EECS 129B Winter 2008 Final Project Report

Due March 17, 2008 on EEE

Team Members

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CNC Router Table

1. Abstract

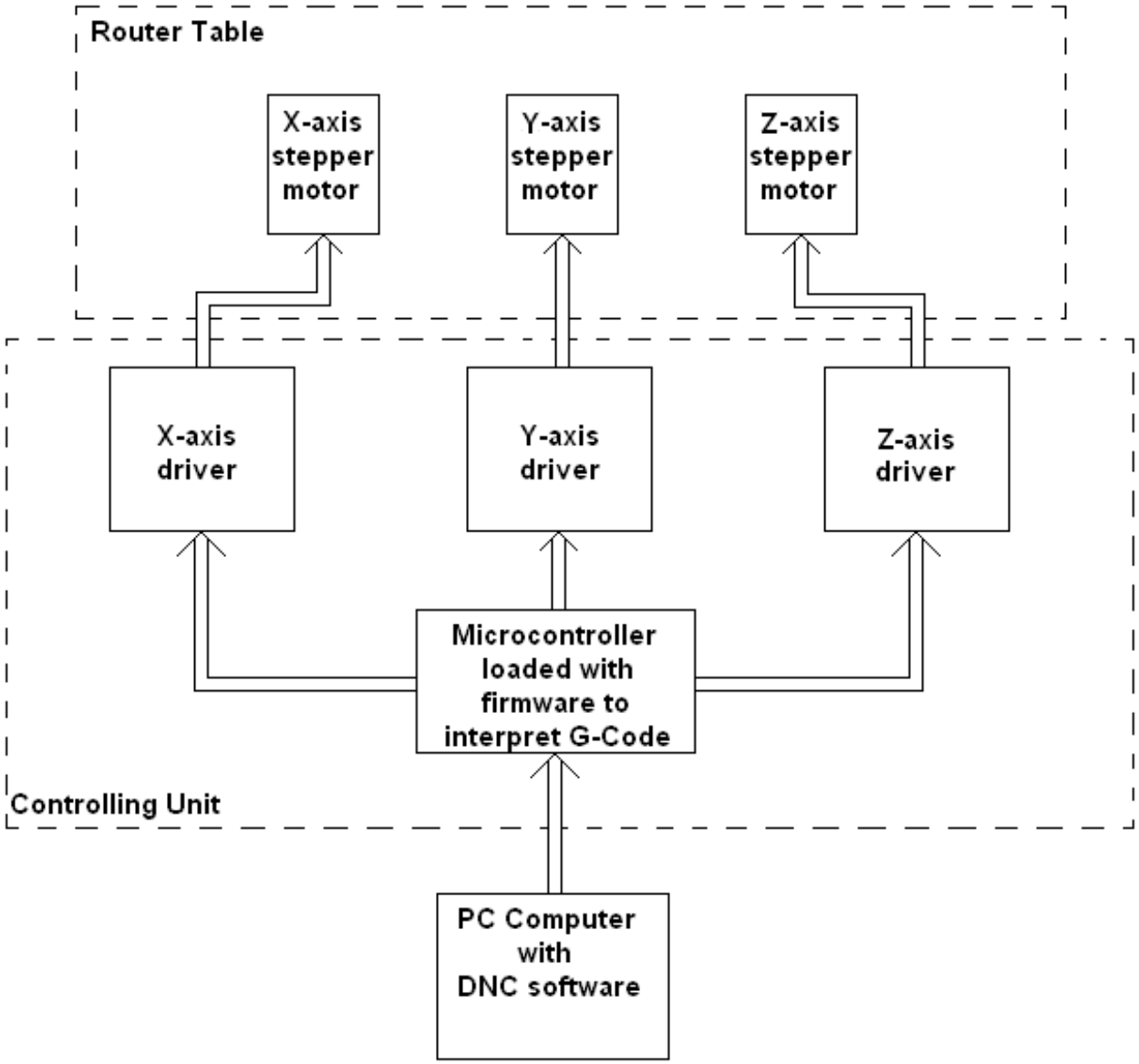
The goal of the project Is to build a 2x2 foot CNC Router Table from scratch - building the table itself with 3 axis of motion, controller with stepper motors, and PC to controller communication protocol. Such a table would be used for prototyping Printed Circuit Boards (drilling holes and milling traces), and engraving on metal, plastic, wood and other suitable materials.

Related Products:

1) CNC Milling machine - used for prototyping and production of parts requiring milling. It is more precise than a routing table, but it is much more expensive as well.

2) Circuit board etching – usually used with photo resist processes that are inexpensive and commonly used. However, lack the ability to produce accurately located through-holes properly indexed to the conductive traces. These holes are necessary for the insertion and interconnection of desirable components. Contrary to the mill solution, this process is very inexpensive, but incomplete as a solution.

2. Project overview (High level)



3.

Project components

Project is involving three different type of engineering practice: mechanical, electrical and computer engineering.

- Mechanical engineering

  Mechanical engineering part involves building 3-axis router table. Each axis consists of a slider and a lead screw, where lead screws are attached to the stepper motors through collar. Router head is attached to the Z axis and moves in vertical direction in purpose of drilling holes or thread milling. Axis X and Y allow head to move through the working area.

- Electrical

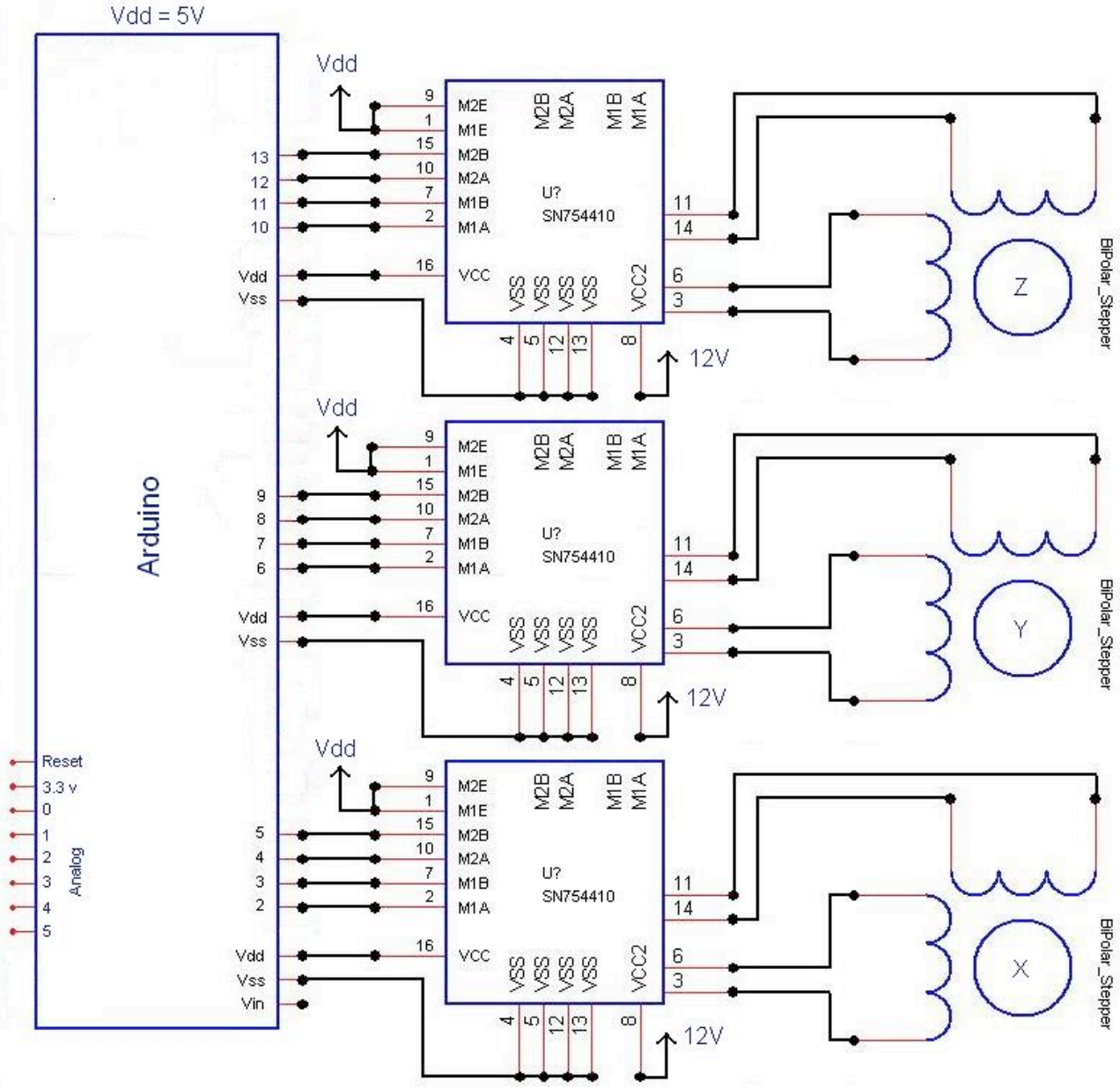
  Electrical engineering part involves building circuit that controls router moving directions, feed rate and feedbacks. Circuit consists of microcontroller that receives coordinates from the PC and interprets them into current router location and direction it suppose to move. Then microcontroller sends signals to the appropriate stepper-motors drivers, which on their side drives their motors.

- Software (Programs)

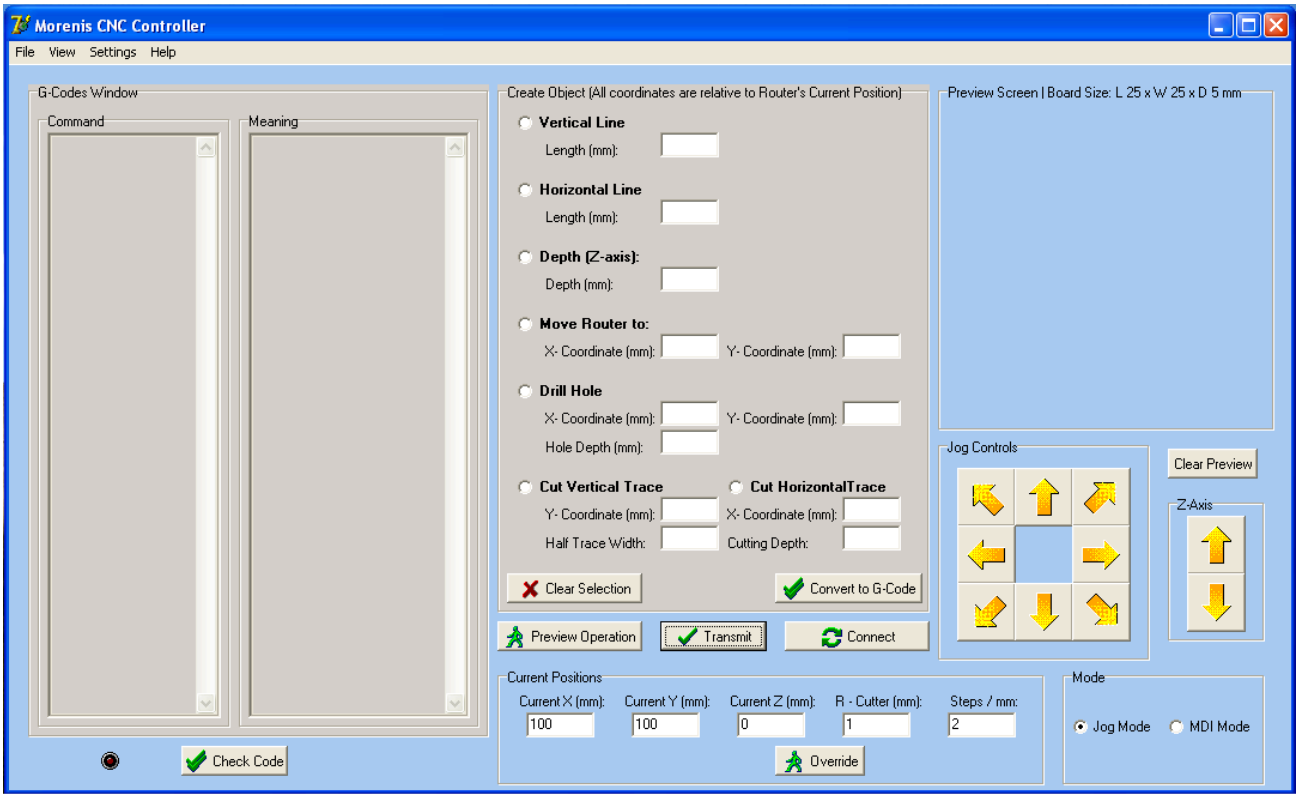
  This stage involves two parts. The first part is the software that is installed on the PC side. This program is interfaces with user. Two modes of operation are possible. First, MDI Mode, consists of table with sequential commands that user provides for execution on the router table. Commands execute one after another and send to the controlling unit through USB interface. Second, JOG Mode, allows user to move router manually, through clicking on the arrow keys.

  The second part of the software is installed on the microcontroller as a firmware and receives commands that arrive from the PC side. Firmware interprets commands and processes them as the number of pulses to the motors.

Wiring diagram:



Software Interface:



G-Code Table:

	G-Codes:					
	Meaning	**G-Code**	**Param1**	**Param2**	**Param3**	**Op.Code**
	UP	G10				T0010
	DOWN	G11				T0011
	LEFT	G12				T0012
J	RIGHT	G13				T0013
O	UP-LEFT	G15				T0015
G	UP-RIGHT	G16				T0016
	DOWN-LEFT	G17				T0017
	DOWN-RIGHT	G18				T0018
	Z-UP	G20				T0020
	Z-DOWN	G21				T0021

Line Opcodes:				
Meaning		**Op.Code**	**Param1**	**Param2**
Horizontal Positive:		T0001	X	steps/mil

Horizontal Negative:		T0002	X	steps/mil
Vertical Positive:		T0003	Y	steps/mil
Vertical Negative:		T0004	Y	steps/mil
Z_Pozitive:		T0005	Z	steps/mil
Z_Negative:		T0006	Z	steps/mil

	Line	G01	X	Y		Line Op.Codes		
M	V-Trace	G02	Y	T	D	Sequence of Line Op.Codes		
D	H-Trace	G03	X	T	D	Sequence of Line Op.Codes		
I	Z-Axis	G04	Z			Line Op.Codes		
	Drill Hole	G05	X	Y	D	Sequence of Line Op.Codes		
	Move	G07	X	Y		Sequence of Line Op.Codes		

Stepper Motor Truth Table:

Enable	M1A	M1B	M2A	M2B	
0	-	-	-	-	All off no lock
1	1	0	1	0	Step 1
1	0	0	1	0	Step 2
1	0	1	0	1	Step 3
1	1	0	0	1	Step 4

4. Design description

The static table was built first, with the x, y, and z axis, each with its appropriate slides and lead screws. Each lead screw was connected to a stepper motor which drives it. A controller-unit was used to drive the stepper motors. This unit includes the ICs (motor drivers) that communicate with stepper motors and a microcontroller that sends driving signals to these motor drivers.

The controller unit was designed to receive coordinates from a PC through a USB connection. This required writing the software that breaks every user-given command, such as arc, circle, line, hole or other, into three coordinates and sends them to the controlling unit, which move the router head onto the position and do the operation. The software keeps a queue of commands that need to be executed. There also possible to use pre-designed CAM (Computer Aided Manufacturing) software that imports defined geometry file (such as AutoCAD or SolidWorks file) and automatically converts it into commands and sends them for execution to the router table.

5. System test plan

At (X, Y, Z) and To (X, Y, Z) denotes absolute coordinates

By (X, Y, Z) denotes relative coordinates

Test Number	Description of Set-up	Input or Stimulus	Expected Behavior
1	Set router head at initial position (0,0,0).	Jog to the position X=10mm, Y=15mm, Z= 5mm	Router head moves To (10,15,5)
2	Set router head at initial position (0,0,0).	Program router head to automatically travel X=10mm, then X=20mm, then Y=10mm, then Z=10mm	Router head moves after the sequence is done To (30,10,10)
3	Set router head at initial position (0,0,0).	Jog to the position X=10mm, Y=15mm, Z= 5mm And then Jog to the position X=5mm, Y=10mm, Z= 0mm	Router head first moves To (10,15,5) And then router head moves back By (-5,-5,-5) Every time any axis changes its direction of movement, error in linear motion must be added to avoid its affect on coordinate system.

Test Number	Description of Set-up	Input or Stimulus	Expected Behavior
4	Set router head at initial position (0,0,0).	Drill the hole at X=20, Y=30	Router head moves To (20,30) Then Z moves Down 15 mm Then Z moves Up 15 mm
5	Set router head at initial position (0,0,0).	Mill the line from (10,15) to (20, 35)	Router head moves To (10,15) Then Z moves Down 10mm Then Router head Moves By (10,20) Then Z moves Up 10mm

6. Project timeline

1. Router table was drawn in CAD.
2. According to the drawings, mechanical design was build, part by part and assembled together.
3. Microcontroller circuit was build.
4. Firmware was programmed into the microcontroller.
5. Software part was written.
6. Serial communication link between software and microcontroller was established.

7. Division of work

Design and implementation of Mechanical, Electrical and Software parts was done by Egor

Morenis.

8. Cost

Part	Number of Units	Total Cost
Particle Board (5/8 In. x 11-3/4 In. x 48 In.)	2	6.49
Wood Beam 2 In. x 4 In. x 104 1/4 In.	7	13.79
Lead Screw 3/8in., 2ft	3	29.97
Coupler Nut	3	11.07
3/8 1In. Nut	3	3.57
1/2 Galvanized Nut	24	28.56
2-1/2 In.1-lb Box of 96 Dry-wall Screw	1	4.47
Aluminum Rod 1/2in., 2ft	6	59.94
Slide 2ft	4	71.96
Slide 1ft	2	35.98
Stepper Motor (Standard)	3	124.99
Stepper Motor (High-Torque)	3	243.00
Stepper Motor Wires	3	15.00
Fiberglass Cupper PCB Blank	1	9.99
Arduino Microcontroller	1	34.95
IC STEPPER MOTOR DRIVER 16-DIP	6	12.78
IC Heat Sink	3	20.97
RS-232 Connectors (Male)	3	8.97
RS-232 Connectors (Female)	3	8.97
RW-232 Connector Enclo-sure	6	14.99
Bulk Parts (Resistors/ Capacitors)	50	20.00
RSW-232 10 ft. Extension Cord	3	29.97

Part	Number of Units	Total Cost
250W Mini ATX Computer Power Supply	1	29.99
ATX Power Supply Tester	1	19.99
Wires 10 ft.	5	49.95
Router Head	1	69.99
Washers (Box of 30, 1/2in.)	1	9.99
Plastic Enclosure with foam	1	29.99

Total cost of project: $1020.28

9. Problem encountered and comments

Challenges:

1) Axis Alignment: make all axis perpendicular to each other, where x-axis and y-axis are parallel to the ground.
2) Stepper Motor Torque Calculation: choose stepper motors for every axis that powerful enough to drive router head.