The Development of Microcontroller-based Electrostatic Air Filter Device using Flyback Transformer

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Abstract: This study aimed to develop a microcontroller-based air filter device using electrostatic method with high voltage obtained from flyback transformer. The design of flyback transformer required several circuits, such as ATmega 328 microcontroller, optocoupler, and driver, whereas the electrostatic method was applied by arranging aluminum metal plates parallel with three anodes and cathodes. The results showed that the duty cycles of 30%, 40%, 50%, 60%, and 70%, produced an output voltage of 2.632 kV, 7.250 kV, 13.16 kV, 20.01 kV and 27.55 kV, respectively, with the amount of dust particles as much as 0.2122 grams, 0.5147 grams, 0.8960 grams, 1.1620 grams and 1.9267 grams. These results suggest that higher the duty cycle results in higher output voltage and larger amount of filtered dust.

1 INTRODUCTION

The development of research on high voltage is rapidly increased; It requires a large and complicated circuit. However, the research on the application of high voltage is not only for industrial scale, but also must be developed in all fields, especially in the health sector (Barsoum, 2015). In the field of high voltage health, it can be used as an air filter. Air is an environmental medium that is a basic human need, so it needs to get serious attention. Healthy air at homes and offices is a necessity in the era of modern society. We cannot deny that particulate air in homes and offices can endanger human health (Sudrajad A, 2019). Based on WHO data in 2012, around 7 million people die each year from diseases related to air pollution. In this case including heart disease, stroke, lung and breathing, and cancer. On the other hand, pollutants in the air not only endanger health but also disrupt the climate such as fine particle, black carbon, and surface ozone (O_3)(Soemirat, 2014).

Dust particles are in the air for a relatively long time in a state of floating and then entering the human body through breathing so that it can endanger health. Every material including dust can be considered as an electrically charged particle that will have the property of attraction with other particles of different charge and repel with particles that have the same charge (Gianto, 2015). Regarding that, a study conducted by Raditya et al. showed an air filter with a trade capacity of 8 kV using the Walton Cockroft method electrostatically. However, they could only precipitate dust of 0.001541 grams in 60 hours with an average of 0.000154 for six hours (Raditya, 2011). Therefore, further study needs to be done on the development of air filter device.

Based on those explanations, in this research, an electrostatic air filter was developed using high voltage obtained from flyback transformer. The air filter is carried out using aluminum plates arranged in a parallel order, by providing an electric field so that dust particles in the air settle to the plates with different charges. The system was controlled by utilizing ATmega328 microcontroller.

2 METHODS

The method of conducting this research was carried out in two stages, namely the design of a high voltage device using the flyback transformer method and an air filter device using the electrostatic method.

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2.1 Design High Voltage Devices using the Flyback Transformer Method

Flyback Transformer is a transformer with a ferrite core that generates a high voltage on the cathode ray (CRT) both on television and on the monitor. The main function of this transformer is to trigger (fire) electrons in a CRT tube. Flyback transformer has several winding namely primary and secondary winding. Secondary windings are wound in geater amounts than primary winding with the aim of different voltage levels so that they can bend and accelerate the electron beam. Flyback transformers are made of a coil with quality wire wrapped around the ferrite core with air blemishes. This function is to store energy in air blemishes and induce.

To get the output voltage in kilovolts, several circuits are needed, namely the ATmega 328 Microcontroller, optocoupler, and driver. The advantage of using the flyback method is that it can produce high output voltages with low input voltages. The process of the circuit can be seen in Figure 1 below:

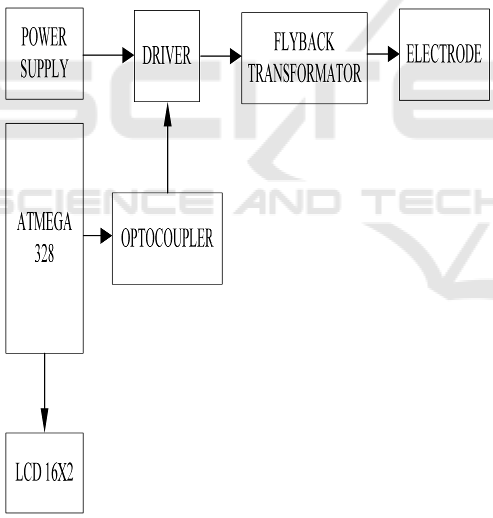


Figure 1: Block diagam

In the process a minimum voltage of 5 volts is needed to activate ATgaga 328, to provide regulating the duty cycle at the foot of the Atmega 328, the duty cycle setting uses a progam that is entered through a computer to the Atmega 328, the duty cycle can be adjusted using a potentiometer which will then be displayed on the LCD. The progam process of the Atmega series can be seen in Figure 2 below:

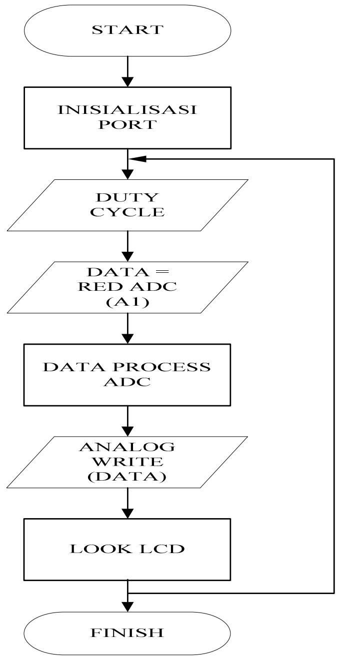


Figure 2: Flowchart

In this circuit, all components must be in a high voltage phase, so it is not damaged, such as the optocoupler. The function of the optocoupler is to deliver high voltage to the Insulated Gate Bipolar Transistor (IGBT) driver, which will then be transmitted to the flyback transformer leg. Then from the flyback will come a high voltage in the kilovolt scale, which is measured using a 40kV high Lutron High Voltage Probe. The series of all the tools can be seen in Figure 3 below:

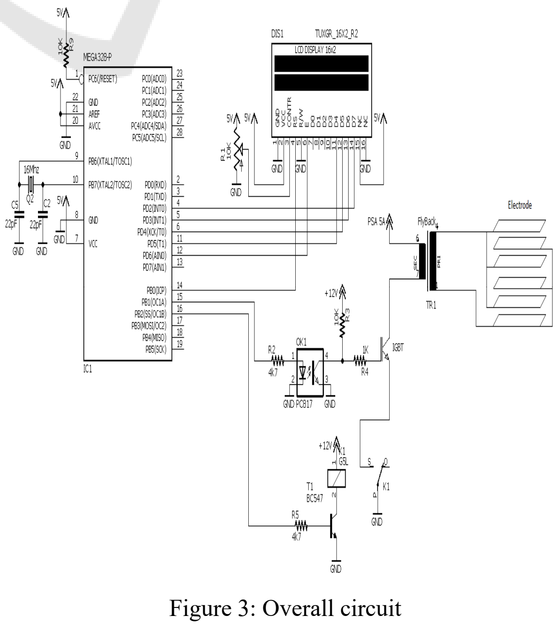


Figure 3: Overall circuit

2.2 Design the Air Filter using the Electrostatic Method

The dust has to settle properties due to the earth's gavity force. Also, the dust has static electricity (electrostatic) properties that will be attracted to particles opposite the charge and away from similarly charged particles. The material that we normally experience can be seen from a form of three kinds of particles which have mass and particle charge can be seen in Table 1 below:

Table 1: Mass and particle charge

Particles	Symbol	Load	Mass (kg)
Proton	P	+e	1.67×10^{-27}
Neutron	N	0	1.67×10^{-27}
Electron	E	-e	9.10×10^{-31}

Electrostatic is the force that arises on two objects that have static electricity, this is in accordance with the sound of Colomb's law "The electric force (attraction or repulsion) between two electric charges is proportional to the amount of electric charge each and is inversely proportional to the square of the distance split between the two electric charges. "

$$F = k\frac{q_1 \times q_2}{r^2} \quad (1)$$

The design of the air filter referred to here is an aluminum metal plate arranged parallel to three anodes and three cathodes intermittent with a length of 30 cm, width 20 cm and 0.8 mm thick, aligned with a distance of 2.5 cm. This is done so that no plasma discharge occurs when connected to a flyback. The series of overall tools can be seen in Figure 4 below:

Figure 4: Overall set of tools

3 RESULT AND DISCUSION

From a current of 220 ACV, the current is changed to 12 DCV using a power supply and then converted to 5 DCV using a Regulator IC, which will then be connected to the Atmega 328. The Atmega 328 microcontroller circuit also obtained a frequency that passes through the optocoupler that is equal to 3 kHz.

3.1 Measurement of High Voltage using the Lutron 40kV HV Probe

With an input voltage of 12 volts on the flyback, an output voltage using a 40kV Lutron HV probe is obtained. The Lutron 40kV HV Probe readout used a scale with a ratio of 1: 1000 on the multimeter reading, the output voltage obtained from the flyback at a duty cycle of 30%, 40%, 50%, 60%, and 70% can be seen in Table 2 below:

Table 2: Measurements with the 40kV Lutron HV Probe

Duty Cycle (%)	Vout (kV)
30 %	2.632
40 %	7.250
50 %	13.16
60 %	20.01
70 %	27.55

From the data in table 2, can be illustrated graph output voltage vs. duty cycle as in Figure 5 below:

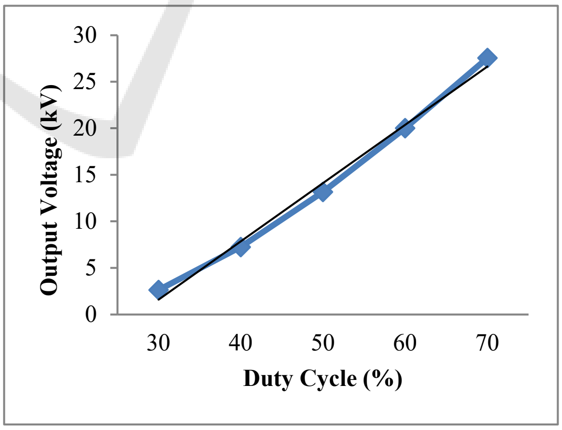


Figure 5: Graph of output voltage vs duty cycle

Figure 5 shows that the higher the duty cycle, the higher the output voltage. This is because the PWM pulse width expressed in the duty cycle changes linearly which causes the output voltage to change.

3.2 Dust Weight with 2.632kV (30% Duty Cycle)

Dust weight with a voltage of 2.632kV at a 30% duty cycle. And obtained the weight of dust at each time of data collection, in table 3 below:

Table 3: Dust weight at any time at 2.632kV

Time (Hours)	Dust Weight (g)
18:00 – 00:00	0.0205
00:15 – 06:15	0.0032
06:30 – 12:30	0.0211
12:45 – 18:45	0.0668
19:00 – 01:00	0.0135
01:15 – 07:15	0.0033
07:30 – 13:30	0.0303
13:45 – 19:45	0.0404
20:00 – 02:00	0.0070
02:15 – 08:15	0.0061

From the data in table 3, we can illustrate the dust vs. time weight graph as in Figure 6 below:

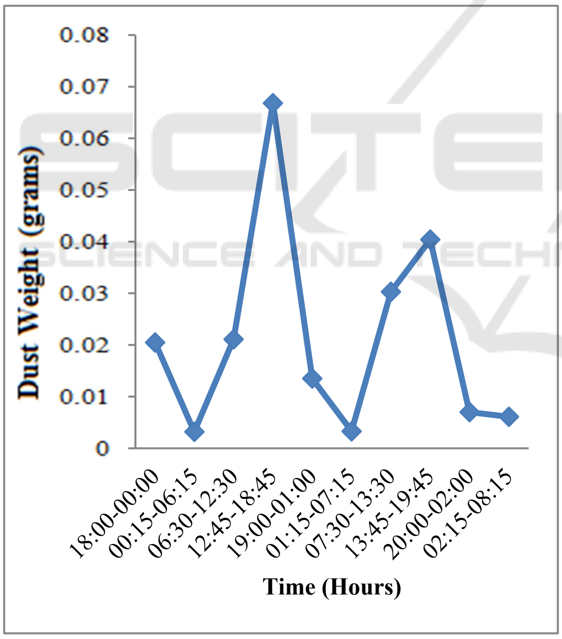


Figure 6: Dust weight vs time graph at 2.632kV

Based on the graph above, it can be seen that the weight of dust at 12:45 - 18:45 WIB more than the others, the weight obtained is as much as 0.0668 grams, this is because at that hour many vehicles are passing or congestion that occurs occur. Whereas at 00:15 - 06:15 WIB less than the others, the weight obtained is 0.0032 grams, this is because at that hour it can be said that there is almost no driving activity.

3.3 Dust Weight with 7.250kV (Duty Cycle 40%)

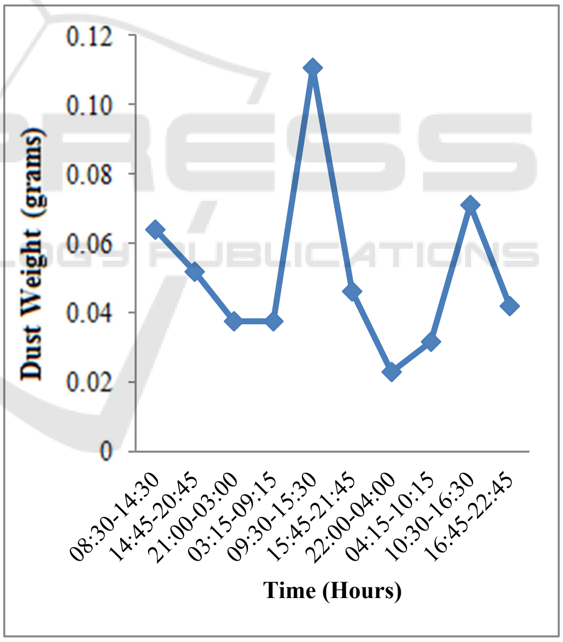
Dust weight with a voltage of 7.250kV at a 40% duty cycle. And obtained the weight of dust at each time of data collection, in the following table 4:

Table 4: Dust weight at any time at 7.250kV

Time (Hours)	Dust Weight (g)
08:30 – 14:30	0.0639
14:45 – 20:45	0.0518
21:00 – 03:00	0.0375
03:15 – 09:15	0.0375
09:30 – 15:30	0.1105
15:45 – 21:45	0.0461
22:00 – 04:00	0.0229
04:15 – 10:15	0.0316
10:30 – 16:30	0.0710
16:45 – 22:45	0.0419

From the data in table 4, we can illustrate the dust

Figure 7: Dust weight vs time graph at 7.250kV



Based on the graph above, it can be seen that the weight of dust at 09:30 - 15:30 WIB more than the others, the weight obtained is as much as 0.1105 grams, this is because at that hour many vehicles are passing or congestion that occurs occur. While at the time of 22:00 - 04:00 WIB less than the others, the weight obtained is as much as 0.0229 grams, this is because at that hour it can be said that there is almost no driving activity.

3.4 Dust Weight with 13.16kV (Duty Cycle 50%)

Dust weight with a voltage of 13.16kV at a 50% duty cycle. And obtained weight of dust at each time of data collection, in the following table 5:

Table 5: Dust weight at any time at 13.16kV

Time (Hours)	Dust Weight (g)
23:00 – 05:00	0.0449
05:15 – 11:15	0.0741
11:30 – 17:30	0.1912
17:45 – 23:45	0.0820
00:00 – 06:00	0.0594
06:15 – 12:15	0.0746
12:30 – 18:30	0.1282
18:45 – 00:45	0.0724
01:00 – 07:00	0.0628
07:15 – 13:15	0.1064

From the data in table 5, we can illustrate the dust vs. time weight graph as in Figure 8 below:

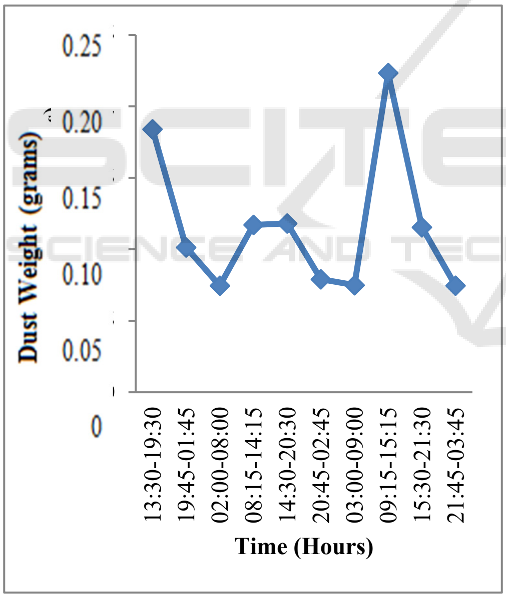


Figure 8: Dust weight vs time graph at 13.16kV

Based on the graph above, it can be seen that the weight of dust at 11:30 - 17:30 WIB is more than the others, the weight obtained is as much as 0.1912 grams, this is because at that hour many vehicles are passing or congested occur. Whereas at 23:00 - 05:00 WIB less than the others, the weight obtained is 0.0449 grams, this is because at that hour it can be said that there is almost no driving activity.

3.5 Dust Weight with 20.01kV (Duty Cycle 60%)

Dust weight with a voltage of 20.01kV at a 60% duty cycle. And obtained the weight of dust at each time of data collection, in the following table 6:

Table 6: Dust weight at any time at 20.01kV

Time (Hours)	Dust Weight (g)
13:30 – 19:30	0.1840
19:45 – 01:45	0.1013
02:00 – 08:00	0.0745
08:15 – 14:15	0.1170
14:30 – 20:30	0.1181
20:45 – 02:45	0.0790
03:00 – 09:00	0.0749
09:15 – 15:15	0.2233
15:30 – 21:30	0.1554
21:45 – 03:45	0.0745

From the data in table 6, we can illustrate the dust vs. time weight graph as in Figure 9 below:

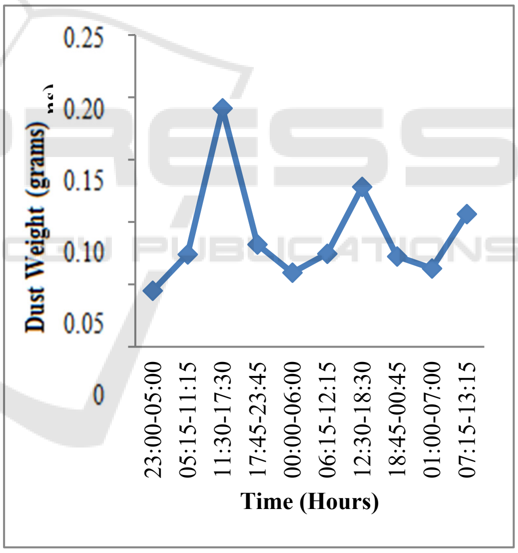


Figure 9: Dust weight vs time graph at 20.01kV

Based on the graph above, it can be seen that the weight of dust at 09:15 - 15:15 WIB more than the others, the weight obtained is as much as 0.2233 grams, this is because at that hour many vehicles are passing or congested occur. While at the time of 21:45 - 03:45 WIB less than the others, the weight obtained is as much as 0.0745 grams, this is because at that hour it can be said that there is almost no driving activity.

3.6 Dust Weight with 27.55kV (Duty Cycle 70%)

Dust weight with a voltage of 27.55kV at 70% duty cycle. And obtained the weight of dust at each time of data collection, in the following table 7:

Table 7: Dust weight at any time at 27.55kV

Time (Hours)	Dust Weight (g)
04:00 – 10:00	0.1288
10:15 – 16:15	0.2588
16:30 – 22:30	0.1922
22:45 – 04:45	0.0948
05:00 – 11:00	0.1289
11:15 – 17:15	0.3179
17:30 – 23:30	0.1677
23:45 – 05:45	0.0901
06:00 – 12:00	0.2571
12:15 – 18:15	0.2905

From the data in table 7, we can illustrate the dust vs. time weight graph as in Figure 10 below:

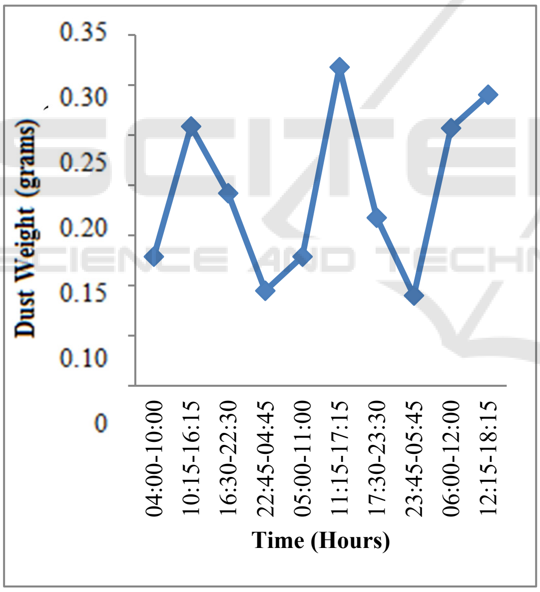


Figure 10: Dust weight vs time graph at 27.55kV

Based on the graph above, it can be seen that the weight of dust at 11:15 - 17:15 WIB more than the others, the weight obtained is as much as 0.3178 grams, this is because at that hour many vehicles are passing or congested occur. Whereas at 23:45 - 05:45 WIB less than the others, the weight obtained is 0.0901 grams, this is because at that hour it can be said that there is almost no driving activity.

3.7 Relationship of Heavy Dust with Output Voltage

With the voltage released by the flyback on duty cycles of 30%, 40%, 50%, 60%, and 70%. Then obtained the amount of dust that can be generated during ten times of data collection, each data collection is carried out for 6 hours. Can be seen in the following table 8:

Table 8: Dust weight at each output voltage

Vout (kV)	Dust Weight (g)
2.632	0.2122
7.250	0.5147
13.16	0.8960
20.01	1.1620
27.55	1.9267

From the data in table 8, we can draw a graph of dust weight vs. output voltage as shown in Figure 11 below:

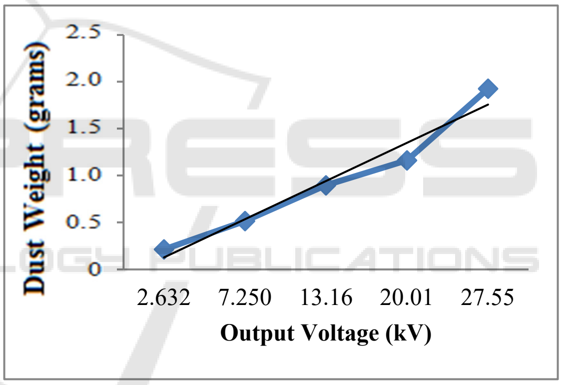


Figure 11: Dust weight vs output voltage graph

Figure 11 shows that the higher the output voltage the more dust weight. This is due to the electrostatic process of aluminum metal plates with dust running well.

4 CONCLUSIONS

The results show that with duty cycles of 30%, 40%, 50%, 60%, and 70%, producing an output voltage of 2.632kV, 7.250kV, 13.16kV, 20.01kV, and 27.55kV, with dust successfully absorbed as many as 0.2122 grams, 0.5147 grams, 0.8960 grams, 1.1620 grams, and 1.9267 grams. So it can be concluded that the higher the duty cycle, the higher the output voltage and the more dust that can be filtered.

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