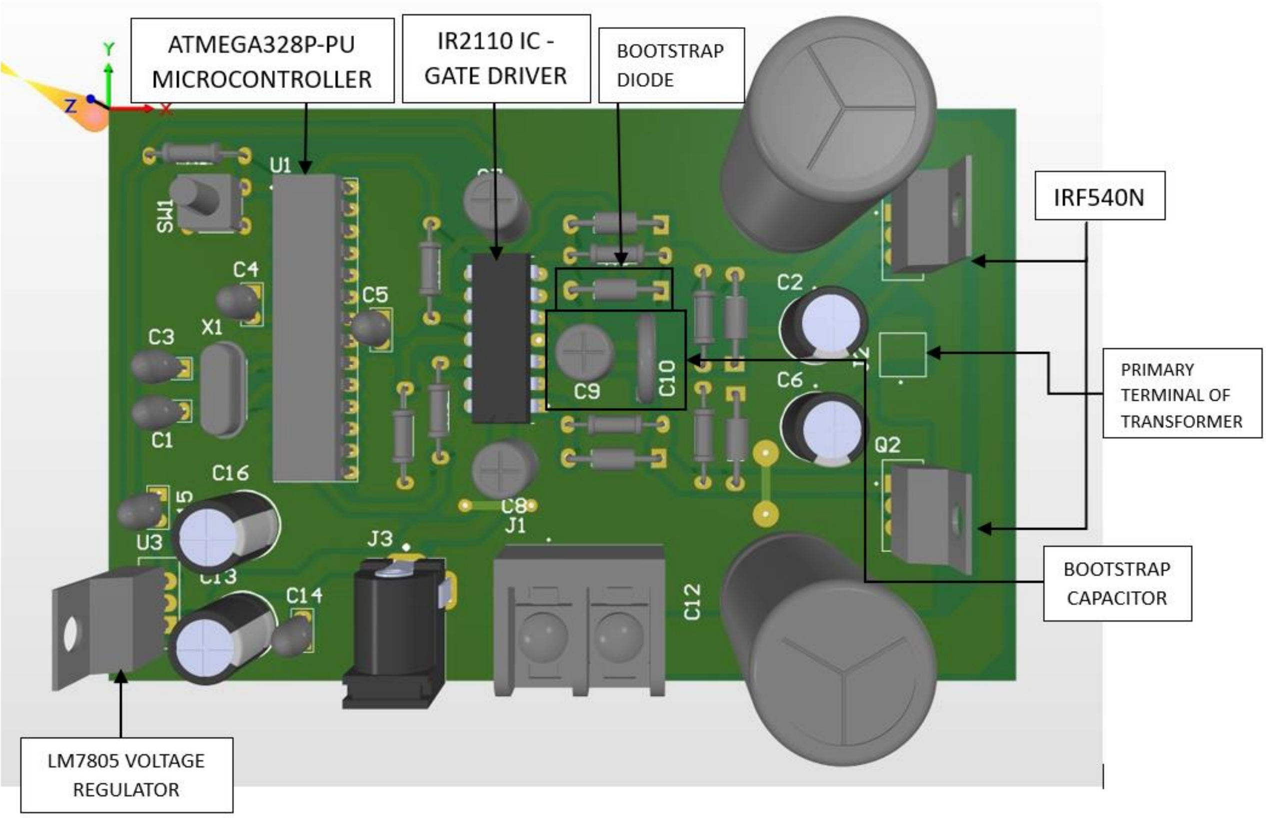

Fig.1 PCB layout of driver circuit

The PCB was designed using Altium software. The circuit was etched onto a copper clad board and each component were soldered onto it. The PCB required a 12V DC and 24V DC Power Supply of which the 24V DC Power was supplied by SMPS.

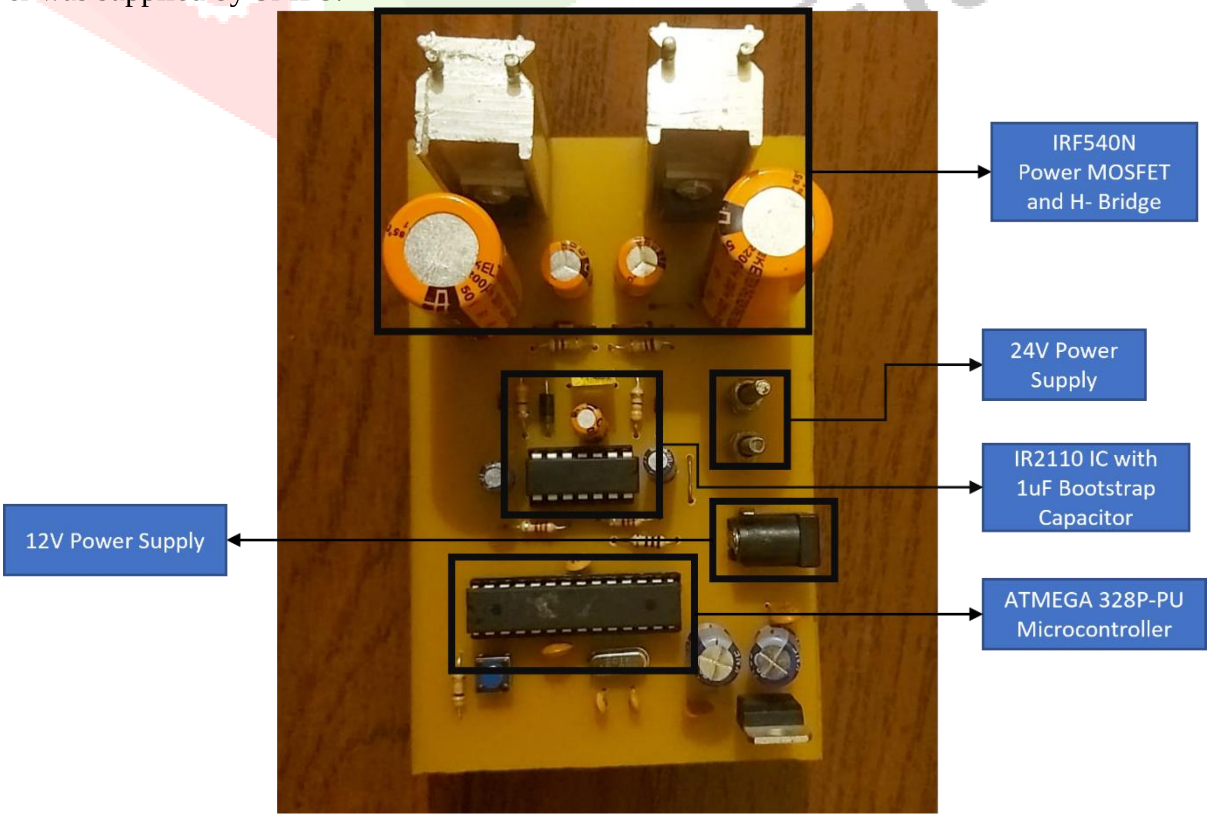

Fig.2 Hardware implementation of driver circuit onto PCB

The Cockroft Walton Multiplier Circuit was implemented onto polycarbonate sheet (Fig 5.10). It was then coated with varnish to prevent the capacitors from internal discharge. The output was then taken from the end of the last capacitor and connected onto the precipitator.

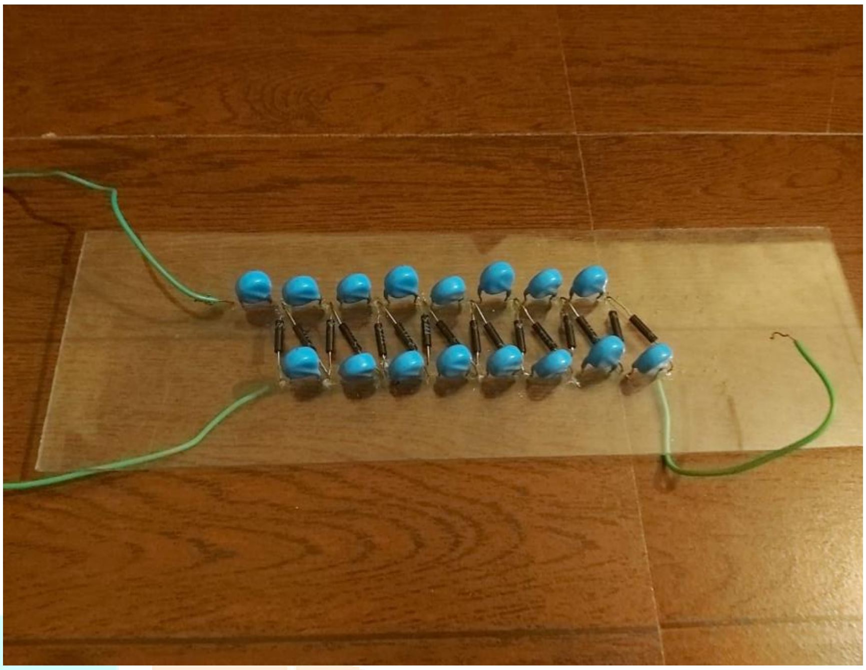

Fig.3 Hardware implementation of Cockroft-Walton Multiplier

The hardware implementation of an electrostatic precipitator project involves assembling the necessary components to create a functional system that can remove fine particles from air stream using electrostatic forces. The implementation for a small scale electrostatic precipitator project was possible using a PVC pipe of 4-inch diameter as the body of the electrostatic precipitator. This material is chosen due to its properties like lightweight, fire resistance, non-toxic material, etc. The negative electrode is a stainless steel mesh, which is attached to the inner wall of the PVC pipe. Stainless steel is chosen due to its properties such as high corrosion resistance, high tensile strength, and temperature resistance. The mesh is chosen due to its ability to create a large surface area for particle collection and efficient flow of gas. A stainless steel sheet is rolled up to be shaped as a cylinder. The cylinder acts as the positive electrode, and it is placed in the centre of the PVC pipe. The cylinder is attached to a high-voltage power supply to generate an electrostatic field between the positive and negative electrodes. The electrostatic field charges the particles in the gas stream, which then become attracted to the negatively charged stainless steel mesh and are collected there.

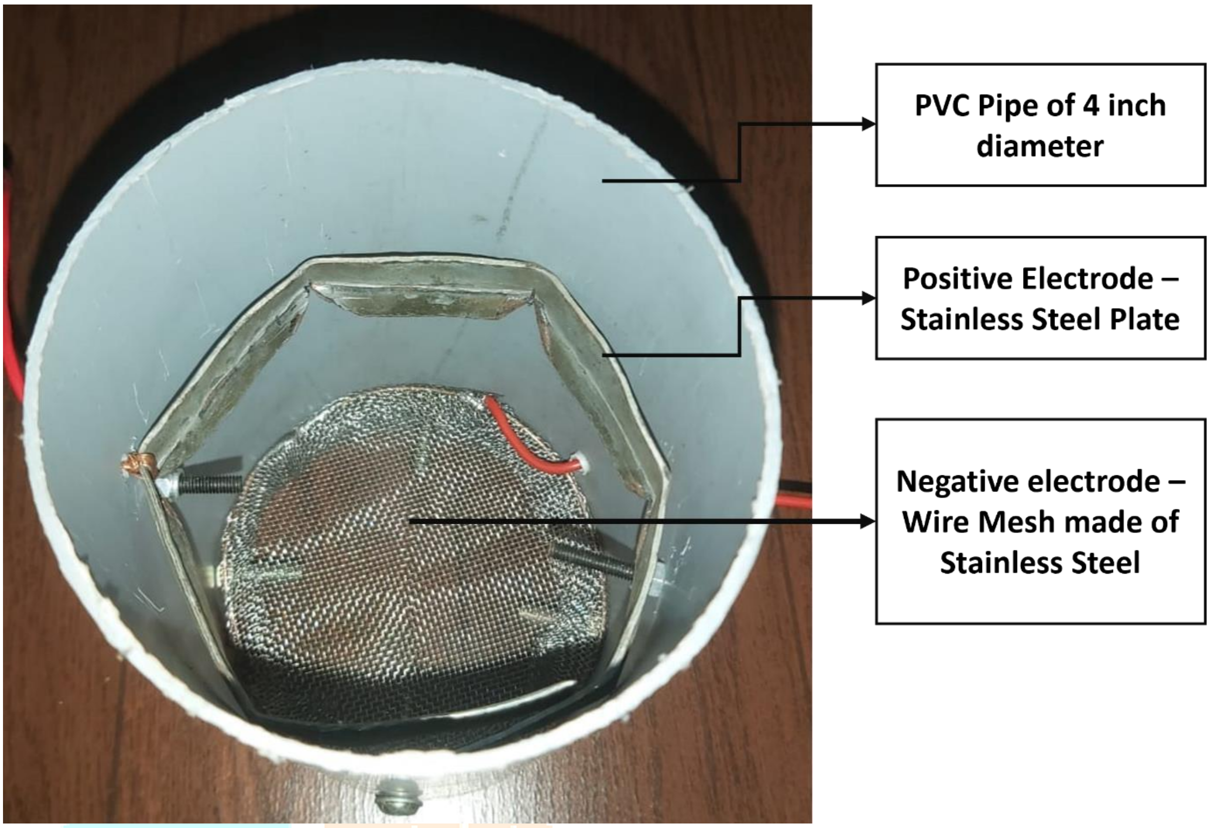

Fig.4 Hardware implementation of precipitator

The materials used in this implementation were chosen based on the requirements of the project, such as the need for lightweight, fire resistance, and efficient particle collection. This working model is designed for carrying out the process of charging the gas particles that can be collected and separated efficiently. To ensure the efficient operation of the electrostatic precipitator, the gas flow rate and spacing between the electrodes must be optimized.

IV. RESULT

The circuit used for generating 50kHz includes a driver IC - IR2110. The circuit was constructed onto a PCB with 2 input supply - 24V and 12V DC supply. As stated earlier the 24V supplies the H - Bridge circuit, used to generate a square wave of 50kHz that is input to the primary of the flyback transformer.

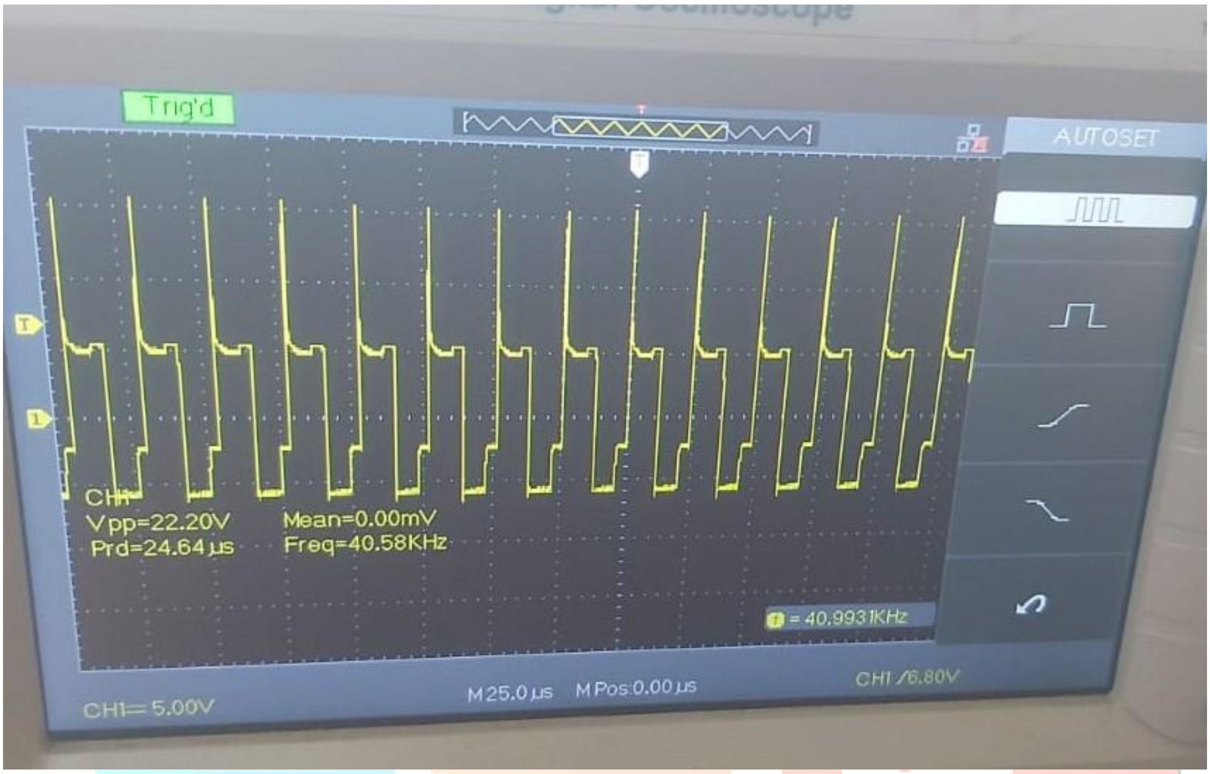

Fig.5 Output of driver circuit with 12V input to H-bridge

The driver circuit produced a square wave of 50kHz with 24V peak to peak voltage The Cockroft Walton Multiplier is used to multiply the input voltage to generate high voltage at the output. This circuit was designed to generate an output of 59.30kV for
an input of 5kV.

The circuit produced an arc length greater than 5cm. Due to the limitation of measuring the voltage, the assumption that an arc of 1cm generates 10kV was considered and as a result, the output voltage of the Cockroft Walton Multiplier circuit is greater than 50kV as shown in Fig 6.1.

The Electrostatic Precipitator was designed to filter the particulate matter from the air stream passing through it. A model of the Electrostatic Precipitator was designed as shown in Fig 5.10. The model was tested using smoke from Agarbathi. When the precipitator is OFF, precipitation does not occur, and smoke is visible as shown in Fig 6.2. Whereas when the precipitator is ON, the smoke particles are collected onto the positive electrode and the air stream is clear as shown in Fig 6.3.

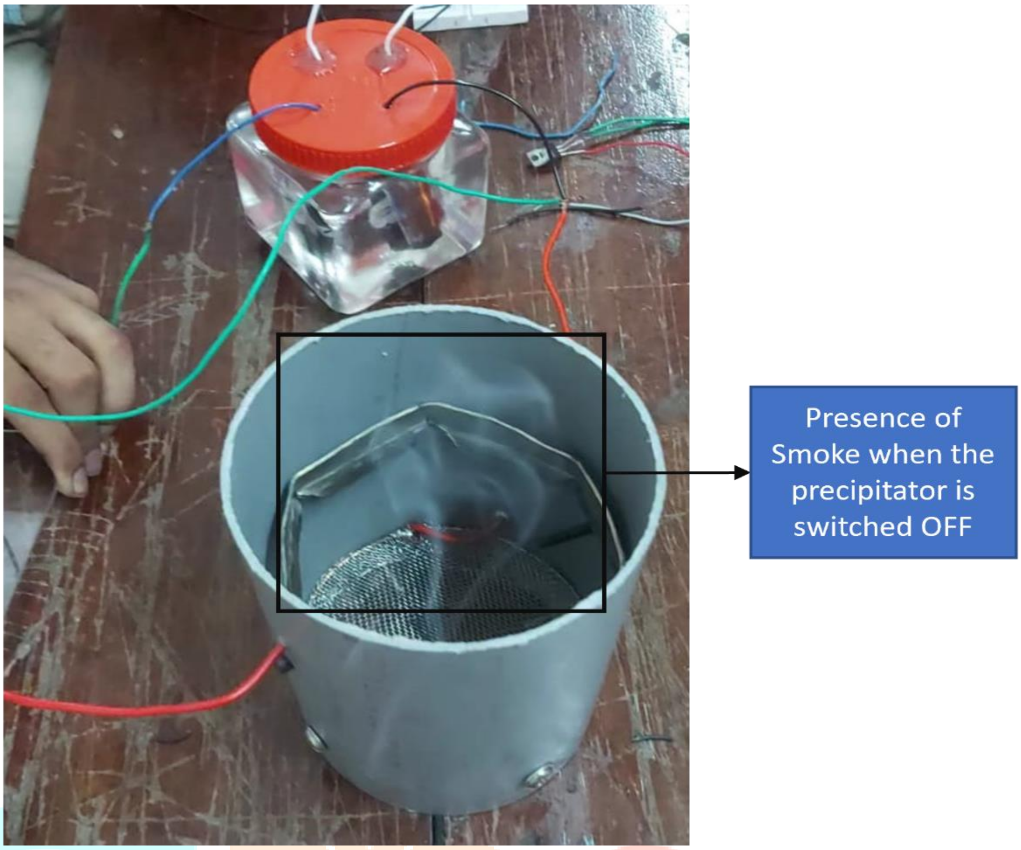

Fig.6 Electrostatic Precipitator is OFF

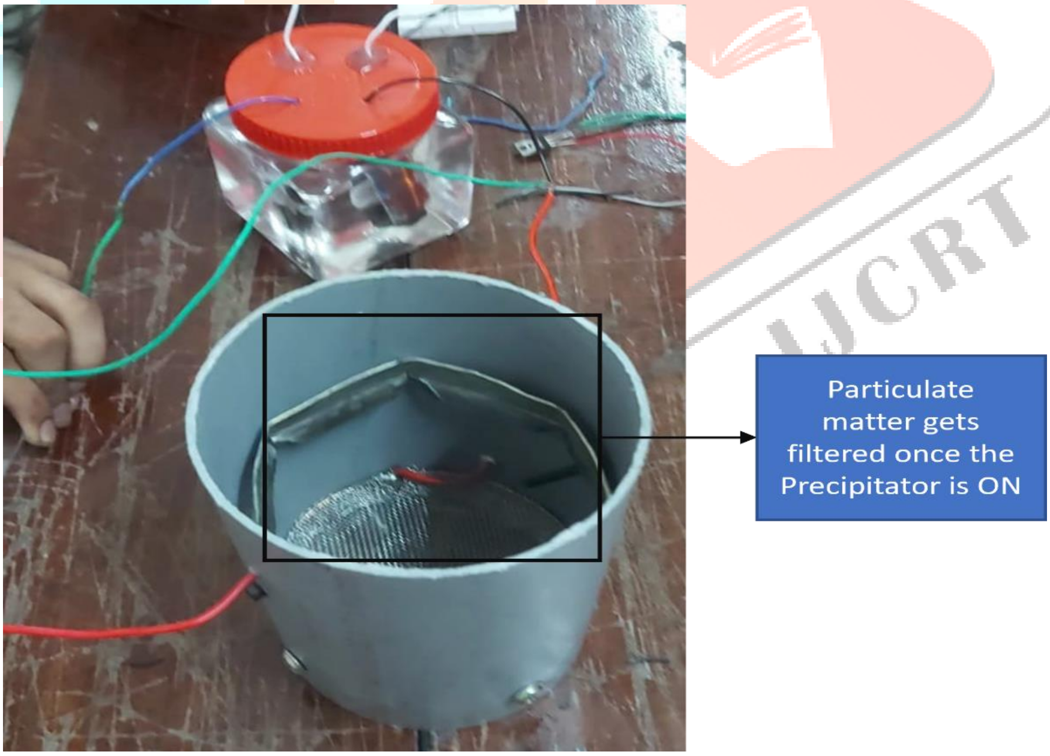

Fig. 7 Electrostatic Precipitator is ON

V. CONCLUSION

The project aimed at creating a model that would filter particulate matter from the air stream produced by domestic incinerator. Through thorough research and itera- tion. an Electrostatic Precipitator was designed, with a compact design compared to bulky traditional precipitators used in industries to filter particulate matter from the air stream. The high voltage required for the precipitator was provided by using a Cockroft-Walton multiplier which multiplies the voltage from the flyback transformer. The prototype model of the precipitator was designed and tested by passing smoke from Agarbathi. Particulate matter was filtered from the air stream and clear gas was given out.

VI. ACKNOWLEDGEMENT

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VII. REFERENCE

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