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CNC Plotter Printed Circuit Board

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ABSTRACT

Printed Circuit Board is a component or material that has a circuit path where electronic components will be installed or placed. In general, conventional PCB manufacturing requires several processes, such as printing on photo paper first, then screen printing the image and then removing the paper stuck to the PCB. In this research, the PCB engraving process will be operated using G-Code and GRBL controllers to control the machine. FlatCAM software is also used to prepare CNC work to create PCBs on CNC routers. The use of 3 stepper motors will provide a good carving composition in terms of movement of the x, y and Z axes, as well as the use of a spindle to control the drill bit which functions to carve the PCB layout. From the results, it was found that the process of making PCB paths has the precision of the engraving results from the predetermined design.

Keywords : CNC, PCB Plotter, G-Code, FlatCAM

1. Introduction

PCB (printed circuit board) is a place to store a series of electrical components without cables. In its development, this board has really helped revolutionize the shape of electronic devices in terms of design and size. The PCB board fabrication process continues to improve, apart from developing existing methods, new methods are also being sought to improve product quality, processing time and production costs [1] [2] [3] . In general, conventional PCB manufacturing requires several processes, such as printing on photo paper first, then screen printing the image and then removing the paper stuck to the PCB. [4] . CNC machines have computers that can convert G-Code characters into language that can be recognized by the machine and then processed [5] [6] [7] . CNC has many benefits for application, one of which is as a PCB board engraver to produce circuit paths or layouts, the use of CNC will produce layouts that are neater, safer and faster to work on compared to manual processes. In the manual process, the first step is to use an image schematic created for a particular application and transferred to the PCB, then the ironing process and use of chemicals. Obviously, this process requires quite a long time and great care to avoid errors. Meanwhile, the PCB plotter method is a method used to create layouts automatically based on the programming layout that has been designed. Previous research has applied making PCB layouts with CNC using an Atmega 128 but has the disadvantage of not using GRBL software so that the layout used cannot be seen, and controlling the x, y and z axes still uses a keypad. So, in this research improvements were made by making CNC using Arduino with the use of G-Code and GRBL software so that the operating process would be easier and more optimal.

2. Materials and Methods

a. CNC Shield

CNC (Computer Numerical Control) is a machine that is categorized as a machine tool, controlled by a personal computer using numerical language (command information with value symbols, graphs and icons) in accordance with approved standards [8] . The CNC Shield is designed to protect the Arduino from overheating of the motor driver and add hours of trouble-free operation to the plotter. The Arduino program is used to control each stepper motor using the A4988 driver module. The purpose of this Shield is to control the three axes (X, Y and Z axes) of the plotter machine, meaning control of the stepper motor [9] [10] .

Figure 1. CNC Shield [9]

b. Nema 17 Stepper Motor

Stepper motors are electromechanical devices that work by converting electronic pulses into discrete mechanical movements. Stepper motors move based on a sequence of pulses given to the motor. Therefore, to drive a stepper motor, a stepper motor controller is needed which generates periodic pulses [11] .

Figure 2. Nema 17 Stepper Motor [11] .

c. GRBL Software Candle

GRBL software is designed to send G-Code (Geometric Code) to CNC machines, such as 3D milling machines. GRBL is Arduino-based CNC control software for controlling CNC movements which can be uploaded to the Arduino library. Basically GRBL is a hex file that can be uploaded to Arduino so that Arduino can read commands in G-code/Nc [12] . G-Code is a programming language that humans use to tell machines how to do things. For 3D printers, G-Code contains commands to regulate the movement of stepper motors in the X, Y and Z axes in the 3D printer. G-code consists of G- and M-commands that have movements or actions to be performed [13] . GRBL is designed to optimize continuous reading of G-Code commands using Arduino with operational accuracy. G-Code is a movement execution command code from a CNC machine. Currently GRBL can only be used for 3 axis machines, namely X, Y, and Z [14] .

d. FlatCAM

Flatcam is software that can change various designs and produce CNC routers. In flatcam PCB design, Gerber files are used to produce Gcode , which Gcode will drive the CNC machine [3] [15] [16] .

e. Hardware Design

This stage is the design of the components used. Schematic of the electronic circuit on the machine consisting of Arduino, CNC shield, stepper driver, Nema 17 motor, spindle motor, DC relay, limit switch.

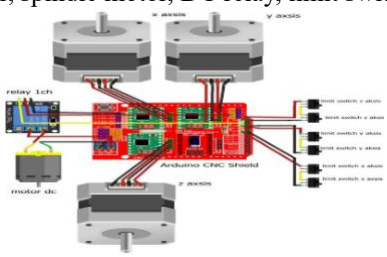
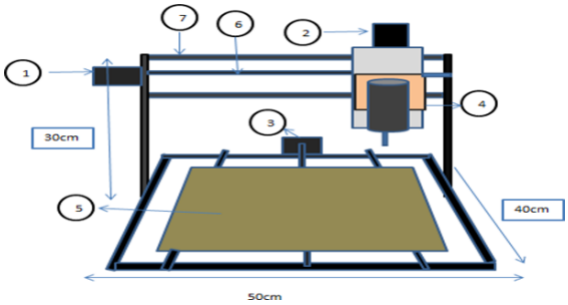


Figure 3. Hardware Design

f. Mechanical Design

This part of the machine uses angle iron and 2020 *aluminum* profiles as the main materials. This material is very suitable for use on CNC machines, because the material is light and strong, so it really supports the accuracy of machine work. This CNC machine measures 50cm long, 40cm wide and 30cm high .



Information:
1. Nema motor x x axis
2. Z axis nema z motor
3. Motor nema y y axis
4. DC Spindle Motor
5. Job Board
6. Ball Screw
7. Iron vslot

Figure 4. CNC Mechanical Design

g. Software Design

The following is *a flowchart* of the first process when the system is turned on, namely making a serial connection. After the serial connection is successful, it will run *to* read the machine position, after that set the machine to the machine position so that it reaches the desired zero point, after that open the *GCode file* and send the *GCode file* to the microcontroller. When the sending process is complete and the user still wants to print another PCB design, the user can repeat all the previous processes. If you no longer want to print, the user can end *the software* by closing *the software* .

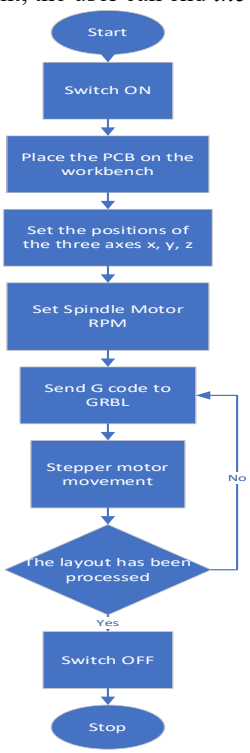


Figure 5. Software Design

3. Results

Some test results from this tool are as follows.

a. Testing the error value for the accuracy of the x-axis movement
This test aims to determine the x-axis error value, whether the movement on the x-axis is correct or an error. In testing, the x-axis will be moved using *software* by 10mm to 100mm .

Table 1. X-Axis Movement Accuracy Error Test Results

No	Long (mm)	Measurement results Axis x (mm)	Error (%)
1	10	10	0
2	20	20	0
3	30	30	0
4	40	40	0
5	50	50	0
6	60	60	0
7	70	70	0
8	80	80	0
9	90	90	0
10	100	99	1
Average error			**0.1**

b. Testing the error value for the accuracy of the x-axis movement
This test aims to determine the y-axis error value, whether the movement on the y-axis is correct or an error. In testing, the y-axis will be moved using *software as* far as 10mm to 100mm.

Table 2. Y-Axis Movement Accuracy Error Test Results

No	Long (mm)	Measurement results Axis y(mm)	Error (%)
1	10	10	0
2	20	20	0
3	30	30	0
4	40	40	0
5	50	50	0
6	60	60	0
7	70	70	0
8	80	80	0
9	90	90	0
10	100	99	1
Average error			**0.1**

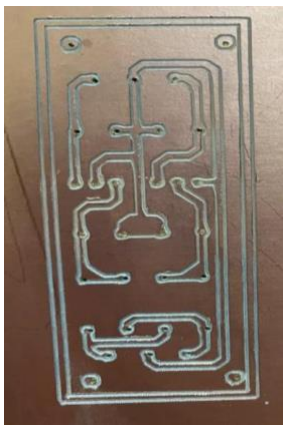
c. Testing the error value for the accuracy of the Z axis movement
This test aims to determine the z-axis error value, whether the movement on the z-axis is correct or an error. In testing the z-axis will be moved using *software* by 1mm to 10 mm .

Table 3. Z-Axis Movement Accuracy Error Test Results

No	Long (mm)	Measurement results z-axis (mm)	Errors (%)	Accuracy (%)
1	1	1	0	100
2	2	2	0	100
3	3	3	0	100
4	4	4	0	100
5	5	5	0	100
6	6	6	6	100
7	7	7	7	100
8	8	8	8	100
9	9	9	9	100
10	10	9.9	0.1	99.9
Average error			**0.01**	**99.99**

d. PCB paths print testing with FR2 and FR 4
In this test, two different PCBs were used and the same drill bit was intended to determine the difference in results from the two PCBs, namely FR 2 and FR 4.

Table 3. PCB Print Results with FR 2 and FR 4

NO	PCB Type	Print results	Information
1	FR2 is made from paper impregnated with plastic resin Phenolic formaldehyde in terms of flexibility, this type is quite flexible		It can be concluded that the results of using an FR2 type PCB are quite good, but there are a few lines that are not neat because the FR2 material is a little elastic.
2	FR4 is made of woven fiberglass which is then coated with resin in terms of material This type of PCB is quite hard and does not bend easily		It can be concluded that the results of using a PCB with the FR4 type path look neat because the PCB material is not elastic, a hard material

It can be seen that using a PCB with FR2 type looks uneven because the FR2 PCB material is slightly elastic causing the surface to be slightly wavy and for experiments with the 4 lane FR type it looks neat because the PCB material is not *elastic* .

e. Testing PCB print results
At this stage, the results of testing are the results of the layout design that has been made using a PCB layout maker application which will later be printed using a CNC machine that prints PCB lines, whether the printed lines and distances for each component have the same results or not.

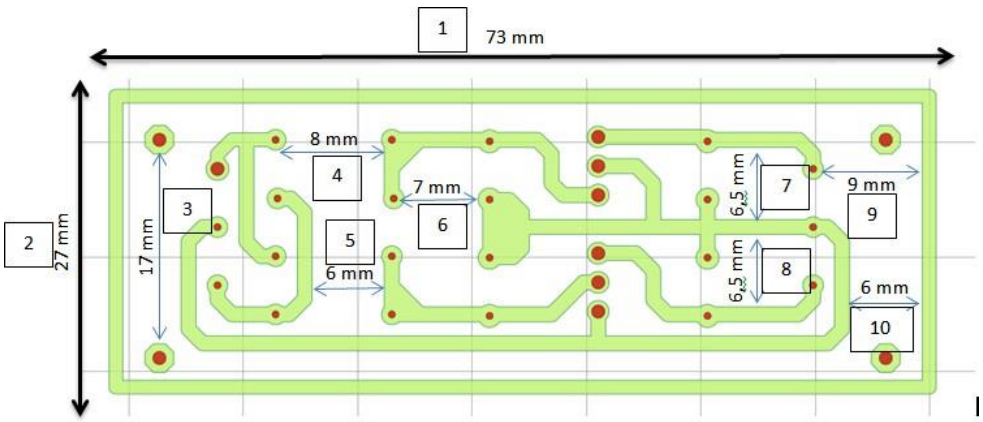


Figure 6. Design Layout

The image is the result of a PCB *layout design* that has been created using a PCB path maker application with specified distance sizes.

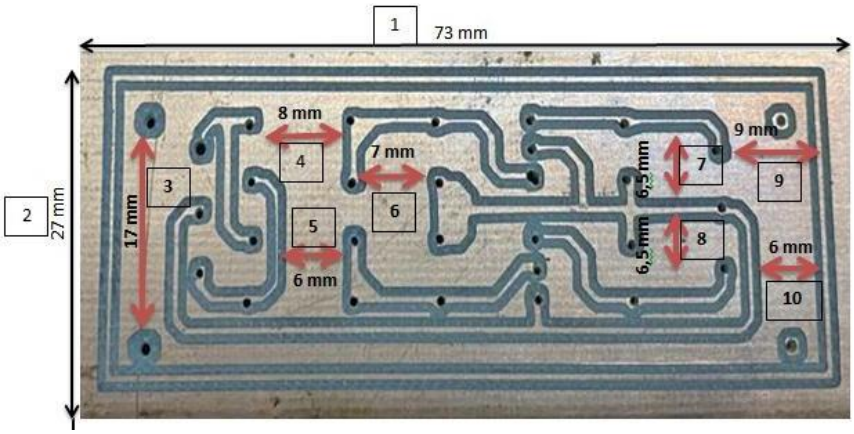


Figure 7. PCB Print Results

In Figure 4.8 is the result of a PCB print using the *layout design* that was created in Figure 4.7. It can be seen that the distance between components has the same similarity as can be seen in Figure 4.8.

4. Discussion

PCB (Printed Circuit Board) is component base from Suite electronics. PCB has function for connect between component electronic One with others. PCB is used for makes the assembly process easier component Because cable liaison component Already changed become track copper. Frequent manual processes very done moment This own enough flow complicated, where at the beginning first thing to do is create a PCB layout with software that can used, next do print PCB path can with use whiteboard marker permanent, ironed or laser printing. This manual thing Still Lots own Lots lack Where sometimes the path printed on the PCB can just disconnect that makes the connecting process track electronic must done return. Many studies have been done do discussion related topic this , has done study for the PCB milling process using a 3 axis robot with configuration movement based on 3 axes base namely X, Y and Z [15] , discussion related convenience For PCB manufacturing is also growing with utilization CNC machining , development with produce mini CNC machine with low cost For making or PCB drawing is expected can increase good flexibility [17] . Study furthermore use of CNC for PCB engraving is also being developed To use efficient and reduced workmanship use material chemistry in the PCB printing process [2] . Utilization Arduino Uno also provides convenience in the manufacturing process engrave PCB directly automatic with utilise CNC machine [9] , deep processing PCB manufacturing is also developed in the drilling process matter this can also be done done development more carry on For complete the internal process PCB manufacturing automatic utilise machine [16] . Utilization of available software convert PCB design with easy will speed up the manufacturing process , with strengthening from side of the hardware used [18] . Utilization of G-Code with using the GRBL controller as controller CNC machine , GRBL controller will works For drives stepper motors and GRBL software, stepper motors, spindles as well as eye drill will move [19] . CNC a lot very possible development done For produce convenience application made PCB path automatic [20] .

5. Conclusions

The conclusions from the research that have been carried out are as follows:

a. This PCB line printing CNC machine has a movement accuracy of % error with an error value of % for the X axis of 0.1mm, the Y axis of 0.1 and the Z axis of 0.01 .
b. The type of PCB that has good printing results is PCB FR4
c. The results of the PCB layout carving using a CNC machine exactly match the design provided.

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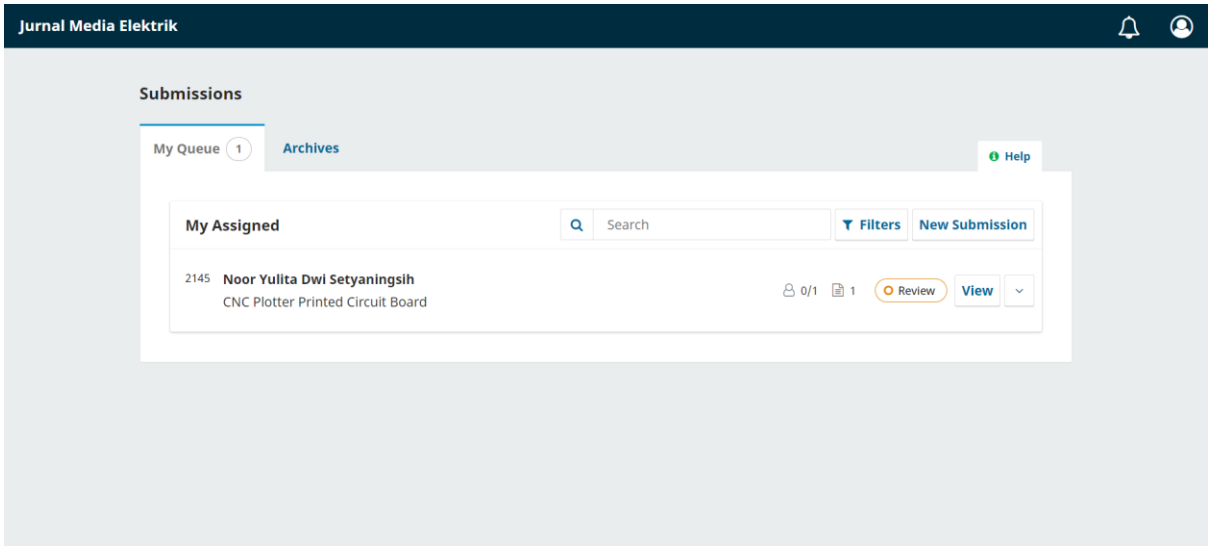

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CNC Printed Circuit Board strip printer with FlatCAM software

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ABSTRACT

Pritcd Circuit Board is one part of the field of electronics that has many roles and benefits. This automatic PCB path manufacturing will provide many benefits to users that were previously still done manually. In this research, the PCB carving process will be operated using G-Code and GRBL controller to control the machine. The use of 3 stepper motors will provide a good carving composition in terms of x, y and Z axis movements, as well as the use of spindles for drill bit control that functions to carve PCB layouts. From the results, the PCB path manufacturing process is faster and has the accuracy of the specified design.

Keywords: CNC, PCB Plotter, G-Code,

1. Introduction

PCB (printed circuit board) is a place to put a series of electrical components without wires, in its development this board is very helpful in revolutionizing the shape of electronic devices in terms of design and size. The PCB board fabrication process continues to improve, in addition to developing existing methods, new methods are also being searched to improve product quality, processing time and production costs [1][2][3]. CNC has many benefits to be applied, one of which is as a PCB board engraver to produce circuit paths or layouts, the use of CNC will produce layouts that are neater, safer and faster in work compared to manual processes. In the manual process The first step is to use the drawing scheme made on a specific application and transferred to the PCB then the ironing process and the use of chemicals, obviously this process requires quite a long time and great accuracy to avoid mistakes. While the PCB plotter method is one way used to create layouts automatically based on the layout programming that has been designed. Previous research has applied the manufacture of PCB layouts with CNC using Atmega 128 but has shortcomings where it has not used GRBL software so that it does not look like the layout displayed is used, and x, y and z axis control still uses a keypad. So that in this study, improvements were made by making CNC using Arduino with the use of G-Code and GRBL software will make the operation process easier and maximum.

2. Materials

a. CNC Shield

CNC Shield is designed to protect the Arduino from overheating of the motor driver and increase the plotter's operating time for hours without problems. The program on the Arduino is used to control each stepper motor using the A4988 driver module. The purpose of this Shield is to control all three axes (X, Y and Z axes) of the plotter machine, meaning control on the stepper motor [4][5].

Figure 1. CNC Shield [4]

b. Nema 17 Stepper Motor

A stepper motor is an electromechanical device that works by converting electronic pulses into discrete mechanical motion.

Commented [Yn1]: add a **discussion** section to strengthen your research results. The discussion is a separate point from the article section

Commented [Yn2]: materials and methods are made into one part

The stepper motor moves based on the sequence of pulses given to the motor. Therefore, to drive the stepper motor, a stepper motor controller is needed that generates periodic pulses [6].

Figure 2. Nema 17 Stepper Motor [6].

c. GRBL Software Candle

GRBL software is designed to send G-Code (Geometric Code) to CNC machines, such as 3D milling machines. GRBL is an Arduino-based CNC control software for controlling CNC movements that can be uploaded to the Arduino library. Basically GRBL is a hex file that can be uploaded to Arduino so that Arduino can read commands in G-code / Nc [7]. G-Code is the programming language used
humans to tell machines how to do things. For 3D printers, the G-Code contains commands to set the motion of the stepper motor in the X,Y and Z axes in the 3D printer. G-code consists of G- and M-commands that have a gesture or action to be performed [8].

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d. FlatCAM

Flatcam is a software that can change various designs and produce cnc routers. In the flatcam PCB design utilizes a gerber file to produce Gcode, which Gcode will drive the CNC machine [9][10].

3. Methods

a. Hardware Design

At this stage is the design of the components used. Electronic circuit scheme on the machine consisting of arduino, CNC shile, steper driver, nema 17 motor, spindle motor, DC relay, limit switch.

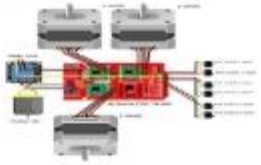
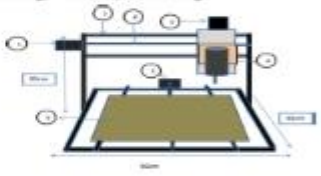


Figure 3. Hardware Design

b. Mechanical Design

This part of the machine uses the main material elbow iron and *velot aluminum* profile 2020. This material is very suitable for use in CNC machines, because the material is light and strong, so it is very supportive for the accuracy of the work of this CNC machine measuring 50cm long, 40cm wide, and 30cm high.



Information:

1. Nema motor x x axis
2. Motor nema z axis z
3. Motor nema y axis y
4. Motor Spindle DC
5. Job Board
6. Ball Screw
7. Iron valut

Figure 4. CNC Mechanical Design

c. Software Design

The following *flowchart* of the process for the first time when the system is turned on, namely making a serial connection. After the serial connection is successfully made, it will run *therd* to read the position of the machine, after that set the machine to the desired zero point, after that open the *GCode* file and send the *GCode* file to the micknikontroler. When the sending process is complete and the user still wants to print another PCB design then the user can repeat all previous processes. If you don't want to print then the user can end the *software* with close *software*.

Figure 5. Software Design

4. Results

Some of the test results of this tool are as follows.

a. Accuracy error value testing x-axis movement

This test aims to determine the x-axis error value whether the motion on the x-axis is correct or error, in the x-axis test it will be moved using *software* as far as 10mm to 100mm.

Table 1. Error Test Results of X-axis Motion Accuracy

No	Long (mm)	Measurement results X-axis (mm)	Error (%)
1	10	10	0

2	20	20	0
3	30	30	0
4	40	40	0
5	50	50	0
6	60	60	0
7	70	70	0
8	80	80	0
9	90	90	0
10	100	99	1
	Average error		**0,1**

b. Accuracy error value testing x-axis movement

This test aims to determine the value of the y-axis error whether the motion on the y-axis is correct or error, in testing the y-axis will be driven using *software as far as 10mm to 100mm*

Table 2. Error Test Results of Y-Axis Movement Accuracy

No	Long (mm)	Measurement results Y-axis(mm)	Error (%)
1	10	10	0
2	20	20	0
3	30	30	0
4	40	40	0
5	50	50	0
6	60	60	0
7	70	70	0
8	80	80	0
9	90	90	0
10	100	99	1
	Average error		**0,1**

c. Testing of accuracy error values Z-axis axis movement

This test aims to determine the z-axis error value whether the motion on the z-axis is correct or error, in the z-axis test it will be moved using *software* as far as 1mm to 10 mm.

Table 3. Error Test Results of Z-axis Motion Accuracy

No	Long (mm)	Measurement results Z-axis (mm)	Error (%)	Akurasi (%)
1	1	1	0	100
2	2	2	0	100
3	3	3	0	100
4	4	4	0	100
5	5	5	0	100
6	6	6	6	100
7	7	7	7	100
8	8	8	8	100
9	9	9	9	100
10	10	9,9	0,1	99,9
		Average error	**0,01**	**99,99**

d. PCB line print testing with FR2 and FR 4
In this test using two different PCBs and with the same eye, it intends to find out the difference in the results of the two PCBs, namely FR 2 and FR 4.

Table 3. PCB Print Results with FR 2 and FR 4

NO	PCB Type	Printouts	Information
1	FR2 is made of paper impregnated with resin plastic phenol formaldehyde in terms of its flexibility, this type is rather pliable		It can be concluded that the results of using PCBs with fr2 type are quite good but there is a little untidy path in the fr2 material is slightly elastic

It can be seen that using PCBs with FR2 type looks less flat because the FR2 PCB material is slightly elastic causing the surface to jump slightly and for experiments with the FR 4 line type it looks neat because the PCB material is not *elastic*.

e. PCB print yield testing
At this stage is the test result of the layout design results that have been made using the PCB layout maker application which will later be printed using a CNC machine PCB path printer whether the print results and distances in each component have the

same results or not

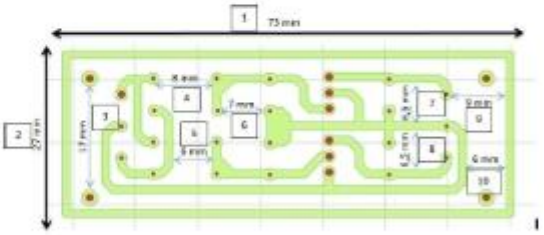


Figure 6. Layout Design

The image is the result of a PCB layout design that has been created using a PCB path maker application with a predetermined distance size.

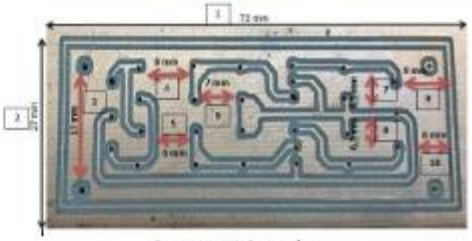


Figure 7. PCB Print Results

In Figure 4.8 is the result of PCB printing using the *layout design* that has been made in figure 4.7, it can be seen that the distance between components has the same similarity can be seen in figure 4.8

5. Conclusions

The conclusions of the research that have been conducted are as follows:

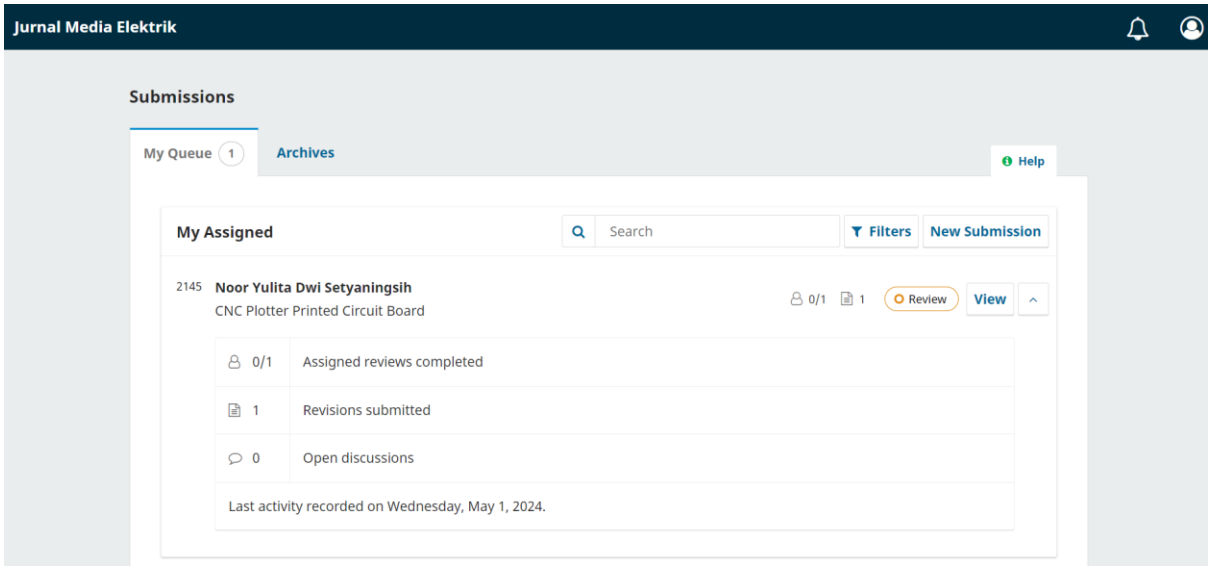
1. This PCB path printer CNC machine has % motion error accuracy with error value % X axis 0.1mm, Y axis 0.1 and Z axis 0.01.
2. The type of PCB that has good print results is FR4 PCB
3. The results of carving PCB layouts using CNC machines are right according to the design given.

References

[1] D. Suwandi and J. BadruzzamanIstiyanto, "Mikrofabrikasi Jalur PCB Menggunakan Metode Visible Ligth Maskless Photolitography," *J. Teknol. Terap.*, vol. 1, no. 1, pp. 1–10, 2015.

[2] T. Pramuji, I. suputro, L. Retno Hidayati, and J. Teknik Elektro Politeknik Negeri Semarang Jl Sudarto, "Rancang Bangun CNC (Computer Numerical Control) Untuk Pembuatan PCB Berbasis Arduino," *Orbith*, vol. 19, no. 1, pp. 43–49, 2023.

BUKTI MELAKUKAN REVISI



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