Prototype Wireless Controller System based on Raspberry Pi and Arduino for Engraving Machine

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Prototype Wireless Controller System based on Raspberry Pi and Arduino for Engraving Machine

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***Abstract*—This paper aims to explore the theories and techniques behind procedures of wireless controller system for mini CNC milling machine. The developed controller enables the machine tool to be controlled based on wireless communication and NC data generated from CAD/CAM systems. Then, a computer vision component using a web camera is proposed for the NC machine tool monitoring. It is explained the position on the machining table. This newly designed wireless controller system can be widely used in electrical and medical industry for making small parts and engraving small features. Fabricated prototype wireless controller system was calibrated and tested under various self-testing procedures to meet industrial standard. Comprehensive cost analysis and profit estimation was conducted after completion of the prototype.**

Keywords- Wireless controller system; Prototype ;Raspberry PI;Arduino; Mini CNC machine.

I. INTRODUCTION

With the development of electronic and computer technology and computer technology, the performance of Numerical Control (NC) system is becoming more and more perfect, and the application fields are expanding. At the same time, industry has a sustainable development in World. In modern decentralized manufacturing environments, online supervision and control of industrial process have become a major factor for industrial productivity and profitability as it decreases machine downtime, service and training costs as well as all of their attendant problems [1]. The key technologies of NC engraving machine have been studied. Based on the function and performance requirements of the engraving machine, the whole control system consists of initialization module, parameter setting module, coding module, manual processing module and inverter-motorized spindle module. The design philosophy and method of these modules are presented in this paper [2].

Information technology with computer and internet as representative brings revolutionary influence on manufacturing, so manufacture based on knowledge and information is an important development direction. The open literature reports a number of research works in the past decades on web-based manufacturing applications [3-5]. Literature [6] introduced virtual CNC machining technology, and it pointed out that to realize machine tool designing, machining test, machining simulation and controlling by computer is an important direction, but the virtual CNC system lacked the application of network technology. Literature [7] researched CNC machining process planning towards cloud manufacturing to realize machining information shared, but the system lacked the ability to process machining data into machining knowledge. Literature [8] mainly presented Germany "Industry 4.0" project, and the fourth industry revolution marked by intelligent manufacture combines traditional manufacturing technology and network technology. Computer Numerical Control (CNC) machining is a complex process, and human intelligence and equipment automation will be combined by computer and network to create favorable condition for information integration and collaborative manufacturing [9]. Research on data sharing and intelligent CNC machining system realizes the communication and data sharing between human and equipment [10].

The main objective of using wireless networks and mobile communication technology, on the basis of the smart phone supported structure, or Personal Digital Assistant (PDA) based wireless and mobile environment that can establish a new man to machine cooperation manufacturing mode to access information anytime, anywhere, and give full play to human intelligence and machine intelligence, the part of original CNC system function is transferred to the smart phone or PDA, that is done by the programming, simulation, machine adjustments, download and onsite data processing collection, system diagnostics and decision making process and so on.in addition, using Raspberry PI with sensors to create wireless controller system has concept of Internet of Things (IoT).

II. SYSTEM DESCRIPTION

According to the aim of research, a developed system had been used consist from two parts:

A. Engraving Machine

The engraving machine is an entry-level CNC equipment, the work area is 200 mm in X-axis, 200 mm in Y-axis and 70 mm in Z axis, Y-axis moves to table movement. Frame in part of 10 mm thick Poly Vinyl chloride (PVC) plate. A 12 mm diameter light bars of aluminum is used for coupling three stepper motor. A NEMA 17 stepper motor rated 1.7 A, 3.06 V, spindle motor is DC motor, rated power 300 W, with tool holder type ER11 collet, professional sandwich diameter 3.175 mm. The machine parts and assembling are shown in figures

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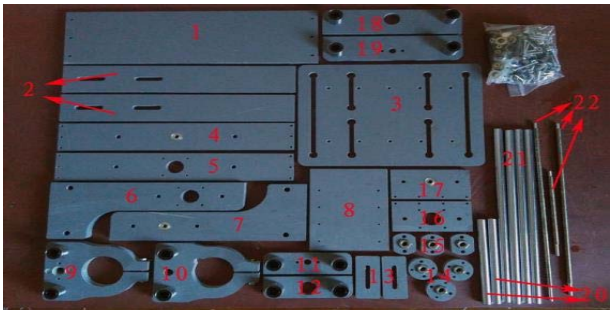
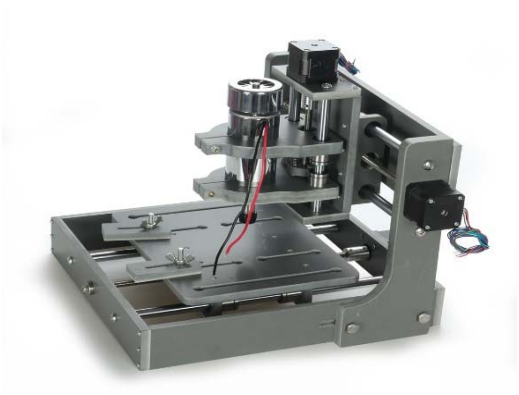
(1.a) and (1.b) respectively while the parts are list in table (1).



(a)



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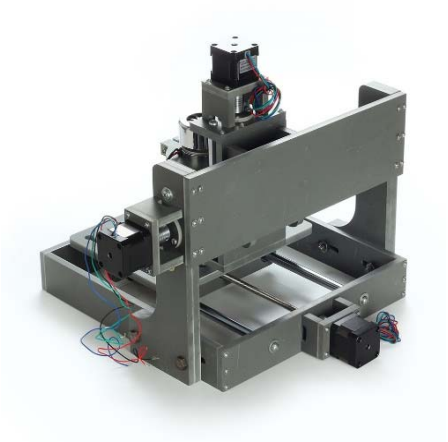


(c)

Figure 1. Engraving machine (a) Mechanical frame components, (b and c) Engraving machine.

TABLE I. ENGRAVING MACHINE PARTS LIST.

1	Backplane.	12	X-axis bearing plate (right).
2	Base plate (side).	13	Workpiece plate.
3	Table plate.	14	Eliminate backlash nut under the plate.
4	Base plate (front).	15	Eliminate return difference nut plate.
5	Base plate (back).	16	Z-axis screw bearing plate (Top).
6	Right side vertical plate.	17	Z-axis screw bearing plate (Bottom).
7	Left side vertical plate.	18	Y-axis bearing plate (rear).
8	X bearing plate.	19	Y-axis bearing plate (front).
9	Spindle motor seat (Top) .	20	Z-axis screw bearing feed rod.
10	Spindle motor base (Bottom).	21	X-axis, Y-axis bearing feed rod .
11	X-axis bearing plate (left).	22	Screw (the shortest of which is the Z-axis, the longest is X-axis).

B. Wireless Controller System

Our design includes the following parts TB6560AHQ axis drive board (is PWM chopper-type stepping motor driver IC designed for sinusoidal-input micro step control of bipolar stepping motors), a 24V,5A switching power supply, transformer with multiple output, full wave bridge rectifier, Raspberry Pi, Arduino Uno that can control the following drive current of 3A stepper motor and 300W use of small engraving machines. Controlled by CAM software system. These parts divided into:

1) External Interface Function: The external interface configured as:

- Power source: Outlet with operation voltage of 220V AC.
- Voltmeter Panel Meter: from 0 to 300V AC Voltage.
- Power indicator: When the power switch on, the LED is on, after turned off the power switch, the LED turned off.
- Spindle indicator: If spindle working, the LED turned on, when spindle off, the LED turned off.

- Emergency stop button: When engraving machine work and nonstandard situation occurring pressing button turn off spindle immediately and machine stop working.
- Spindle motor interface: Using high reliability 4 core plug cable connector, connect to spindle motor wire.
- Stepper motor interface: Using high-reliability 4 core plug cable connector, connect all 3-axis stepper motors to all 3 plugs installed on External interface box.
- Cooling Fan: 24V, 2.4W DC axial fan used to decrease the temperature inside box.

2) Internal Boards and The Designed Circuits: The aim of this design is to manufacture a wireless controller system that has integrated Machine Control Unit (MCU) with CAM software and operation system gives a leverage of remotely control over local network or from specific IP address and certainly directly from web browser of PC, Tablet device or any phone with Bluetooth or Wi-Fi and LAN, as shown in figure (2).

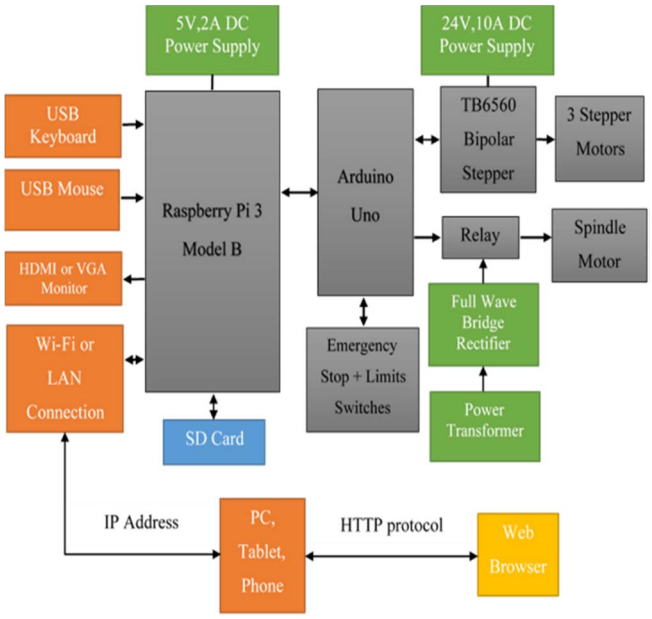


Figure 2. Block Diagram Design of Wireless Controller System.

The discerption of figure (2) can be summarize according to following:

a) *Hardware equipment:* The components of design are implemented with the concepts of the modules which it:
- *Raspberry Pi:* is a Linux powered computer, the operating system of Raspberry Pi supports modern programming languages like python, Node JavaScript

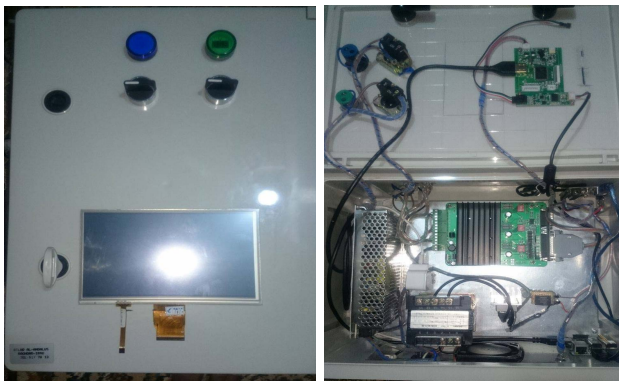


Figure 3. Front view of Control Box.

[1], also has General-purpose input/output (GPIO) so it can directly connect with devices, sensors and many real world devices. Raspberry Pi represent a workstation because it connects the control system of machine with CAM system and interfacing with other devices like monitor, mouse, keyboard, web camera, sensors. as shown in figure (4).

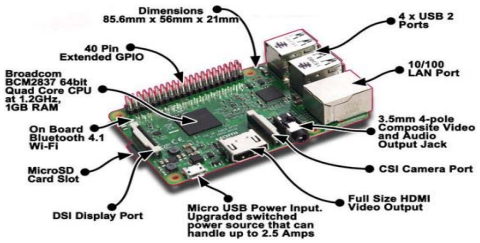


Figure 4. Raspberry Pi 3Model B.

- Arduino Uno: a microcontroller board based on the ATmega328P, it has 14 digital input/output pins (6 pins can be used as PWM outputs), 6 analog inputs, a USB connection. To use Arduino Uno as a drive controller for stepper motor and spindle need to pins from number 2 to 7 for stepper motor and pin 13 for spindle enable, using analog pin A0 for emergency

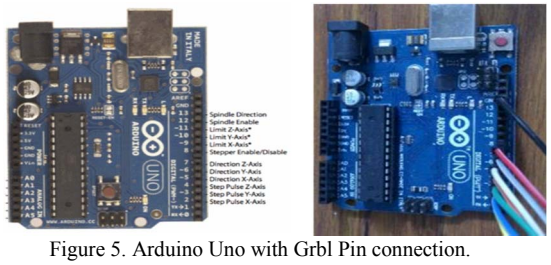


Figure 5. Arduino Uno with Grbl Pin connection.

stop as figure (5).
- *TB6560AHQ:* Three-axial Stepper Motor Drive Board with double bridge MOSFET driver, the output standard is 3-axis drive and a 4-axis as expansion interface, so can expand 4-axis freely. The maximum voltage is 40V, maximum drive current is 3A, peak current is 3.5A, Built in temperature protection and

overcurrent protection. as shown in figure (6), the 3-axis ports have 4 terminals A+, A-, B+, B- two uses for stepping signal and two for power supply to stepper motor. Parallel ports control has a 25 pins from these pins will take only 8 pins, 6 pins for motors signals and to spindle signal. These 8 pins connect to Arduino Uno to take control of motor drive. Four grade subdivision setting that's synchronizing, 1/2, 1/4, 1/16 stepping. There are three Dial Switches; they can respectively set the subdivision step numbers. The position limit extended interface can connect with the limit switch, they can automatically sudden stop when anyone of the axle reach the limit position, automatic semi-flow control can lock the motor when there isn't drive pulse. So that the motor can be effectively protected, saving electric energy, and increase of its service life.

- The components for spindle motor control are:
  i. Transformer: a transformer with multiple input and output terminals, can change AC voltage from 220 or 110 to 50 AC voltage.
  ii. Relay (JZC-32F): a subminiature intermediate power relay with 5A-110V,10A-220V switching capabilities.
  iii. Full wave bridge rectifier (KBPC1010): a 10A high current bridge rectifier, electrically isolated metal case for maximum heat dissipation, as shown in figure (7).
- Power supply (SZ-120-24): provide 24V DC and 5A DC from 220V AC.
- Stepper motor (17HD40005-22B): This stepping motor has two-phase 4-wire. The sequence order is AB-BC-CD-DA, from shaft end to see CW with Stepping angle 1.8°.

b) *Software requirements:* The software can be summarized according to many fields:

- *Operation System:* The operation system of Raspberry is Raspbian Jessie, this operating system come with Java Script library.Node.JS an asynchronous event driven Java Script runtime, Node is designed to build scalable network applications. HTTP is a dominate protocol in Node, designed with streaming and low latency in mind. This makes Node well suited for the foundation of a web library or framework.

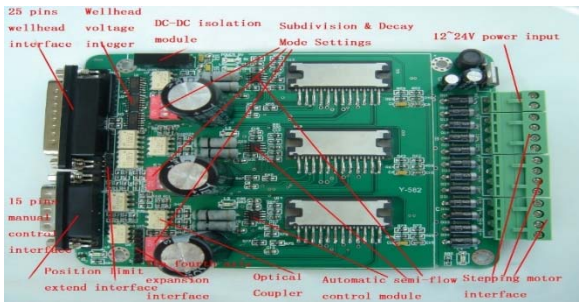


Figure 6. TB6560AHQ 3-axis stepper motor driver board.

- *Grbl:* An open source, embedded, high performance G-code parser and CNC milling controller written in optimized C that will run on a straight Arduino, Grbl is software for controlling the motion of machines that make things.
- *Code Uploader:* Uploading Arduino HEX files with Xloader software, Xloader software upload a compiled Arduino sketch (HEX file) to Arduino board using the bootloader. That means doesn't need a flash programmer.
- *Win32DiskImager:* A Windows program used to write boot images to a SD Flash device or USB flash device and making it bootable.
- *CNC.JS:* a web-based interface for CNC milling controller running Grbl.
- *BCNC:* is a program written in python. The sender is robust and fast which able to work kindly with old or slow hardware. using Grbl CNC command sender with features of auto leveler, G-code editor.

III. SOFTWARE IMPLEMENTATION

(a): Transformer. (b): Full wave bridge rectifier. (c): Relay.

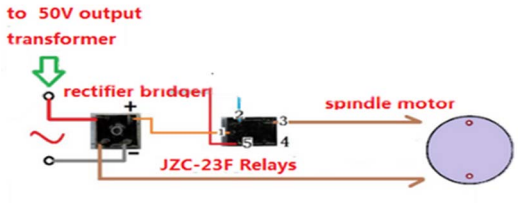


Figure 7. Spindle Motor Control.

Any embedded system or microcontroller to make interactive with other devices needs a software. In this work, software used for Raspberry Pi and Arduino according to the following procedure:

A. *Raspberry Pi Software Installation*

The steps can be summarized as follows:

1) Download the image file (.img) of Debian Jessie Operation System from official web site and save it on hard drive.

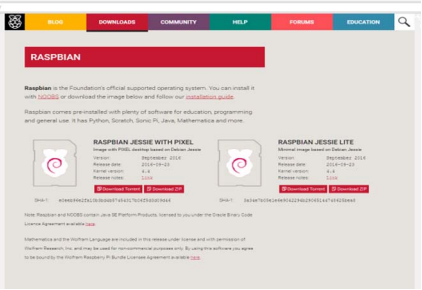


Figure 8. Raspbian Official page.

2) Download *Win32DiskImager from www.sourceforge.net downloads page and install.*

Figure 9. Win32DiskImager Official page.

3) Insert SD card to PC or Laptop card reader.

Figure 10. Laptop card reader.

4) Format SD card.

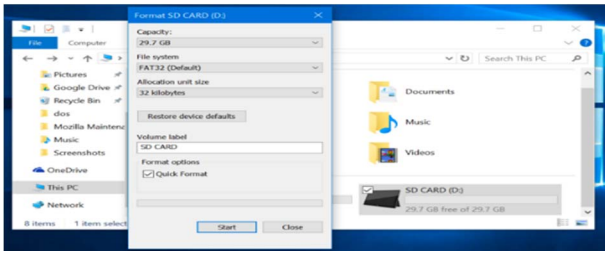


Figure 11. SD card format.

5) Run Win32DiskImager.exe and from software menu search for image file and select it.

6) Press Write and wait for the program to write the operating system onto the SD card.

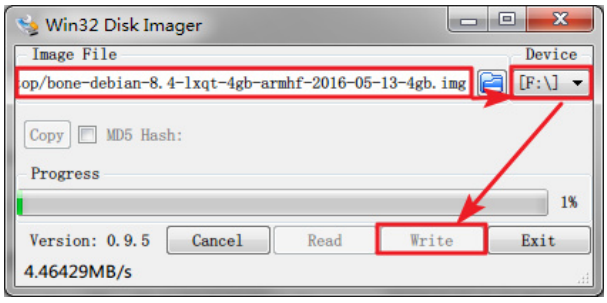


Figure 12. Writing Debian Jessie image file.

7) When the writing is done insert the SD card into the Raspberry Pi and power it up.

B. Compiling Grbl to Arduino

The GRBL setup for Arduino can be as following:

1. Download the Grbl source code (v0.9i) as HEX file for atmega328p,16mhz and Baud Rate 115200 bps.
2. Download Xloader software to upload the HEX file to your Arduino.
3. Install Xloader software and select the HEX file to upload it.
4. select the correct Arduino Board Setup, Correct COM Port and change Baud Rate to 115200 bps.

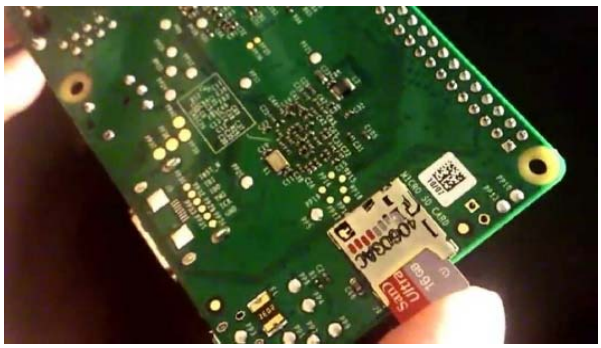


Figure 13. Plug SD card to Raspberry Pi.

5. Click on the upload button to send the HEX file to Arduino Uno board, the Rx and Tx led will flash as shown in figure (14).

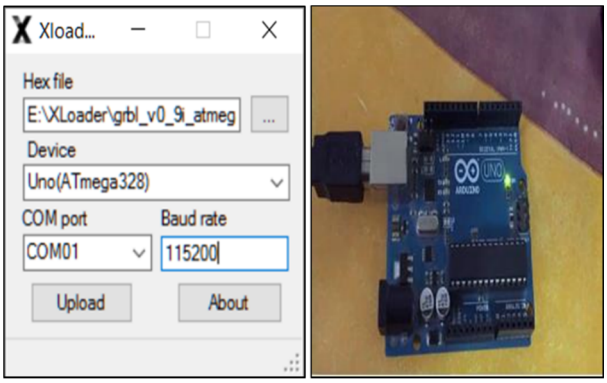


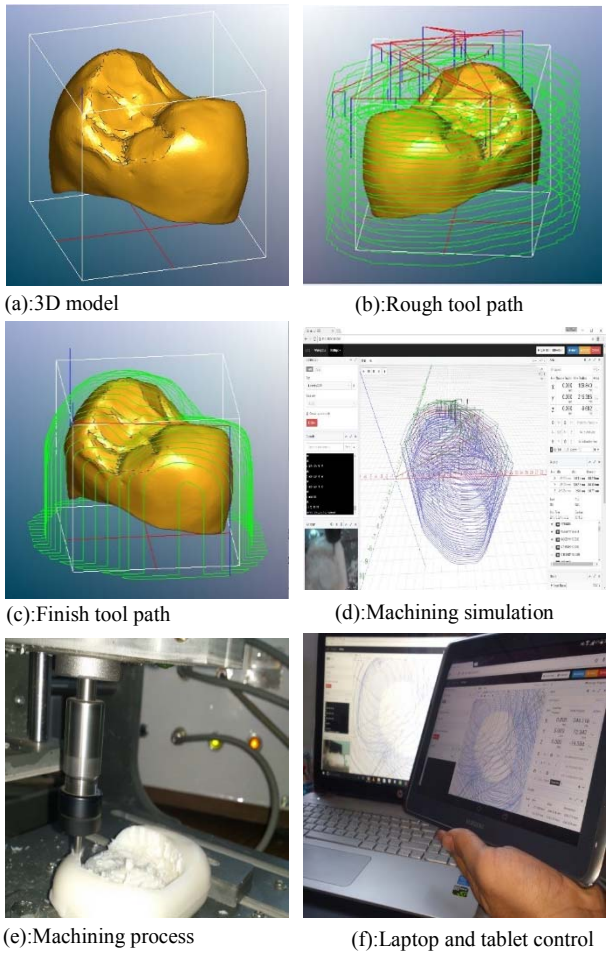
Figure 14. Xloader Software uploading to Arduino Uno.

IV. CONFIRMATION CASE STUDY

For confirmation a test is done by powering the system, when powered, it first booting operation system Raspberry Pi. After booting system, will be connected to WLAN and running cnc.js server, which is giving access to Grbl controller who run by Arduino Uno. By typing IP address in browser and click enter, a web page with title CNC V1.6.6 will opened.

The Graphical User Interface (GUI) of CNC V1.6.6 was tested with laptop, tablet and android phone. The test includes moving three axes, run webcam to monitor the work piece and running spindle.

The final test of the system is done by manufacturing a crown tooth as a medical application for dental purpose. The data of tested crown tooth is imported from 3D scanner from dental laboratory in college of dental. The data of crown tooth is a STL file as 3D model and this file had been imported by UG-NX10 to generate tool path and G-code. The generated G-code had been sent using Wi-Fi to the machine as shown in figure (15).



(a):3D model (b):Rough tool path

(c):Finish tool path (d):Machining simulation

(e):Machining process (f):Laptop and tablet control

Figure 15. Test and result.

V. CONCLUSION

In this paper, wireless controller system provided a simple, reliable NC machine network technology and manufacturing information management, performance management system. It entirely changed the traditional NC machine tools with manually inputting program and single input, independent operation, single process of manufacturing and other functions, also can realize the remote control and remote service, carried out the information collection of remote processing and performance management, making the CNC machine tool had the network communication function of two-way, high-speed and ensuring the flow of information communication between different NC resources, which will realize a new method that the technology of wireless communication network applied Numerical Control (NC) system was proposed to control CNC machine. The Wi-Fi connection between NC system and PDA was set up based on virtual serial port technology, NT port software technology and USB dongle. Designing and programming to wireless communication module, the information of NC machine, including NC code, cutter location data and so on, was regularly accessed from top-level application program by wireless communication network embedded in all-software NC system based on windows or LINUX OS.

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