5/2/2011

EE 318

3 Axis PCB Drilling Machine

Professor Jayanta Mukherjee | Ashay Shah

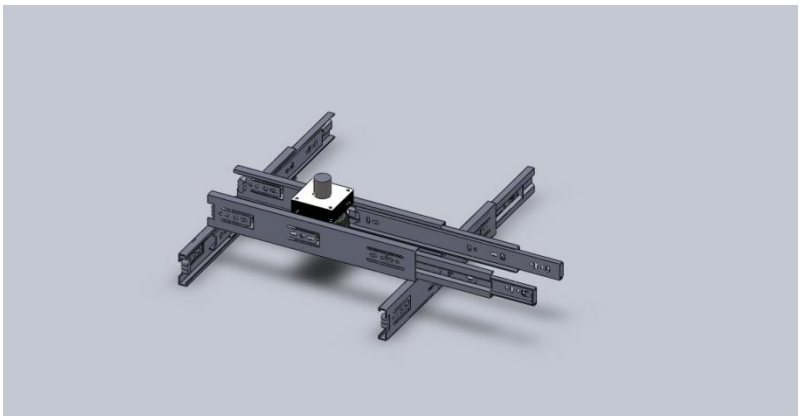
Overview

The project aims at the creation of a (computerised) numerical controlled drilling machine. This machine will have three degrees of freedom and will be capable of drilling holes up to 1.5mm in glass epoxy substrate.

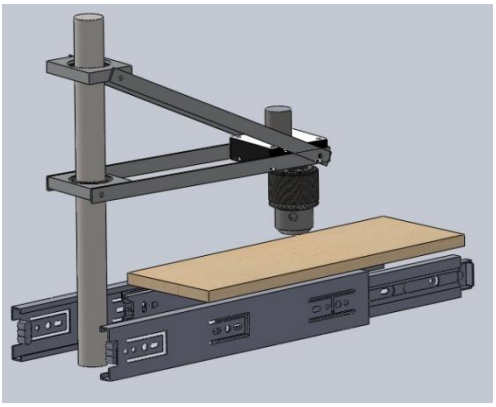
Design

Mechanical

1. The basic structure will have two pairs of linear guides along the X and Y axes.
2. A platform on top of the double structure will be formed.
3. This structure can now move independently along the two axes.
4. The moving platform has a motor attached to a small drill chuck.
5. The motor itself can move up and down so as to drill the PCB placed below.



6. A two axis machine requires two pairs of sliders.
7. This is more expensive than using an R-theta arrangement.
8. An r-theta arrangement will further allow usage of multiple heads on the same theta unit.
9. This would allow drilling of holes of multiple sizes without the need to change drill bits. (As a future prospect for the project.)
10. Hence, an R-theta arrangement was proposed.



Actuation

1. The actuation of the X and Y axes will be controlled using a screw attached to a stepper motor.
2. This will allow for precise movement of the chuck along the X and Y axes (ignoring backlash).
3. The up and down movement will be manually controlled (2-axis only).
4. This movement will be implemented using a rack and pinion arrangement.
5. The drill chuck will be attached to a high torque motor.

Electronics

1. The drill motor will actuated using a relay. The relay will be driven by the microcontroller using a transistor as a switch.
2. The stepper motors are to be driven using a dedicated stepper motor driver.
3. ADuC7128 is the microcontroller of choice.
4. USB interfacing will be accomplished using CH340 USB to RS-232 converter.

Implementation

Design

1. The lower X movement was built using a pair of sliders as per the original design.
2. The sliders were rotated by 90 degrees so as to allow easy mounting of both the sliders and the drilling board.
3. This part of the machine is rigid and works to spec.
4. The upper movement was built using hinges instead of bearings.
5. This was due to the ease of use of hinges in comparison to bearings.
6. However, the hinges do not have the required rigidity for the application.
7. Hence, this part of the section will have to be redone.
8. The vertical section of the CNC was built on perpendicular to the slider mounting.
9. However, due to lack of mechanical trusses and welding, the vertical section was fixed on just two rivets.
10. This is not strong enough for the forces required during drilling.
11. A novel slider mechanism was tried for this application.
12. It involved using a nylon slide instead of ball bearings.
13. This would make the slider even cheaper.
14. However, this slider does not show the required free motion that would be expected.
15. Hence, this mechanism is to be shelved.

Design Part II

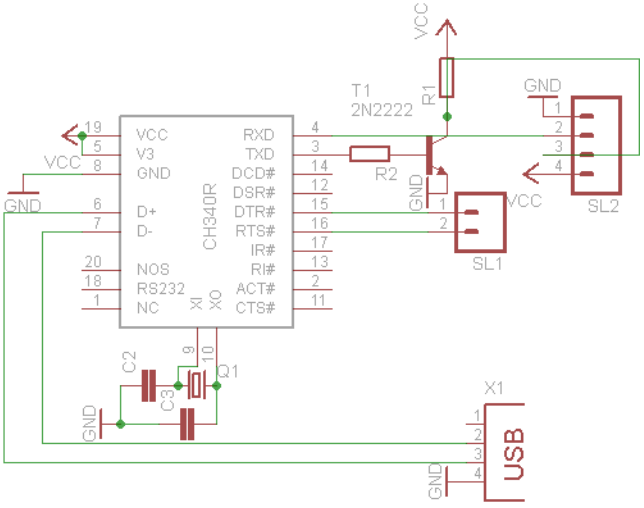
1. A new design with bearings was made.
2. It involved using of two bearings used to fix an 8mm induction hardened rod.
3. This rod is strong enough to bear the load of the drilling assembly.
4. The drilling assembly is attached to the rod using a pair of couplings.
5. A vertical slide is attached to the coupling pair.
6. The use of this arrangement gives the structure geometrical rigidity.
7. All motions are accomplished using a ball-screw on a stepper motor.
8. The stepper motor has the following characteristics

a. Stall Torque: 1.86Kg/cm at 1.5Amp (0.75A per winding), 6V
b. Stepping angle: 1.8 degrees / step
c. Shaft: Diameter: 4mm, Length: 16mm
d. Dimensions: Length and Width: 42mm, Thickness: 26mm
e. Mounting: Four 3mm (M3) bolts 31mm apart on the corners
f. Winding type: Bipolar
g. Winding Resistance: 8Ohms
h. Motor weight: 176gm

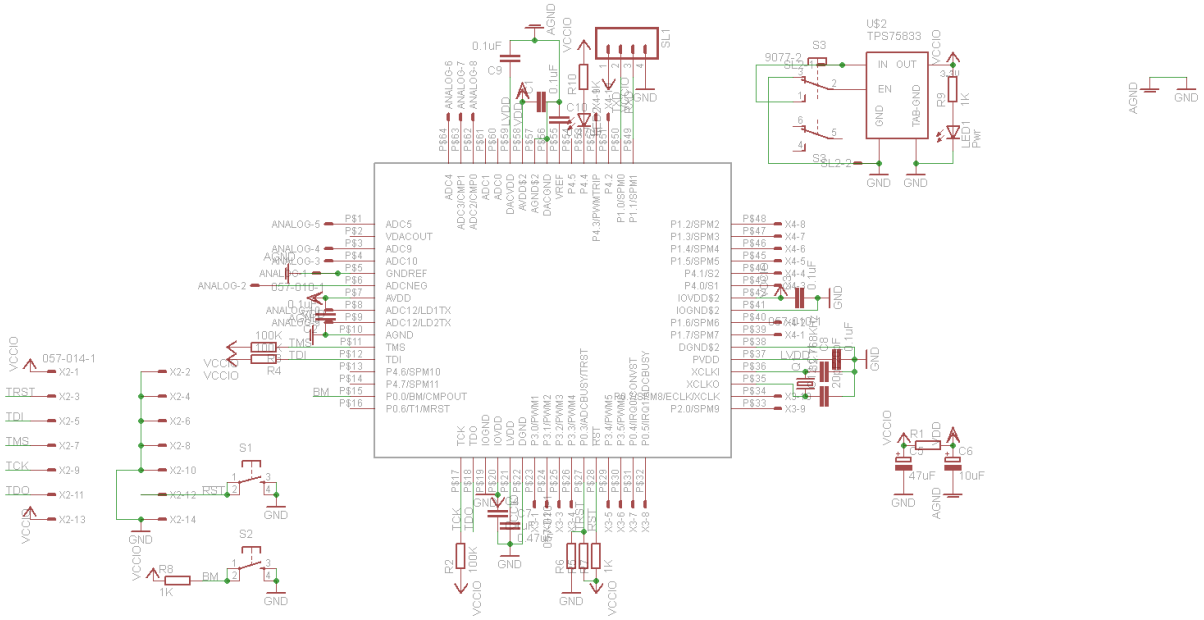
9. Two types of ball-screws actuations were used
10. 6mm: 1mm/rotation
11. 8mm: 1.25mm/rotation
12. This implies that the actual accuracy of the system is 6um in the X and Z directions.
13. The theta accuracy changes with the system. The R*theta accuracy is 5um.
14. However, the actual accuracy of the system is much lower than that calculated due to backlash and play errors.
15. The drilling motor to be used is a 300rpm of 10watt power.
16. The power required for the drilling is given by uc*MRR
17. The max material removal rate is given by pi*(1E-3)^2*(drilling speed)
18. Hence, the drilling speed can be as high as 100m/s ideally
19. This is assuming that the drill bit is completely efficient.
20. This project uses standard HSS drill bits.
21. So, the speed is reduced to 348mm/s.
22. This translates to a frequency of 7 kHz (approximately).

Electronics

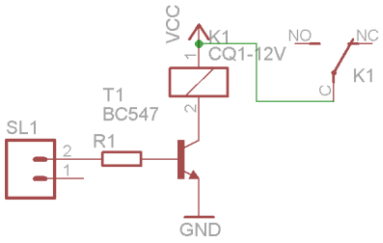
1. The USB interface built works up to spec and was demonstrated. A circuit for the same is attached.

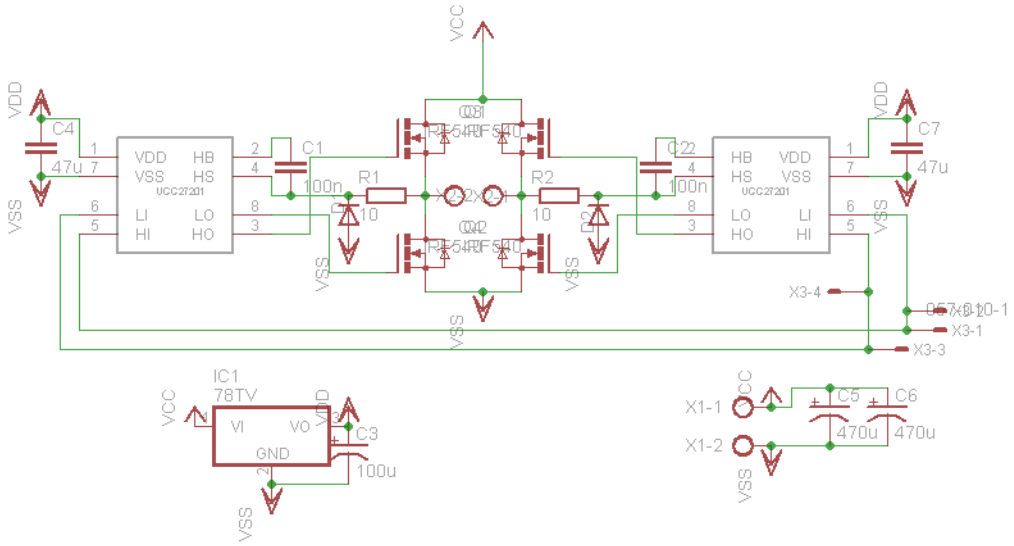


2. The microcontroller board works up to spec.
3. It is able to communicate with the PC. This was demonstrated during the demo.
4. A schematic of the circuit is attached.



5. The stepper motor drivers have been built and work up to spec.
6. This has been tested though not yet demonstrated.
7. A schematic for the same has been attached.
8. A motor driver based on UCC 27201 was proposed.
9. However, it has reliability issues when driving inductive loads.
10. Hence, it has to be shelved.
11. A schematic for the last updated circuit is attached.
12. The drilling motor is to be run in one direction only.
13. Further, there is no need for speed control in this motor.
14. Hence, the motor driver was replaced with a simple relay circuit.
15. The schematic of the circuit is attached below





Challenges

1. Using the USB interface for communication between the computer and the drill machine.
2. Accurate implementation of mechanical design.
3. Using of sensors to limit the drill area, so as to avoid damage to the machine.
4. Using and driving stepper motors to reach precise destination.
5. If necessary, using feedback loops to control the drill position precisely.
6. Calculation of required torque and speed requirements of the drilling motor.
7. Creation of an intuitive user interface for the computer front-end.