

Arduino Controlled CNC Printing Circuit Machine

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ABSTRACT

Arduino UNO development board, which controls the movement of the axes in the Printed Circuit Machine with Arduino-Controlled CNC, communicates with the CNC Shield board. 3 NEMA 17 (stepper motor) and 3 A4988 step motor drivers are used in the Printed Circuit Machine in order to provide movement between the X-Y-Z axes. Commands were sent to the step motor drivers through the CNC Shield and the positioning of the drill bit was provided by operating the step motors controlling the axes. After the hardware part of the study was finished, the calibration settings of the CNC machine axes were made using the UGS (Univarsal G-code Sender) program and the Printed Circuit Machine was made ready for operation. The circuit to create a printed circuit board was drawn in the PROTEUS 8 program, the required GERBER file was taken from PROTEUS ARES and the G-codes of the circuit were created in the Copper CAM program. Finally, the GRBL Controller and G-codes were sent to Arduino UNO and the printing circuits of the Printed Circuit Machine with Arduino Controlled CNC were engraved and drilled. In this study, the removal and drilling of the printed circuit, which is one of the electronic card design stages, was carried out with the Arduino Controlled CNC Machine and the need for people in electronic card printing was minimized.

KEYWORDS: CNC Machine, Printed Circuit Board, G-code

1. INTRODUCTION

In the industry sector, one of the most important inventions made on workbenches that process hard materials such as stone, wood and metal was the introduction of CNC Router machines in the 1950s. CNC Router machines were created by equipping the benches with computers. CNC Router machines are a system that increases productivity and reduces the risk of broken parts. Many jobs can be done at the same time on CNC machines. Therefore, they are extremely efficient machines in terms of use. In CNC Router machines, the processing time is fixed, and it is possible to follow the production to be made, to control the production and to estimate how long the production will take on average. In this respect, the CNC Router increases the control power of the manufacturer in terms of manufacturing options, cost per job and production planning.

The fact that those who use CNC Router machines are experts can result in the least damage to the work done. Regardless, even if interruptions occur in computerized systems and programs, it is necessary to

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have good knowledge of the machine in order to enter the correct data into the system. It requires professionalism to know which material can be cut more efficiently with which tip on the CNC Router machine. The only aspect of CNC Router machines that compels the manufacturer is the high price of the CNC Router. Due to the high transportation costs and taxes of the machines imported from abroad, domestic manufacturers generally prefer domestic companies that manufacture CNC Routers. The price of CNC machines purchased from companies producing CNC Router is cheaper than those purchased from abroad. In addition, domestic CNC Router manufacturers producing CNC Routers provide better after-sales support than those purchased from abroad.

There are many large companies that manufacture CNC Routers in Turkey. These companies export CNC Routers not only in the country but also abroad. Domestic CNC Router manufacturers, whose machines are of the highest quality as possible, do not use any Chinese parts in production. Thus, those who

prefer local companies that manufacture CNC machine tools will have trouble-free use for many years and in case of any malfunction, they will be able to easily reach the company and find a solution to their problems (Stras, 2019).

With the increase in the number of CNC machines and the development of technology, electronic card production has increased in many fields. Many processes are required to fully prepare the printed circuit board. These processes cause delays in mass production.

Akçaoğlu's aim in his project is to make exemplary machines by referring to the CNC working principles and the automation of these machines. The design and work simulation of the machine was drawn using the Solid Works drawing program. All parts of the machine were created one by one with 3D drawing in the drawing program and the machine design was completed with the combination. He completed the drawings using ready-made parts and made the necessary drawings on CNC machines. Mechanical movement of the machine is provided by stepper motors and motors are controlled with necessary motor driver circuits. The computer control program is created in 3 steps; design program, tool path creation, machine tool control program. The CNC controlled machine tool project was made by controlling the system according to the international standards used in the industry. While choosing the shapes and methods used in their work, they considered that their work would yield the most appropriate results without leaving the standard CNC machine format. The mechanical design of the machine was made in a virtual environment using Solid Works and Auto Cad. The design has become a machine by drawing the existing materials and mechanical parts in one piece, assembling and assembling. The motor is a stepper motor and the power is transmitted to the ball screw via a 1/2.5 ratio pulley and a timing belt. The machining axis consists of 3 axes: X 50mm Y 50mm Z 50mm. Movement of all three axes is provided by stepper motors. The movement of the machine is adjusted by sliding on 4 R20mm and 8 R16mm linear roller bearings. 16 mm / 5 mm screw shaft and 3 ball nuts are used for power transmission. 20mm Plexiglas is formed by using CNC milling machine as the mechanical chassis material (Akçaoğlu, 2009).

Ausome, in his project, has ordered all parts and materials of the CNC Router machine over the internet. Then, a set of DC cables is connected to the driver board of the main power cables coming from the power supply. The cables from the connection cables of the driver card to the X-Y-Z ports are connected to the driver card, and a stepper motor is

used to drive the stepper motors in the X-Y-Z axes and to provide 1 movement for each of the X-Y-Z axes. In addition, geared and toothless 8 mm shafts are used for easy movement of the axes. It was controlled by Arduino and the necessary G-CODEs were searched and the appropriate G-CODE was used. 4 CNC Shields and Arduino are powered by USB (Ausome, 2015).

Yıldırım, In his project, Internet research was conducted and projects were carried out with the help of certain sources. Using the AutoCAD program, the mechanical parts of the machine and a full-size 3-axis CNC Router drawing were completed. All parts of the machine have been prepared with 2D technical drawings. For the construction of the external mechanism and some parts of the machine, outside help was obtained by going to the industry. The remaining parts were purchased online and externally. He also considered using aluminium instead of materials called hard plastic. In this way, the machine parts are designed to be light and easy to process. These aluminium hard materials are prepared by cutting into the required shapes and drilling holes. Then, the materials were combined and experiments were carried out with a single axis stepper motor, a simple driver and a computer program. The mechanical part of the machine was made ready by making precise measurements and bringing all the materials together. The MCU (Micro Controller Unit) and PC software of the project remained. They controlled the system with the GUI (Graphical User Interface) they designed and operated the machine automatically with the punch files (Baysal & Yıldırım, 2008).

Tekin used a board called MDF so that his work would be cost-effective and he planned his design on A4 paper. The design was inspired by another CNC Router project. For the movement of the X, Y, Z axes of the CNC machine, 10x26x8mm iron bearings and 18cm length, 17mm thick iron pull-pull rails were used. 6mm gear shafts are used to transfer the motion coming from the motors to the X, Y, Z axes. Nema17 Stepper Motor, DC 5V 1.2A motors are used and shield is used to drive these motors. This project is coded with Arduino Uno. Later, after the project was collected, it was put into use as a milling machine (Tekin, 2015).

Duran, in the project he has done, a system that will cost less than the Arduino Mini CNC project in a simpler way has been considered. A mechanism has been established with the small engines of CD/DVDs. Arduino Uno was used for this project and 2 servo motors were used. Two L293D motor drivers are used to drive these motors. And CD/DVD mechanism is

used to provide the movement of my system. First of all, the inside of the CD or DVD readers was dismantled and the necessary part, the engine and the sliding mechanism, was provided. He then fixed the drives, one vertical and the other horizontal. A servo motor sled has been added to the vertical system, enabling the stylus to be lifted and lowered while writing with the servo motor. In this way, more beautiful and perfect writing is provided (Duran, 2016).

Gül planned his project by considering the least cost. Arduino Nano is used in the project. He used damaged DVD or CD-ROM for the movement of the axes. Servo motor Mg90 is used to provide movements and 2 L293d motor drivers are used to drive these motors. A 5V, 2 Ampere battery or adapter is used for power supply. 20×16 cm and 5 mm thick plexi-plate was used to fix the X-axis, and 15×16 cm and 5 mm thick plexi-plate was used to fix the Y-axis, 75×75 mm and 5 mm thick plexi-plate was used for the drawing board. . 1 piece of M5 bolt and nut is used to fix the pen. The rail system inside the DVD or CD-Rom drive is used. In this part, the stepper motor is connected to the worm screw shaft and the laser reader part connected to the shaft is adjusted to move as the shaft rotates. In total, two stepper motor rail systems were removed and mounted on the mechanical part. The mechanical part that will provide the movement of the axes has been used as these. Other mechanical parts were removed from the 3D printer. In the electronic system, two stepper motors that will move the x and y axes and one servo motor that will raise and lower the pencil are connected. Then the necessary codes were uploaded to the Arduino Nano. Gcode was output with INKSCAPE and made available after necessary adjustments (Robimek, 2016).

Cengiz and Ekim, In their research, the design of the four-axis CNC milling machine was carried out by controlling the pre-made CNC system, taking measurements from it, and measuring the distance between the milling machines according to the usage requirements of the four-axis CNC milling machine. The movement of the CNC machine tool on the Y axis is provided by the movement of the nut pair on the stepper motor. The table of the machine is fixed and other parts are moved. The slider is fixed to the four corners of the counter with bolts. The records on which these slide rails move are fixed to the workbench with shaft brackets. The screw shaft, which starts to move from the stepper motor, will move the nut fixed on the work table due to the reversibility effect. For this reason, the "Y" axis of the system is designed to move precisely according to the

screw pitch. 4-axis CNC control card is Mach3 brand and supports up to 4 axes. The speed is controllable. It shows high quality and high performance in high speed operations. PWM has 0-10V output. There are 15 inputs and 8 outputs. There is also a relay output socket that can operate the paper cutter with computer control. The Mach3 control board is connected to the computer with a USB cable. The record shift system is designed to reduce and eliminate friction caused by motion, thus providing optimum motion by reducing heat and instability caused by system motion. A 4-stage motor is used in the system. Each stepper motor used is a motor capable of drawing 3 amps of torque at 2.2 Nm. The diameter of the screw shaft nut pair used in the system is 16mm, the upper tooth = 20mm, the diameter of the tooth root $d_f = 18\text{mm}$ and the pitch of the tooth is 5mm. Thanks to the ball screw nut pair, the movement on all shafts is dependent on the thread pitch. Thanks to the first system setting and mechanism definition setting input on the control card, the control card calculates the number of revolutions after the ball screw is connected to the stepper motor and transmits the progress amount to the system. The component used to drive between the stepper motor and the screw shaft in the drive system is a 24x34 mm coupling. In the system, the collet group is used for inserting and removing the cutting tools. A collet set, which is more advantageous than the chuck, is preferred because it has the advantage of fast tool change. The power supply used in the system is 24 volts, 14.6 amps and 350 watts. Delta VFD-EL spindle motor driver with an output frequency of 0.1-600Hz will be used to control the speed of the spindle motor to be used in the system (Uyar, Beler, & Çetinkaya, 2012).

2. CNC (COMPUTER NUMERICAL CONTROL)

The printed circuit layout stage of electronic circuits brings up an important issue, especially in the industry. The characteristics and dimensions of the components on the circuit are the most important factors affecting the layout (Çakır, Küçüksille, & Altıntaş, 2018). CNC (Computer Numerical Control) Machine is a system that performs automatic processing by programming with a computer installed on it. Examples include CNC machine tools, lathes or CNC (Topal, 2019).

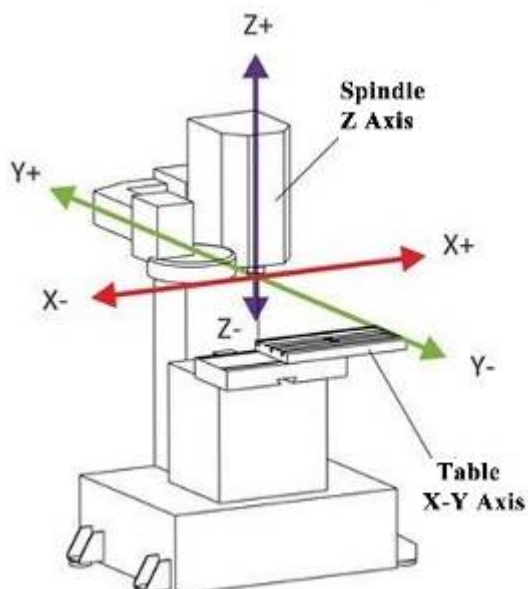


Figure 1. CNC Control Panel

The basic working logic of CNC machine tools is based on human language operations. Machine tools can be operated by translating commands encoded with numbers, letters and similar symbols into machine language. At any step of the process, the command loaded into the control unit of the CNC machine tool can be stopped. It is possible to stop the work of the working CNC machine, make changes and continue again. Depending on the brand and model of the equipment, the commands written in the computer environment can be loaded into the CNC machine in many different ways. Figure 1 shows the CNC control panel. The CNC control panel contains an electronic circuit that sends signals to the motor driver. Thus, the axis of the CNC machine can be moved to the coordinates specified in G-CODE. In order for the CNC control panel to control the operation of the machine tool, the CAD/CAM operations must be executed correctly, the G-CODE data file must be created and transferred to the CNC control (Robotiksystem, 2019).

3. ARDUINO CONTROLLED CNC PRINTING CIRCUIT MACHINE

In this study, Arduino Controlled CNC and Printed Circuit Machine was designed. Electronic cards were

produced by scraping the paths of the circuits and drilling their pads. In the hardware part of the study, the mechanical part and the circuit of the Arduino Controlled CNC and Printed Circuit Machine are included. In the mechanical part, the skeleton of the CNC machine was formed and the position of the stepper motors and drill bits that would enable the movement of the axes were determined. The components that provide control in the hardware part are Arduino UNO, CNC Shield V3.0, A4988 stepper motor driver board and NEMA 17 (step motor). CNC Shield V3.0 expansion board is installed on Arduino UNO microcontroller board. A4988 stepper motor driver was installed in the slots of CNC Shield V3.0 and the motors were started with the energy applied by A4988 to the pins of NEMA 17. After the hardware part of the Printed Circuit Machine was completed, calibration settings were made from the UGS (Universal G-CODE Sender) program.

After designing the hardware of the Printed Circuit Machine with Arduino Controlled CNC, the circuit for which the printed circuit will be extracted was drawn using the PROTEUS 8 program and the GERBER files of the circuit were created. GERBER files contain information about the paths of the electronic card. The depth of engraving in how many mm to remove the circuit paths is set in the CopperCAM program. Drill bits to be used in engraving and drilling of the printed circuit board are introduced in CopperCAM. In addition, G-CODEs that will enable the movement of the CNC machine have also been created in this program. In order to control the CNC machine with G-CODEs, HEX codes have been uploaded to the Arduino UNO development board through the Xloader program. In this way, the Arduino UNO development board will determine the rotation angle and rotation speed of the stepper motors with the G-CODEs sent from the GRBL Controller program to the Arduino UNO development board.

The steps to be followed for the creation of the printed circuit board using the Arduino Controlled CNC and Printed Circuit Machine are shown in the diagram in Figure 2.

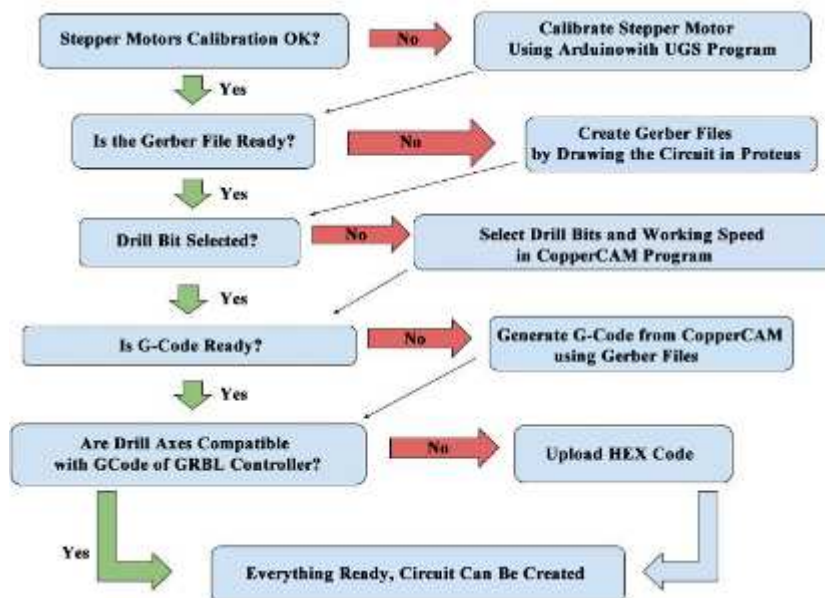


Figure 2 Working Diagram of Arduino Controlled CNC Printing Circuit Machine

3.1. Control and Power Circuit

The control of the Printed Circuit Machine is carried out using Arduino Uno microcontroller board. CNC Shield V3.0 expansion board is installed in Arduino UNO. In Figure 3, it is seen that CNC Shield V3.0 is attached to Arduino Uno and 3 A4988 stepper motor drivers are integrated into the pin sockets of CNC Shield V3.0. The CNC Shield V3.0 expansion board houses 4 stepper motor driver slots and facilitates motor control in multiple stepper motor control applications. 3 NEMA 17 (stepper motor) and 3 A4988 stepper motor drivers are used for the control of 3 different axes (X-Y-Z) in the Printed Circuit Machine.



Figure 3. Arduino UNO, CNC Shield V3.0 and A4988 Stepper Motor Driver

The commands sent from the Arduino UNO development board were transmitted to the A4988 stepper motor driver via the CNC Shield V3.0 board, and the rotation angle and rotation speed of NEMA 17 were controlled by changing the voltage values applied by the driver IC to the pins of NEMA 17. 3 NEMA 17 (stepping motors) were used to provide 3 separate axis movement in the Printed Circuit Machine and the drill bit was moved between the axes with the commands sent from the Arduino UNO board. Figure 4 shows the connection diagram of CNC Shield V3.0 and NEMA 17.

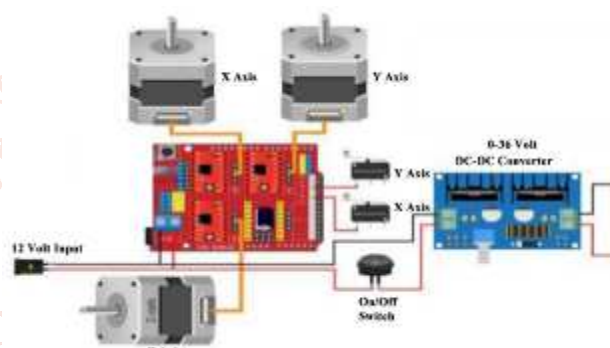


Figure 4. Connection of CNC Shield V3.0 and NEMA 17s

3.2. Calibration Setting

The calibration of the Arduino Controlled CNC and Printed Circuit Machine was made with the UGS program. By using the UGS (Universal G-CODE Sender) program, communication between the computer and the circuit board is provided. For communication between the card and the computer, the port in which the card is inserted is selected and the baud rate is set to 115200. When the communication is successfully established, the calibration settings of the machine can now be made. With the values entered in the UGS program, the X-Y-Z axes of the CNC machine can be moved forward-backward, right-left, up-down, in mm length. By measuring how many mm the moved axes move with the caliper, the relevant section of the UGS program is entered. In this way, it is ensured that the values entered on the screen and the actual values match each other and the error is minimized.

Figure 5 shows the calibration settings and related sections with the UGS program. The values entered in the Move section allow the axes of the CNC machine to move in mm. The Measure section is the field where the data obtained from the measurement of the moving axes with the caliper are entered. Calibrate

section is the section where the tested Move/Measure ratio is entered and the current measurements of the CNC machine are saved. By saving the tested dimensions in the Calibrate section, the calibration setting of the CNC machine was made and the shifts in the axis movements were minimized.

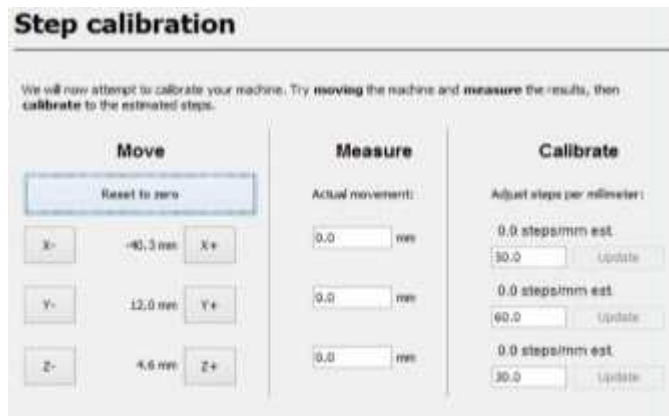


Figure 5. Calibration Adjustment with UGS Program

By saving these values to the program, it can be ensured that the CNC machine works according to these values in every printed circuit production. However, it is recommended to update these values again when changing the position of the CNC machine.

3.3. Removing G-code

The circuit board to be produced in the Printed Circuit Machine with Arduino Controlled CNC was drawn in the PROTEUS 8 program. GERBER files of the drawn circuit were created in PROTEUS 8 program. The GERBER files of the circuit board where engraving, drilling and cutting operations will be applied are saved as documents with .txt extension. Figure 6 shows the selection of the desired features in GERBER files.



Figure 6. Properties in the GERBER File

In the CopperCAM program, the length and thickness of the drill bits to be used for engraving, drilling and cutting operations can be recorded. After the GERBER files are created, drill bits with different properties should be introduced to the CopperCAM

program and the selection of drill bits suitable for engraving, drilling and cutting operations should be matched. GERBER files, where engraving, drilling and cutting operations will be made, were also called into the program and the drill bits with which the files would be processed were selected. Figure 7 shows the selection of drill bits.



Figure 7. Drill Bit Selection

The drill bit used in this study is 0.1 mm in diameter. In the CopperCAM program, the tool to perform the engraving was selected and the engraving depth was 0.35 mm, and the cutting depth was chosen as 1mm for the tip that would perform the cutting. While the drill bit is cutting, its speed is reduced to 5mm/s to prevent damage to the circuit board.

The way in which the CNC machine will engrave is also calculated at this stage. For the scraping process, the matched drill bit is automatically selected and the scraping path is created. Then, the created engraving paths were translated into the machine language G-CODE. Separate G-CODEs for scraping, drilling and cutting layers have been issued and axis and drill commands have been made suitable for use on the CNC machine. In addition, G01 X0 Y0 commands are written between M05-M02 at the end of the G-CODEs created, and after the CNC machine finishes its operation, its axes return to the starting point and are ready for the next printed circuit design.

3.4. GRBL Controller

In order to ensure the communication between the program and the CNC machine from the interface of the GRBL Controller program, the communication is started by selecting the port. When the communication starts, the motors are locked and the CNC machine is ready for engraving according to the data sent from the computer. The G-CODEs are called into the GRBL Controller program, when the start command is given, the CNC machine starts engraving the circuit board. Figure 8 shows the status after G-CODEs are loaded into the GRBL Controller interface.

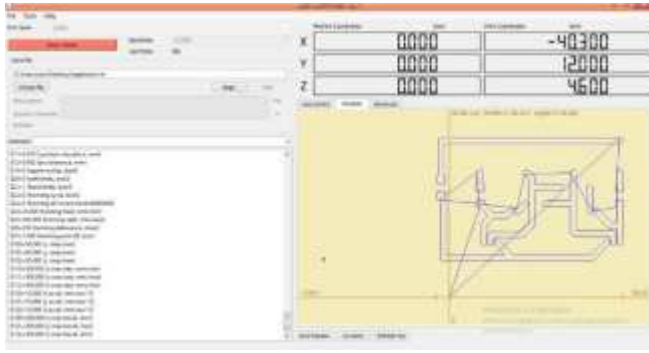


Figure 8. GRBL Controller Interface

4. CONCLUSION

In this study, a Printed Circuit Machine was designed using Arduino UNO development board. By using Arduino UNO development board, CNC Shield V3.0, A4988 stepper motor driver and NEMA 17 (stepper motor) as the main components in the control and power circuit, the Printed Circuit Machine is made ready for engraving and drilling operations based on G-CODEs. Before creating the G-CODEs, the GERBER files of the circuit to be taken from the printed circuit must be created. In this study, GERBER files of the circuit drawn in PROTEUS environment were created and G-CODEs were created using GERBER files in CopperCAM program. Finally, G-CODEs from the GBRL Controller program were sent to Arduino UNO to ensure the operation of the Printed Circuit Machine.

Conventional printed circuit building methods are laborious, expensive and time-consuming. Within the scope of this study, Arduino Controlled CNC and Printed Circuit Machine was designed and time was saved by reducing the steps of preparing the printed circuit board. At the same time, the need for people in electronic card printing was minimized by using the Printed Circuit Machine and it was aimed to reduce human-induced errors. On the basis of this study, the placement and soldering of electronic materials to be soldered on the printed circuit boards can also be done using a CNC machine. In this study, the engraving and drilling of the printed circuit board's paths was carried out with an Arduino Controlled CNC Machine and the need for people in electronic board printing was minimized. Arduino Controlled CNC and Printed Circuit Machine developed within the scope of the project; industry, R&D units, educational institutions, etc. It can be used in the production of electronic cards in institutions. In this way, the production steps of the printed circuit board can be accelerated, saving both time and cost for its users.

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