

Automated Machine that Converts Charcoal Into Conductive Ink for Easier Circuit Prototyping with Monitoring Features

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Abstract

The designed study came up with the idea of creating a machine that will convert the charcoal into the usable conductive ink as an alternative method in the implemented type of PCB etching. The study aims to make an automated Arduino-based device that has a capability to produce a conductive ink which is made of ordinary charcoal that has a less than 100 ohms of resistance along with a small solution of glue and thinner. The lines being drawn from the conductive ink act as the wire to connect electronic components in creating a circuit. The machine has an automated step by step process of making charcoal as a conductive ink will only occupy lower DC voltages to work meaning that the device will still be operational with the use of batteries. Also, it has a built-in ohm meter to test the resistance of the charcoal if it satisfies the 100 ohm resistance and weighing the right amount of charcoal to be processed. Although the machine has cannot calculate and display the exact output resistance and via LCD monitor the current status of the glue and thinner, the device was able to create conductive inks with 100ohm resistance. For the evaluation of the device it has the results of 4.17 for the Functionality, 4.06 for the Reliability, 4.15 for Efficiency and Effectiveness and 4.13 for Portability having an overall mean of 4.13 interpreted as "Good". Lastly, it was recommended that the device has the capability to show the charcoals resistance via LCD, alert the content status of the glue and thinner and capability to show the elapse time of the whole process.

Keywords: charcoal-based conductive ink, automated, PCB, etching, Arduino-based

1 Introduction

Electronic devices have totally changed the way of our life living, it has believed that it started in the 20th century and starting to develop in the 19th century until today. Everyone becomes dependent on their electronic devices because it reduces our daily working activity effort and improves everyone's work and lifestyle. Anything and everything have been influenced by electronics even in the field of medical, communication, military, transportation etc. The electronic devices are the greatest invention. The electronic circuit is a course made of conductors where current can travel. It provides a path for current to flow. The path of the current must start and end at the same point. In another word, electronic circuit must be in a formation of a loop. (D. Lowe, 2012). According to a research of Alejandrino (2020), electrically conductive substances have many advantages in the field of electronics specially if they have adhesive properties. Another is that adhesive-conductive materials (like charcoal and glue) both act as a conductor and an insulator which are some of the requirements in printed circuit boards of PCB. On another side, etching is a practice used in printing and designing a copper circuit board. It is a 'subtractive method where acid is used like ferric chloride (FeCl_3) to remove the unwanted copper based on the designed circuit. While printed circuit boards have copper on its surface when the copper left unprotected it will oxidize because of exposing in surroundings and will become not usable.

Based on a case report, there was a white male toolmaker who has a 5-year history of allergic contact dermatitis. (Baer RL; J Allergy Clin Immunol, 1973). Another case report when was a 25-year-old woman is vomiting after the ingestion of 200 mL Ferric Chloride. The woman had hypoxemia and severe metabolic acidosis with respiratory alkalosis. When 3 hours passed after the ingestion, the woman presented to has drowsy consciousness, tachycardia, tachypnea and protracted vomiting. (WU ML et al; Vet Hum Toxicol, 1998). The case reports is a basis that using the acquired method of etching has a danger in life especially students who may accidentally swallow or ingest the said chemical. Printed Circuit Boards of "PCB" etching is implementing in the Universities to train the students on electronic hardware designing.

Before the problem occurs, the researchers came up with the idea of creating a machine that will convert the charcoal into the usable conductive ink as an alternative method in the implemented type of PCB etching. The "Automated Machine that converts Charcoal as a Conductive Ink"

aims to make an ink which is made of charcoal, but not just simply an ink which is used in writing, it has a capability to conduct electricity. The lines drawn using the conductive ink act as the wire to connect electronic components in creating a circuit.

Materials and Methods/ Experimental Designs

This chapter tackles about the different methodology that the researcher used to develop the study to meet the objectives. This chapter includes Project Design, Project Development, Instruments and Techniques Used, Evaluation Procedure, Evaluation Instrument and Evaluation Criteria.

PROJECT DESIGN

The Project Design is all about the methods and process the researchers use to determine, identify and develop the software and hardware part of the proposed project. Descriptive Method. Descriptive research is “aimed at casting light on current issues or problems through a process of data collection that enables them to describe the situation more completely that was possible without employing this method”. (Dudovskiy, J., 2013, *The Ultimate Guide to Writing Dissertation in Business Studies A Step-by-Step Assistance*). Descriptive method was used since it needs to make an output (conductive ink) that can help students and electricians in developing and repairing basic circuitry without totally relying on existing and conventional process.

The Waterfall Model. First, introduced by W. Royce in 1970. It is also known as Linear-Sequential Life Cycle Model. It is a software development process model emphasizes that a logical progression of steps to be taken throughout the Software Development Life Cycle (SDLC), much like cascading steps down an incremental waterfall. (Powell-Morse, A., Dec. 08, 2016, *Waterfall Model: What Is It and When You Should Use It?*). The waterfall model used for the development of the device was given as follows: Planning, Software Development, Hardware Development, Hardware and Software Integration and Evaluation and Testing.

Planning

A project development starts with planning where all the requirements are being provided and decision-making is being created. This is about looking for all the side of the corners of the project and looking for the solution to resolve the problem found and choosing the best path for a

shorter procedure to fasten the development of the Automated Machine That Converts Charcoal into Conductive Ink for Easier Circuit Prototyping with Monitoring Features.

Software Development

Software development is working on the program of the projects. The algorithm and arithmetic logic part of the hardware part is being sequenced to finish the process of the machine thru programming or making an embedded system.

C (Programming Language). C is a general-purpose programming language which features economy of expression, modern control flow and data structure, and a rich set of operators. C is not a very high level language, nor a "big" one, and is not specialized to any particular area of application. But its absence of restrictions and its generality make it more convenient and effective for many tasks than supposedly more powerful languages. C language was used for the Arduino Microprocessor to work and function in making conductive ink.. For the software application, IDE Software Application will be used using C and C++ language. Arduino Software (IDE). The core language used in the Arduino development environment is the C computer programming language. The Arduino team has developed the standard Arduino library that provides a simple and targeted set of functions that make programming the Arduino interface board about as easy as it can get. Now, these libraries are themselves actually C++, itself a subset of the original C language.

Hardware Development

For the hardware development, the following components and parts are as follows:



Figure 1 Coffee Grinder

Coffee Grinder (Monaris 600N). The coffee grinder was the first key to process the product of the study. It uses to grind coffee beans size breakable objects into fine ground powder using grinding gears inside the mechanism. The researchers modified the coffee grinder model by adjusting the spaces between the gears for a finer ground powder that results in accepted charcoal size are small flakes sizes due to smaller spaces of the gears.



Figure 2 Servo Motor

Servo Motor used for precise angular degree rotation. This device was used in many functions due to its calculated rotation. The machine used two different kinds of a servo motor, the 180-degree, and 360-degree motor. The 180-degree used to move charcoals after the weighing process to grinder hole. While the 180-degree servo used to pump out liquids additive that attached to syringe and move the capping arm.



Figure 3 Load Cell Weight Sensor and HX711 Load Cell Amplifier

Load Cell Weight Sensor (0-1kg) and HX711 Load Cell Amplifier are devices used to weigh the charcoal before undergoing the grinding process because there's only one specific amount of conductive ink targeted to make.



Figure 4 Relay

A Relay is an electronics device switch that operates by an electrical signal. This device used in connection with the AC machines to the Arduino controller for a manageable switching according to the sequence of the system's program. This was attached to the plug of the grinder with one input signal from the microcontroller and to three stepper motor and one dc motor that powers the mixer. Because of its unique properties, silica sand is used for water filtration in a wide variety of applications including potable and waste water treatment, swimming and leisure, brewing, paper processing, chemical processes and power generation.



Figure 5 LED Display and Serial LCD

LCD (Liquid Crystal Display) (16x2) is an electronics device that modulates lights to create different figures. This device was used for the monitoring feature of the study that shows the current stage the machine processing. And Serial LCD II is an interface board display kit with built-in screen contrast adjustment that helps by the minimized wiring connection to the Arduino and easier programming syntax.

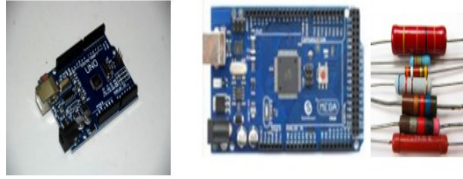


Figure 6 Arduino Uno (left) , Mega (Center) Microcontroller and resistors

Arduino Uno and Mega was the types of microcontroller used in the study. Which serves as the heart and brain of the machine. This contains the uploaded program of the system. It also becomes a built-in ohm meter the moment it receives a specific code and a single resistor (serves as baseline) via IDE for resistance measurement.

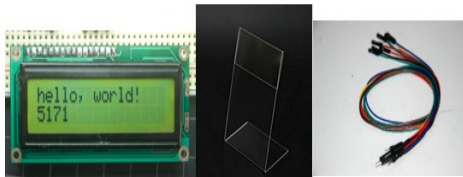


Figure 7 20x4 LCD Display, Acrylic Case and Jumping wires

LCD Display with Acrylic Case and Jumping Wires. Type of wire used to connect hardware components to another component and into Arduino Uno and Mega microcontroller. Jump wires are the bridge path of different signals to each hardware components. Meanwhile, the LCD Display the process and the acrylic case will hold the LCD screen



Figure 8 Stepper Motor and H-Bridge Stepper Driver Module(left) and Stepper Motor BYJ48 and ULN2003 Driver Chip(right)

Stepper Motor with H-Bridge Stepper Driver is a combination of the functions of a DC motor and a servo motor that can make counter or clockwise rotation with the speed is determined. This motor was attached to a gear belt used to move the cup platform in a vertical manner to bring the container cup to different stages. Stepper Motor BYJ48 and ULN2003 Driver Chip used to move upward and downward the mixer platform in mixing process and extruding process, it comes with a ULN2003 driver chip.



Figure 9 DC Motor

DC Motor direct current motor is used as the head motor of a mixer. The mixer is attached to the platform that lifts upward and downward through the displacement of the diameter of the servo motor.



Figure 10 Buzzer

The Buzzer is a small device that produces buzzer sound used to notify the state of the automated machine whether a success or failure in the process, input, and output.

Step-by Step Process

First, the frame for the device is made and fabricated from metal rods that will hold the standard coffee grinder (can be both powered by direct outlet with a 12volt adapter or a 12v battery with step up transformer) as well as the other peripherals for the process. Next, a funnel-like tube that will transfer the grinded charcoal to the next staging process. After the programmed amount of grinded charcoal fills the 1st container, the grinded charcoal is mixed with glue, then thinner from the same container. Afterwards, a small mixing rod that is connected to a motor will then mix the charcoal, thinner and glue. Lastly, a plunger will force the conductive ink outside the container like a large syringe (connected to a stepper motor).

All of the electronic devices' power supply will come from the microcontroller as well as the timing process. The supply of the grinder is regulated by a relay and directly gets power from another source (battery of AC supply)

Hardware and Software Integration

Hardware and Software Integration is the combination of both the hardware and the software design. It's determining the functionality and capability of the two as one combined platform. In this phase, the microprocessor is programmed thru Arduino IDE using C language to control, regulate and automate the hardware in producing conductive ink.

Testing

In this stage, the hardware and software of the machine were developed and to be tested for the errors, bugs, and malfunctions. This stage is the hardware tested alone, then the software tested alone and the integration of hardware and software. Any malfunction found was debugged by making adjustments either to the hardware or software or both for a smoother flow and functionality of the Automated Machine to produce conductive ink

EVALUATION PROCEDURE

The procedure of evaluating the Automated Machine That Converts Charcoal into Conductive Ink for Easier Circuit Prototyping with Monitoring Features begins with an introduction explaining the purpose and objective of the study to the evaluators. Second, the presentation of the machine and it's all over features like the built-in ohm meter, the weighing capability to charcoal, the monitoring display and some other featuring matters the evaluator ask. Third, the demonstrating of the machine from how to put the charcoal to the machine, what the beeping signals means and the inside processes unto its finish product. Fourth, as the demo was done, the evaluation form must be graded depending International Standard Organization certified evaluation form criterion. As soon as the target number of evaluated satisfied, lastly the result must be calculated for the mean grade.

To determine if the results are good and bad, the following criteria below (Likert Scale), will grade the device according to its Functionality, Reliability, Efficiency and Effectiveness and Portability.

AVERAGE	CORRESPONDING REMARKS
4.50-5.00	Very Good
3.50-4.49	Good
2.50-3.49	Average
1.50-2.49	Below Average
1.00-1.49	Poor

Table 1 Likert Scale

2 RESULTS AND DISCUSSION

This chapter is all about the findings and evaluation of the device “Automated Machine that Converts Charcoal into Conductive Ink for Circuit Prototyping with Monitoring Features”. It also includes the present information about the machine capabilities and limitations.

PROJECT TESTING

To gather the desired result for a more conductive and liquid form of ink, the researchers makes an experiment through different combination of mixtures.

Table 2, 3, 4 and 5 shows the data gathered through conducting of experiment on the right mixture for the conductive ink, drying time of applied ink and the measured resistance of the output.

No.	Charcoal		Amount		Texture
	Resistance	Weight	Glue	Thinner	
1	5 ohms	1.30 unit	15 mL	3 mL	Foam
2 (Ideal)	5 ohms	1 unit	20 mL	1 mL	Almost Liquid Form
Good			Bad		

Table 2 Experiment Results of Conductive Ink

It is revealed that based of multiple trials, number 2 suits to be the best candidate (5ohms, 1unit or gram, 20 mL of glue and 1mL of thinner) in making a conductive-adhesive material with link-like properties.

Based on the table above, Trial No. 2 is the ideal combination of charcoal, glue and thinner in creating a conductive ink as well as the ink that used in Tables 3 and 4.

No.	Stroke Length	Temperature	Estimated Time
1 (Ideal)	3cm	Room Temperature	1hour
2	3cm	Under the Sun	30 minutes

Table 3 Experiment Results of Conductive Ink Drying Time

In table 3, by using Trial No. 2 in Table 1, it was discussed the elapse time for drying the conductive ink at room temperature and under the sun. Experiment No. 1 would be the ideal settings or baseline since most electronic circuits are done indoors and drying the ink under the sun is only optional if the user wants to lessen the drying time of the circuit by half

Experiment No	Stroke Length	Resistance
1	1 cm	813 ohms
2	2 cm	1.3k ohms
3 (Ideal)	3 cm	5k ohms

Table 4 Experiment Results of Conductive Ink Resistance

In table 4, also by using Trial No. 2 on Table 1, it was discussed the resistance of the ink according to stroke length. Based on the given table, Experiment No. 3 is the ideal length or baseline since it produces an exact Resistance of 5k Ohms but you can also make a 1.5cm stroke to have an approximate resistance of 1k ohm.

Circuit No.	Components	Voltage Source	Copper Wire	Conductive Ink
1	LDR & LED	9v	3.76 v	3.27 v
2	470 Ω resistor and LED	9v	8.25 v	7.9 v
3	AND IC & LED	9v	6.75 v	4.32 v

Table 5 Parallel Testing between Conductive Ink and Copper Wire In A Circuit

PROJECT CAPABILITIES AND LIMITATION

The project main features and capabilities are the following:

The machine has a built-in ohm meter feature which is used to measure the resistance of the charcoal needed.

The machine has a built-in LCD which displays the measured resistance, selection modes, and the current process.

The machine has a built-in buzzer which will help to notify the user if the measured charcoal is less than equal 100 ohms.

The machine has a built-in weight sensor which is used to limit the quantity of the desired output.

The machine has three built-in buttons which is used in selecting modes and starting of process.

3 EVALUATION RESULT

The design project was high in terms of Functionality and lowest in Maintainability.

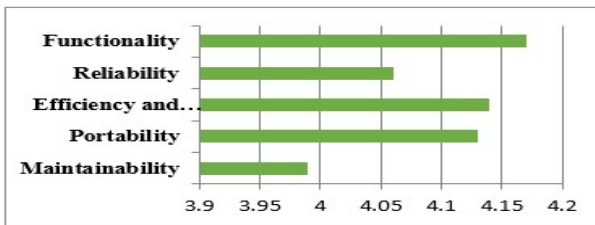


Table 5 The Weighted Mean of the Each of the Five Criteria Showed via Bar Graph

4 Conclusion

Prior to the statement of the problem, answering the main problem “How to design and develop an “Automated Machine that converts Charcoal into Conductive Ink for easier Circuit Prototyping with Monitoring Features”. The researchers proved that the wood charcoal has the capacity to conduct electricity using the said machine which will transform

a charcoal into conductive ink. The researchers also concluded that the output of the machine can be used to repair any PCBs conductive part due too much exposure to ferric chloride. The researchers proved that the conductive ink has a resistance based upon the amount of the charcoal present on the ink.

After the project was completed, the researchers undergo an evaluation process to acquire ratings, comments, and suggestions that can help further improvements on the device. The researchers used stratified random sampling which targeted three groups of evaluators, namely: (a) residents from household respondents; (b) professionals and; (c) expert. The evaluators evaluated the acceptability of the design project in terms of the following five criteria:

Functionality

Functionality of the device was rated (4.17) Good means that the machine function according to its purpose and produce its expected output. (4.30) The device functions according to the intended purpose. (4.15) The device can produce the expected output. (4.15) The device is easy to use and operate. (4.09) The device gives convenience to the users every time they use it.

On an overall computation of machines functionality, the machine scores 4.17 which implies “Good” according to respondent grade.

Reliability

Overall weighted mean scores 4.06 and interpreted as “Good” according to the respondents. (4.06) The device can withstand the intended operation (continuous or intermittent). (4.03) The device is reliable in terms of strength, capacity and performance. (4.09) There is consistency on outputs. (4.06) The device can satisfy the needed outputs of the user.

Efficiency and Effectiveness

“Efficiency and Effectiveness” overall weighted mean is 4.14 and interpreted as Good. (4.27) The device can be used to its maximum design capacity. (3.87) The device can respond to the needs of the end user. (4.21) The device can contribute for the development of the same model of technology. (4.15) The system can enhance individual’s learning. In general, the device is efficient and effective.

Portability

In the “Portability” evaluation, results are gathered based on given score of the respondents. The Overall weighted mean scores is 4.13 and rated as “Good”. (3.84) The device is easy to carry and transfer from one place to another. (4.12) The device has the ability to adapt in new developments. (4.21) The device has the ability to adapt in new specification. (4.33) The liquid containers of additives can be easily refill and remove. In general, despite that the device is not quite easy to carry, the other parameters in the portability section was evaluated as Good or very plausible.

Maintainability

Machines’ “Maintainability” overall weighted mean score is 3.99 and interpreted as “Good”. (3.93) The device can operate accurately with maximum maintenance. (3.34) The device can be adapted to any change in its working condition. (4.15) Troubleshooting/repair can be done easily by the user. (3.99) The parts can easily be change. In general, the device is easy to maintain.

5 Recommendations

Based on the testing and evaluation of the study, the following are hereby recommended for the improvement of the device:

- Include in the device an automated process of measuring the resistance of the charcoal and ability of segregation if the charcoal is less than, greater than or equal to 100 ohms.
- Include the capability of alerting and monitoring the current status of the contents of the thinner and glue.
- Include the capability of creating any desired quantity of conductive ink.
- Include the capability of computing and showing the process elapse time display on an LCD.

- Upgrade the device components to lessen the processing time of turning charcoal into conductive ink.

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