# ANALYSIS ON GRBL CONTROLLER SOFTWARE FOR STEPPER MOTORS ROTATIONS USING ARDUINO UNO

**Compiled as one of the requirements of completing the undergraduate program at the department of Electrical Engineering Faculty**


**By:**

**ALAA H Y ALJUBA**

**D400144007**



**ELECTRICAL ENGINEERING PROGRAM**
**FACULTY OF ENGINEERING**
**UNIVERSITAS MUHAMMADIYAH SURAKARTA**

**2019**

**APPROVAL PAGE**

# ANALYSIS ON GRBL CONTROLLER SOFTWARE FOR STEPPER MOTORS ROTATIONS USING ARDUINO UNO

**SCIENTIFIC PUBLICATION**

by:

**ALAA H Y ALJUBA**

**D400144007**

Has been checked and approved

by:

Supervisor

**Ir. Pratomo Budi Santosa, MT**

**NIK: 627**

**AFFIRMATION PAGE**

**ANALYSIS ON GRBL CONTROLLER SOFTWARE FOR STEPPER MOTORS ROTATIONS USING ARDUINO UNO**

By:

ALAA H ALJUBA

D400144007

**Has been tested in front of Examiners Faculty of Engineering Muhammadiyah University of Surakarta On Aug 19th 2019**

***The council of Examiners:***

1. **Ir. Pratomo Budi Santosa, MT** (.....)
   **( Head of Examiner)**
2. **Heru Supriyono, PhD** (.....)
   **(Member I of Examiner)**
3. **Dedy Ari Prasetya, ST.MEng** (.....)
   **(Member II of Examiner)**

**Dean,**

**Ir. Sri Sunarjono, M.T., Ph.D.**

**NIK: 682**

## TESTIMONY

I hereby declare that in this final project there is no work ever submitted to the degree of scholarship in a college and in my knowledge there is also no work or opinion that has been written or published, except in writing referenced in the manuscript ad mentioned in the bibliography.

If the above statement is found to be untrue, I will be fully responsible.

Surakarta, Aug. 19th 2019

Author

ALAA H ALJUBA

D400144007

# ANALYSIS ON GRBL CONTROLLER SOFTWARE FOR STEPPER MOTORS ROTATIONS USING ARDUINO UNO


## Abstrak

Sebagian besar proses pembuatan produk membutuhkan mesin CNC untuk menghasilkan produk berkualitas tinggi dengan akurasi tinggi. Dan penggunaan mesin CNC masih mahal. Makalah ini membahas kemungkinan untuk membuat sistem bingkai mesin CNC yang murah dan tidak rumit sebagai alternatif untuk mendukung usaha kecil dan menengah. Makalah ini menganalisis tahapan CNC untuk membuat fungsi penuh mesin CNC sesederhana mungkin menggunakan bagian hardware utama, mikrokontroler, motor stepper, driver motor stepper dan power supply. Dan software bagian utama seperti Arduino Integrated Development Environment IDE, Inkscape dan IntelliG-code. Sistem ini digunakan sebagai bingkai CNC untuk tiga mesin yang berbeda, mesin pemotong laser, mesin penggilingan CNC dan mesin cetak 3D. 3-axis sebagai bingkai CNC adalah menempatkan alat di area kerja mesin dengan 3 sumbu yang didistribusikan sebagai X, Y, dan Z dalam tiga arah berbeda untuk mesin CNC dua dimensi. Tujuan dari penelitian ini adalah untuk menemukan desain sederhana dan bingkai mesin CNC berbiaya rendah untuk penggunaan mesin industri serta untuk mendiskusikan hasil dan kualitas mesin CNC berbiaya rendah.



**Kata Kunci:** Mesin CNC GRBL, Mesin CNC Arduino UNO, Kontrol Motor Stepper menggunakan GRBL Software



## Abstract

The most of manufacturing processes need CNC machines to produce high quality products with high accuracy. And CNC machines usage yet is expensive and costly. This paper examines the possibilities to create a low cost and less complexity CNC machine frame system as an alternative to support small and medium enterprises. This paper analyses the CNC stages to create full function of CNC machine as simple as possible using the main hardware parts, microcontroller, stepper motors, stepper motor drivers and power supplies. And software main parts, Arduino Integrated Development Environment IDE, Inkscape and IntelliG-code. This system is used as a CNC frame for three different machines, laser cutting machine, CNC milling machines and 3D printing machines. 3-axis CNC frame system is to locate the tool in the work area of the machine by 3-axis distributed as X, Y and Z in three different directions for two dimensions CNC machines. The purpose of the research is to find a simple design and of low cost CNC machine frame for industrial machines usage and to discuss results and the quality of low cost CNC machines.



**Keyword :** GRBL CNC Machine, Arduino UNO CNC Machine, Driving Stepper Motors with GRBL Software.


## 1. INTRODUCTION

CNC is a Computer Numerical Control *[2]* that used for high precision plotting controls three axis of CNC machine frame by G-code commands. G-code is a language used to tell a computerized machine what to do. CNC is a computerized machine that works on Computer-aided Design CAD and Computer-aided Manufacturing CAM programs. Computer-aided Design CAD programs are to

design images such as Inkscape program or to design PCB traces such as KiCad and Eagle programs. Computer-aided Design programs are to create and improve images quality. Computer-aided Manufacturing CAM programs are to facilitate and automate manufacturing machines processes. CNC machine frame that used in 3-Dimension printers, CNC milling machines and Laser cutting machines, needs a Computer-aided Design CAD to design images and Computer-aided Manufacturing CAM to automate manufacturing processes. Computer-aided manufacturing CAM software sends a G-code *[4]* commands file, the translation of CAD image, to the CNC machine microcontroller to ordinate the movement of the stepper motors those are distributed in 3-axis in three different directions to locate machine tool *[2]* in the CNC machine work area with high precision considering trace edges and sizes according to the CAD design that was translated into G-code file. This project uses Inkscape as a Computer-aided Design CAD and GRBL Controller as a Computer-aided Manufacturing CAM open source programs. In order to implement a low cost CNC machine. This paper suggests to use Arduino UNO microcontroller kit as a CNC machine microcontroller.

### 1.1 Motivation

Due to the importance of CNC machines nowadays. The low cost CNC machines, design and implementation, is perfect to support the field of research on CNC machines and to develop a new CNC machine technology in the University Muhammadiyah of Surakarta in the future. Using modern components and technology to develop a laboratory CNC machines and robots based on G-code controllers enriches researching on control and automation fields.

### 1.2 Contribution Summary

The purpose of this paper is to simplify the principle of 3-axis CNC machine frames for engineers and engineering students. The spindle of CNC milling machine *[3]* can be replaced with a several tools, such as laser cutting, plasma cutting, hot wire, water jet cutting or other tool for variety applications. Also the CNC machine frame can be modified with a new design of 3-axis actuators for several CNC machine functions.

### 1.3 Thesis Outline

This paper explains the components used in this project and their function in chapter 02, chapter 03 is to present the proposed model to build a CNC machine system as simple and as possible, chapter 04 is to explain the machine setup with CAD and CAM programs and machine running results and chapter 05 is the discussion, conclusion and future plan to improve CNC machine frame design.

## 2. THE METHOD AND MAIN COMPONENTS

Starting with preparing the commands to run the CNC machine. Inkscape is good open source software to start working on CNC machines. Inkscape software is used in this project to convert images into SVG or G-code files. G-code is a machine language to tell the machine what to do and to coordinate the 3-axis actuators movements according to the image design. And IntelliG-code software is used in this project to send G-code file to the CNC machine microcontroller via USB port. GRBL code file is an open source low cost high performance code to control parallel-port-based CNC milling motion. The GRBL code file is made specially to run on Arduino UNO handling G-code that sent from Computer-aided Manufacturing CAM software. The machine microcontroller needs to be coded with GRBL file to receive the G-code directly from IntelliG-code. In case that SVG file downloaded to the IntelliG-code, IntelliG-code will convert it into G-code and send it to the Arduino UNO microcontroller via USB port. The Arduino must be connected to the computer while CNC machine is running. Arduino UNO *[1]* has 14 input/output pins. According to the GRBL code file, pins 2, 3 and 4 are step outputs for X, Y and Z respectively and pins 5, 6 and 7 are direction outputs for X, Y and Z respectively. Pin number 8 is stepper enable/disable, pins 9, 10, 11 are axis limits and 12, 13 are spindle enable and direction respectively. See *figure 01* GRBL Pinout

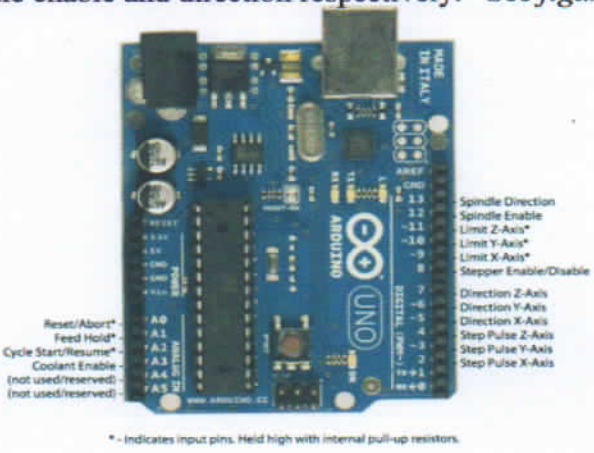


Figure 01.GRBL Pinout.

On the left of *figure 1* there are a Coolant Enable to enable coolers, Cycle Start/resume, Feed Hold and Reset pins to include additional functions to the machine. The minimum machine structure does not need them as long as they are not important to run minimized CNC machine structure. Next pages show the block diagram in *figure 02* and the flowchart of the system in *figure 03*.

This CNC machine system is based on Arduino UNO microcontroller coded with GRBL code file. The microcontroller will process G-code that came from CAM software to input drivers with step and direction pulses.

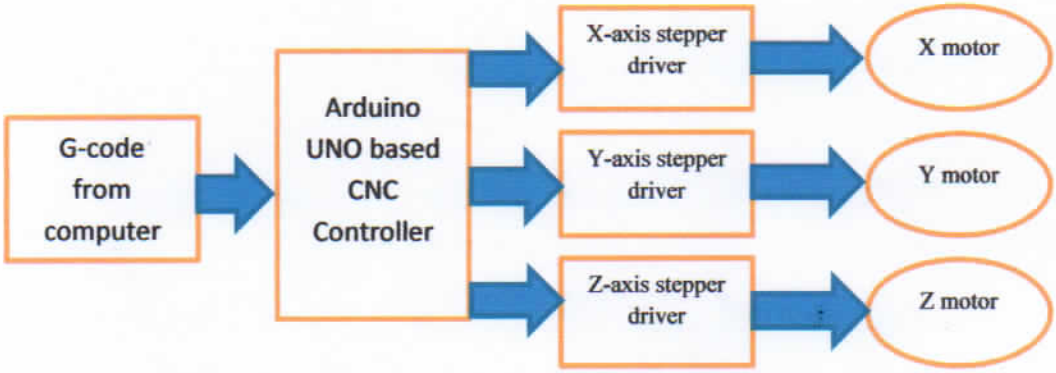


Figure 02. Proposed CNC Block Diagram

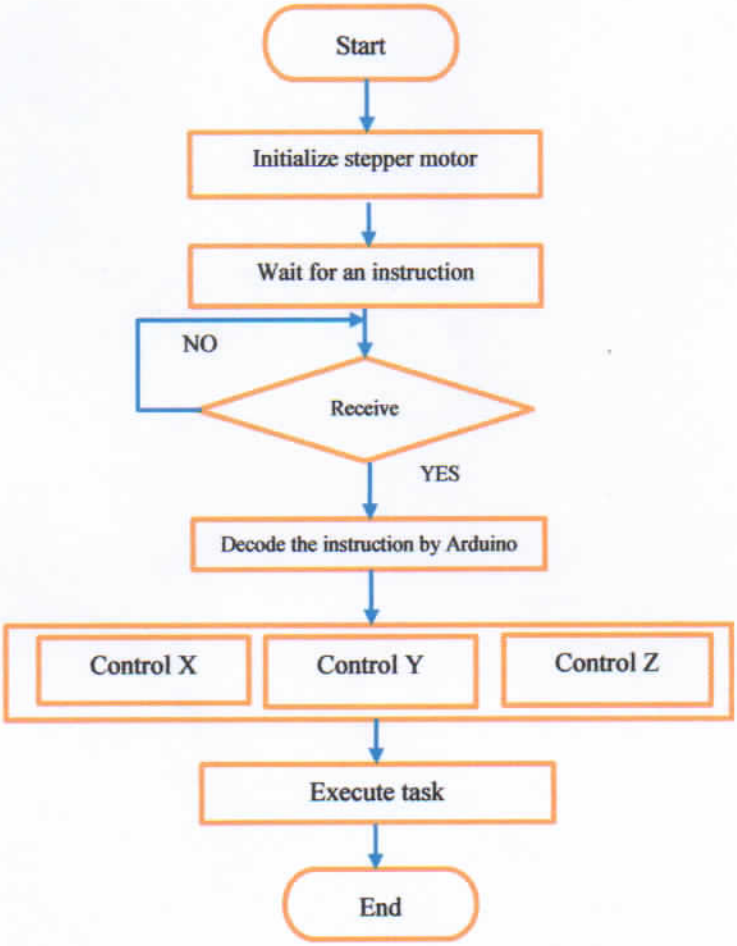


Figure 03. GRBL CNC System Flowchart

## 2.1 Hardware Components

### 2.1.1 Arduino UNO Microcontroller

Arduino UNO *[1]* is a microcontroller board based on ATmega328 microcontroller chip. The Arduino was built to make working with microcontrollers easier because Arduino has a software program to code the Arduino board directly from the computer via type B USB port. The program is Arduino Integrated Development Environment IDE. Instead of using Hand Programmer tool or Programming board, the Arduino can be coded directly via USB port without using assistant tools because it has USB Bridge to convert USB interface into UART interface using ATmega16U2 to input the ATmega328 microcontroller chip. UART is Universal Asynchronous Receiver-Transmitter. Also Arduino microcontroller board has its own voltage regulator makes the board able to be supplied with the range between 6-20 volts DC instead of using external voltage regulator. Take a look at figure 1 Arduino UNO with GRBL Pinout.

### 2.1.2 Stepper Motors

The stepper motor is a brushless-DC motor that divides the rotation into steps. Stepper motors are two different types, unipolar stepper motor and bipolar stepper motor. The difference between each other is the windings connection to the Driver and Stepper Motor Wave Drive SMWD. Stepper motors are electromechanical devices that work on converting electronic pulses into discrete mechanical movements. Stepper motor movement is based on the sequence of pulses given to the motor windings. Therefore, stepper motor movement requires a stepper motor controller that generates periodic pulses. The use of stepper motors has several advantages compared to the use of ordinary DC motors. The rotation angle of the motor is proportional to the input pulse so that it is easier to set. The motor can directly provide full torque when starting to move Position also the repetition movement can be determined precisely. Stepper motor has a good starting, stopping and turning response.

#### 2.1.2.1 Unipolar Stepper Motor

The unipolar stepper motor requires one switch / transistor per coil. To start and stop this motor simply apply a digital pulse consisting only of positive and zero voltage (ground) on one motor winding terminal while the center tap terminals are supplied with a constant positive voltage (VM) of convolution as in *figure 04.* Note that the wave drive of unipolar stepper motor is different with bipolar stepper motor wave drive. Therefore, the stepper motor controller is different.

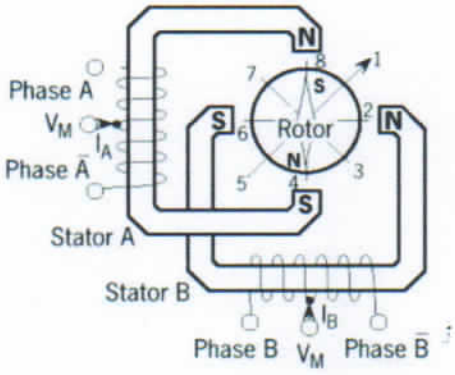


Figure 04. Unipolar Stepper Motor

2.1.2.2 Bipolar Stepper Motor

Bipolar stepper motors need to change the pole of windings voltage for every single step. Controller signal pulses will be changed from positive to negative and vice versa. So at each winding terminal (A & B) must be connected with a signal that swings from positive to negative and vice versa. Therefore a controller circuit that is more complex compared to unipolar motor controller circuit. Bipolar stepper motors have the advantage over unipolar stepper motors that the bipolar stepper motor has larger torque than unipolar at the same pulse frequency. It has no center tap. See *figure 05.*

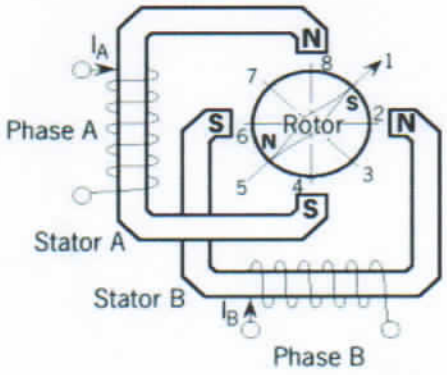


Figure 05. Bipolar stepper motor

2.1.3 Stepper Motor Driver

Motors used in this project are unipolar stepper motors. The stepper motor driver has a stepper motor controller and Amplifire. Stepper motor controller used in this project is L297 Integrated Circuit IC, and ULN2003 as an amplifier. The circuit in *figure 06* is a stepper motor controller. *Figure 06* shows one stepper motor driver of three. 3-axis CNC machine needs three stepper motor drivers.

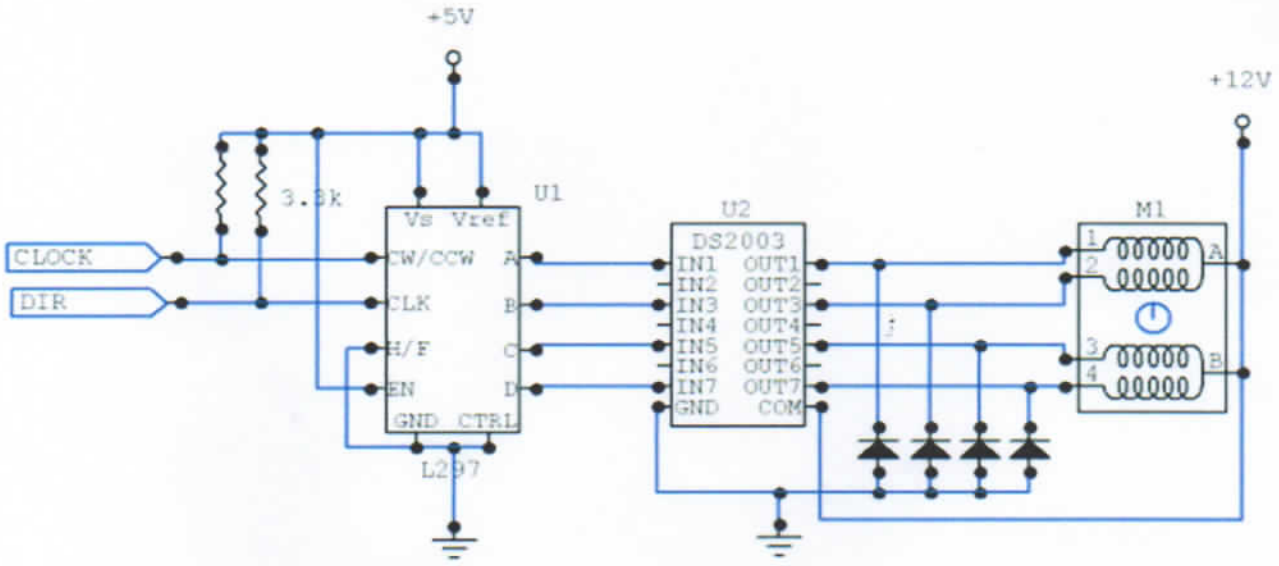


Figure 06. Unipolar Stepper Motor Driver

Use clock input as a motor step and CW/CCW input as a motor direction for minimized CNC machine system design.

## 2.2 Software Components

### 2.2.1 Arduino Integrated Development Environment IDE

The IDE is Integrated Development Environment. It is an integrated environment used to carry out development. It is called environment because through this software, the Arduino microcontroller board coding to perform functions embedded is through the programming syntax in Arduino IDE software. Arduino uses its own programming language that resembles C. The Arduino programming language (Sketch) has been made changes to facilitate beginners in programming from the original language. Before being sold to the market, the Arduino microcontroller IC has embedded a program called *Bootlader* that functions as an intermediary between the Arduino compiler and the microcontroller. Arduino IDE is made from the JAVA programming language. Arduino IDE also comes with a C/C++ library which makes input and output operations easier. Arduino IDE was developed from the Processing software that was remodeled into an Arduino IDE specifically for programming with Arduino. To code the Arduino UNO as a CNC machine controller, download the

GRBL ZIP file from GitHub.com and install it to Arduino UNO library and then compile it to the Arduino UNO board.

### 2.2.2 Inkscape Software

Inkscape is vector processing software that is open source with the GNU GPL (GNU General Public License) license and its main purpose is to be a vector graphics processing device that supports XML, SVG and CSS standards. Inkscape is the same as Corel Draw software, Adobe Illustrator and others, the difference between Inkscape and other software is the use of SVG (Scalable Vector Graphics) which supports the W3C XML standard. The use of Inkscape in this project is to save the design as a SVG file on the computer and import it to IntelliG-code software that is explained next.

### 2.2.3 IntelliG-code Software

IntelliG-code was made to send G-code *[4]* files to the CNC machine controller in easy way whatever the CNC machine controller is, because G-code is the CNC machine language, all of CNC machines are able to receive G-code files from GRBL Controller software. IntelliG-code is not the best software to send G-code files to CNC machine, but it is easy to use that can handle CNC machines.

IntelliG-code can import design files from Computer-aided Design CAD in many formats such as PDF and Scalable Vector Graphics SVG files. GRBL Controller is perfect to be used with Inkscape software because Inkscape software can save images on the computer as SVG files, and SVG can be imported to GRBL Controller easily. This project does not need more than Inkscape and GRBL Controller software after compiling GRBL file to the Arduino UNO board unless the CNC machine used as a PCB maker, the KiCad software is needed. The Inkscape software is to create and save images as a SVG files on computer and then import the SVG file to GRBL Controller to convert it into G-code file and to send the G-code file from GRBL Controller to the CNC machine controller. All of software used to run this CNC machine is open source software.

## 3. RESULTS AND DISCUSSION

### 3.1 Software Section

The model explained in this paper has two main sections, software section includes Arduino IDE to compile GRBL file *[11]* to the Arduino microcontroller board, Inkskape software to create and convert images into Scalable Vector Graphics SVG or G-code files and IntelliG-code software *[5]* to import Scalable Vector Graphics SVG or G-code files to send them to CNC machine controller. *Table 01* shows errors while preparing CNC machine software and their solutions.

Table 01. Software Errors and Solutions

| Error number | Software name | The error/ software message | The solution |
|---|---|---|---|
| 1 | Arduino IDE | Error while installing GRBL file to Arduino IDE library | Extract the GRBL ZIP file > open GRBL master > install GRBL folder to the library. |
| 2 | Inkscape | Inkscape does not have G-code in the library | Download unicorn ZIP file from GitHub.com and extract it in the extensions folder of Inkscape software. |
| 3 | Inkscape | TypeError:--unsupported--operand--type(s)—for--*:--'NoneType' and 'float'. While saving G-code file to the computer. | From document properties, change display unit and units from mm to px. To save G-code file successfully. *[6]* |
| 4 | GRBL Controller 1.0 | The new version of GRBL Controller is Candle software. GRBL controller and Candle are almost the same, but Candle cannot work with GRBL 0.9i. | Use GRBL Controller 1.0 with GRBL 0.9i/ 0.9j. and Candle software with GRBL v1.1.<br>IntelliG-code Software is better than GRBL Controller to use. |
| 5 | GRBL Controller 1.0 | GRBL Controller and Candle software cannot import PDF format files, unlike FlatCAM software. | Use Scalable Vector Graphics SVG and G-code files only. |

| | | | |
|---|---|---|---|
| 6 | Inkscape and GRBL Controller 1.0 | Exporting and importing G-code/ SVG files cannot be automatically. | Move the file manually. |

These are the most common errors while preparing CNC machine using mentioned software above and there are a lot of YouTube videos explain how to use previous software. In case that some errors happened not mentioned in the table 1, copy the message and paste it to google to get the solution easily.

### 3.2 Hardware Section

All of the stepper motor drivers have stepper motor controller and amplifier. The proposed model uses the L297 Integrated Circuit IC [9] as a stepper motor controller and ULN2003 as an amplifier. Operating voltage of L297 figure 07 is 4.75 – 7v, it can be supplied with Arduino microcontroller board because their voltage can be the same, 6 volts for example. *Figure 07* L297 Integrated Circuit L297 inputs are connected directly to the Arduino board outputs for steps and direction.

ULN2003 is a Seven Darlington Arrays *[10]* used as an amplifier. It is connected directly with load voltage 5 – 30 v, it must be separated. This CNC machine has two different power supply outputs even using 5v stepper motor 28BYJ-48 because of its current. *Figure 08* shows L297 Pinout.


Figure 07. L297 Integrated Circuit L297

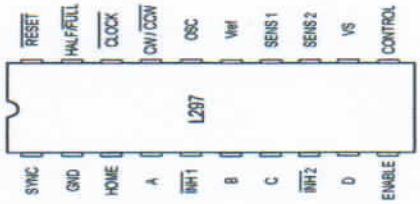


Figure 08. L297 Pinout

Some of pins are not used such as Home, Control, Sync, Vref, and Reset. Two reasons to not use these pins, because this circuit was designed to drive unipolar stepper motor instead of bipolar and it is connected with ULN2003 Seven Darlington Arrays instead of L298n Dual Full Bridge amplifier

IC. The reason I used ULN2003 is that to study the possibilities on designing CNC machine in many different ways in Hardware, Software and Mechanical system in the future. *Figure 09* shows ULN2003 with its pinout. *[10]*

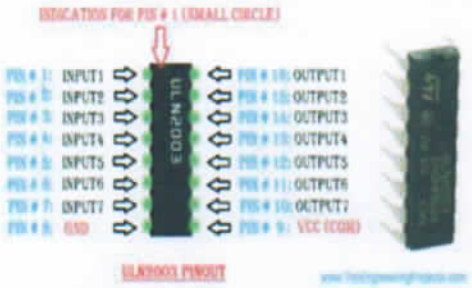


Figure 09. ULN2003 Pinout

Following *table* shows the difference between control and load circuits currents, and the reason why CNC machine has two different power supply outputs even using 5v 28BYJ-48 unipolar stepper motor. Note that the load is not connected to the computer USB port.

Table 02. The Difference Between Control and Load Circuits Current

| Component name | No load current | Full load current | X 3 full load |
|---|---|---|---|
| Arduino UNO board | 50 mA | DC Current per I/O Pin 40 mA | |
| L297 IC | 10 mA | 60 mA | 180 mA |
| ULN2003 IC | | On series with stepper | |
| 28BYJ-48 stepper | | 180mA | 540 mA |

The maximum USB port current is 500mA from USB 1.0 and USB 2.0, and 900mA from USB3.0.

### 3.3 Proposed CNC Machine Process Steps

#### 3.3.1 Software Setup & Test Results

The software job in CNC machine is to send G-code to the CNC machine microcontroller as a final process of software section. Starting with CAD software to design image and save it on the computer as a SVG or G-code file to upload it on CAM software to be sent to CNC machine microcontroller.

Many CAD and CAM software programs can be used to run CNC machine, some of them are open source programs.

3.3.1.1 Inkscape Computer-aided Design Software

Inkscape is an open source Computer-aided Design software that used to design images and save it as many formats including SAV and G-code. Inkscape is an easy software to start with CNC machines because it is able to save files as SAV and G-code directly without additional software to translate them in additional steps.

3.3.1.2 IntelliG-code Computer-aided Manufacturing Software

IntelliG-code *[5]* was made specially to send G-code file to CNC machine based on GRBL microcontroller coded, such as Arduino UNO and Arduino NANO CNC machines. IntelliG-code software is like other G-code sender programs, takes the G-code file and sends it as commands one by one to the CNC machine microcontroller to translate them as coordinated movements to control axis position, also IntelliG-code shows the design and the position of the spindle on the platform. G0X10Y10Z10 *(table 03)* G-code command runs the 3-axis to the same direction and at the same time for a while, the displacement moved by G0X10Y10Z10 command on the actuators is according to the machine settings and actuators specifications, because the CNC machine microcontroller will translate G-code commands into pulses to drive stepper motors moving the actuators. *Figure 10* shows pulses to run Bipolar stepper motor for a few degrees.

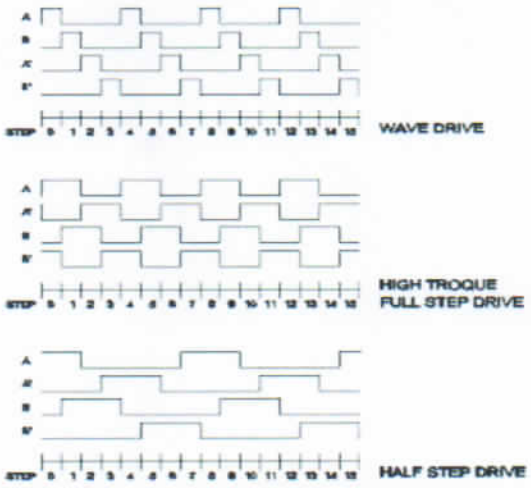


Figure 10. Stepper Motor Sequence

Table 03. G0X10Y10Z10 Functions

| Command Part | Function |
|---|---|
| G0 | Motion Type – Rapid Motion |
| X10Y10Z10 | Define Ending Point |

The specifications of 28BYJ-48 stepper motor that connected to the ULN2003 are limited about Speed Variation Ratio 1/64, Stride Angle 5.625° /64 and maximum Frequency is 100Hz, the system that uses this kind of stepper motors needs to be adjusted from Arduino IDE > serial monitor > $ > $$. By adjusting $100, $101 and $102 to be equal to 64 instead of the default setting 250. This value is how many pulse for one rotation of the stepper motor. note that the NEMA 17 is faster than 28BYJ-48 stepper motor. After setting these values, the CNC machine was run by G-code commands those were created by CNC software mentioned above. The results are shown in *table 4* below.

The system was tested with IntelliG-code software, IntelliG-code software is Computer-aided Manufacturing software that can generate a G-code files and send them to CNC microcontroller. IntelliG-code is similar to GRBL Controller and Universal G-code Sender. *Figure 11* shows the shape that was created by IntelliG-code software and its G-code commands file were sent to the machine successfully.

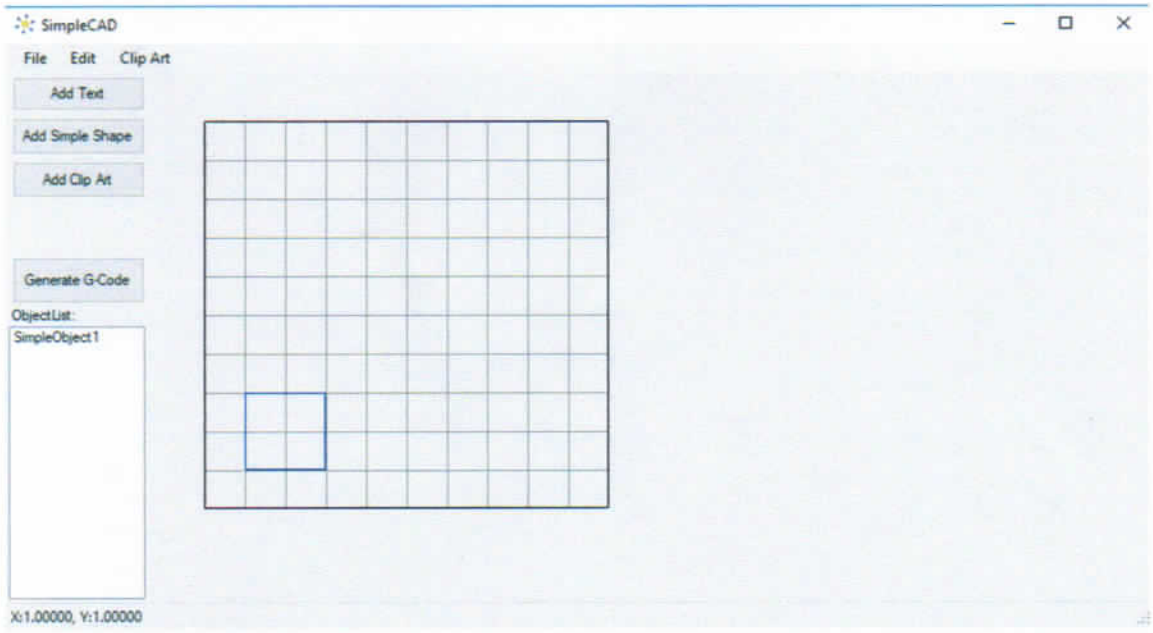


Figure 11. IntelliG-code software canvas

*Table 04* bellow shows the first commands of square shape designed by IntelliG-code software and the movement of stepper motors when they are sent to the machine.

Table 04. G-code Commands and Their Movements

| G-code command | $1 value | X-axis | Y-axis | Z-axis |
|---|---|---|---|---|
| G0 Z0.23622 | 64 | 0 | 0 | 0.23 mm |
| G1 X1.492431 Y0.5075694 Z-0.125 | 64 | 1.49 mm | 0.5 mm | -0.125 mm |
| X0.5 Y0.5075694 Z-0.125 | 64 | -0.99 mm | 0 because the same place with the last command. | 0 because the same place with the last command. |

3.3.2 Hardware Circuits & Test Results

3.3.2.1 Arduino UNO Board

Arduino UNO *[1]* board has three different power inputs. USB port voltage 5V, Vin socket 6-20V and 3.3V pin. Using Arduino board as a CNC controller, USB power is enough in case that stepper motors are supplied with external power supply because GRBL CNC machine does not work without being connected to the computer USB communication, it receives G-code commands from GRBL Controller software. Arduino UNO board was connected to computer USB port and GRBL file was uploaded to the Arduino board successfully. After GRBL file is uploaded, Arduino board is ready to act as CNC controller and to test stepper motor drivers by providing them commands monitoring stepper motors movements considering that the connection of stepper motors leads must be matching the stepper motor and stepper motor driver datasheets.

3.3.2.2 Stepper Motor Drivers

Stepper motor driver has two main circuits, stepper motor controller and amplifier. The common stepper motor driver inputs are STEP, DIRECTION and ENABLE to build the minimized CNC machine system with these necessary pins of control. Proposed stepper motor driver is based on L297 Integrated Circuit that has inputs even for maximized CNC machine system including SYNC input to synchronize many drivers together in case used for heavy duty CNC machines using two or

more stepper motors for each actuator, CONTROL for additional control processes, FULL/ HALF is to change between full step drive and half step drive modes and many other inputs to improve the CNC machine performance. According to the L297 stepper motor controller datasheet *[9]*, STEP and DIRECTION pins are called CLK as a step and CW/ CCW as a direction control in case that used to control bipolar stepper motor, and CLK as a direction and CW/ CCW as a step in case that used to control unipolar stepper motor ( *see L297 datasheet* ) *[9]*. Stepper motor driver based on L297 stepper motor controller and ULN2003 seven darlington arrays is working well with low-power stepper motors as a simple prototype of CNC machine systems. *Figure 12* shows stepper motor driver and *figure 13* shows the hardware CNC machine circuits.

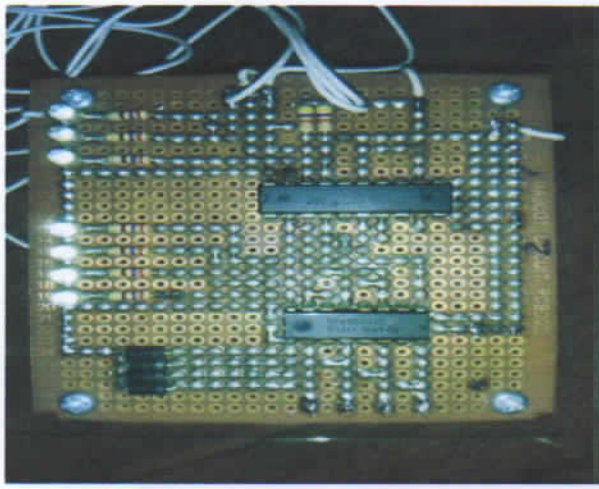

Figure 12. Stepper Motor Driver.

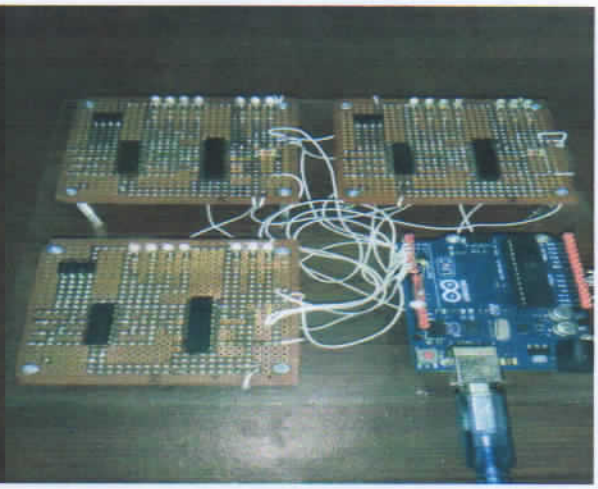

Figure 13. CNC Controller Circuit

## 4. CONCLUSION & FUTURE WORK

### 4.1 Conclusion

The aim of this paper is to discuss the possibilities on designing low-cost educational CNC machine as an alternative of expensive industrial CNC machines, also to improve low-cost industrial CNC machines to support small and medium enterprises and home industries by understanding and applying the basics of CNC machine hardware and software sections. There are a lot of components and software programs can be used to create a CNC machine system, and this paper is just an example trying to simplify the CNC machine system by explaining the relationship between CAD and CAM software, and how to generate G-code to run a CNC machine in easy way in software section of CNC machine system. In hardware section of CNC machine there are microcontroller, stepper motors and stepper motor drivers.

### 4.2 Future Work

In order to improve this system for educational and industrial usage, there are many suggestions maybe help to achieve the target of this paper.

1. Building a mechanical system that supports CNC machine motions considering that the actuators are not able to be adjusted manually by hands, the only way to move the actuator is by running the motor, also provide the actuators with limit switches for safety. *[2]*

2. Using bipolar stepper motors is better than using unipolar stepper motors for CNC machines because the torque of bipolar is bigger than the torque of unipolar stepper motor at the same pulse wide. *See stepper motor specifications.*

3. NEMA stepper motors are common stepper motors used to build CNC machines. There are many sizes of NEMA stepper motors, such as, NEMA 17, NEMA 23, NEMA 42 and others. The meaning of 17, 23 and 42 is the size of stepper motor in inches, 17 is 1.7 inch, 23 is 2.3 inches and 42 is 4.2 inches. *See NEMA stepper motors specifications.*

4. ULN2003 Seven Darlington Arrays is used to drive low-power stepper motors only, such as 28BYJ-48 stepper motor. NEMA stepper motors need bigger amplifiers, L298 dual H Bridge Integrated Circuit with NEMA 17 for example.

5. CNC machine based on Rasbperry pie is faster in engraving/ cutting process and more expensive than CNC machine based on Arduino UNO, and Arduino NANO board is cheaper.

6. Mechanical section of CNC machine can be designed as an arm or other creative designs.

## REFERENCE


[1] Arduino UNO datasheet. The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs). https:// www. farnell. com/datasheets/1682209.pdf

[2] A.Z.KellerA.R.R.Kamath. Reliability analysis of CNC machine tools. Postgraduate School of Studies in Industrial Technology, University of Bradford, Bradford; W. Yorks BD7 1DP, Great Britain.

[3] Designing an accissible workflow for rapid prototyping on a homemade 3-axis CNC machine. Elfaramawy, Ibrahim (2017). UNIVERSITY OF TWENTE STUDENT THESES.

[4] G-code is a type of function used in Numerical Control programming language that contains the information to position a tool to do the actual work. G-code is ... https: //www. thomasnet. com/articles/ custom.../introduction-gcode/.

[5] IntelliG-code software explanation and download. Github .com

[6] Inkscape software, errors solved. Error Gcode Tool extension scale in inkscape. http://www. inkscapeforum. com/viewtopic. php?t=31652.

[7] Kajal J.Madekar1, Kranti R. Nanaware2, Pooja R. Phadtare3, Vikas S. Mane4. 3 B.E . Automatic mini CNC machine for PCB drawing and drilling. Department of Electronics and Telecommunication Faculty, Department of Electronics and Telecommunication Sanjeevan Engineering and Technology Institute, Panhala (Shivaji University).

[8] SAKIB SHAUKAT SARGUROH. Elimination of proprietary control for computerized numerical control (CNC) machine. Department of Mechanical Engineering, A. C. Patil College of Engineering, Kharghar, Navi Mumbai-410 210, India ARUN BHIVA RANE Department of Production Engineering, Fr. C. Rodrigues College of Engineering, Bandra (W), Mumbai-400 050, India.

[9] The L297 Stepper Motor Controller IC generates four phase drive signals for two phase bipolar and four phase unipolar step motors. https://www.st.com/resource/en/datasheet/l297.pdf

[10] The ULN2001A, ULN2002A, ULN2003 and. ULN2004A are high voltage, high current Darlington arrays each containing seven open collector…https://www. seeedstudio.com /document /pdf /ULN2003%20Datasheet.pdf

[11] What is GRBL code file. https://github.com/grbl/grbl.

# ANALYSIS ON GRBL CONTROLLER SOFTWARE FOR STEPPER MOTORS ROTATIONS USING ARDUINO UNO

Compiled as one of the requirements of completing the undergraduate program at the department of Electrical Engineering Faculty

By:

ALAA H Y ALJUBA

D400144007

ELECTRICAL ENGINEERING PROGRAM
FACULTY OF ENGINEERING
UNIVERSITAS MUHAMMADIYAH SURAKARTA
2019