FACULTY OF ENGINEERING (FKJ)

ELECTRONIC ENGINEERING (COMPUTER)

HK20

KS22802 DESIGN PROJECT I

SEMESTER II SESSION 2020/2021

GROUP 5

Lecturer : ASSOC. PROF. DR. JAMAL AHMAD DARGHAM

GROUP 5		
No.	**Name**	**Matrices No.**
1.	HAROLD HARRISON HIRU @ HARRY *(Group Leader)*	BK19110392
2.	RAYMOND CHIAM HENG LIANG	BK19110401
3.	BRADLY SINUSUN	BK19110202
4.	ABDUL RAHIM BIN SAIDI	BK19110293
5.	HONG JUN SAM	BK19110342
6.	MUHAMMAD NUR AZWAN BIN BENDARAH	BK19160442

TABLE OF CONTENT

EXECUTIVE SUMMARY

Drilling manually can be exhausting and take a lot of time, effort, and focus to get the best-desired results. Unfortunately, most of the results vary and have different accuracy since the human error occurs every single time if drilling manually. To avoid this problem happening and make the drilling process on the Printed Circuit Board (PCB) easier, we need to develop an automatic drilling machine that meets the user requirement.

By ensuring it is on the right budget development, to build it, we will do the following:

- The material build is mostly from wood and some metal
- Have a keypad to locate the location to drill
- Using logic gate to make an automatic movement of the drill
- The drill pin can be customized manually
- Can drill multiples holes depend on the user

The benefits of automated drilling are enormous. Some of the advantages using automatic drilling machine:

- High accuracy and finish: Automated drilling can achieve high levels of accuracy for the same tasks which are tedious and time-consuming for humans to execute.
- Flexibility: This will depend on the particular configuration of the equipment. Depending on the tasks required you can have automation that is flexible or specific to one particular task. Also, significant updates can be done just by updating software rather than hardware, though it will be required depending on the functionality required.
- Repeatability & Consistency: The same task can be repeated any number of times with the same consistency using automated drilling. The levels of consistency are beyond what is achievable by humans.
- Production benefits: Though automation is costly, subsequent production costs are lower due to repeatability, consistency, increased speed of production, and reduced labour required. Automated drilling also provides enhanced safety as the requirements for human interaction are very low when the surface is worked on.

CHAPTER 1

INTRODUCTION

1.0 Project Overview

ABC company manufactures printed circuit boards (PCBs). There are around 20 different components used in the manufacturing of the PCBs. Currently, the holes for placing these components on the PCBs are drilled manually.

1.1 Problem Statement

The company requires the design and production of a prototype of an automatic drilling station that can be used to replace the manual drilling operation.

1.2 Project Purpose

The purpose of this project is to build an automated Printed Circuit Board (PCB) drilling machine to meet the requirements of ABC company. Here are the following requirements:

- The station should operate on standard electrical supply in Malaysia.
- The maximum size of the PCB board that we use is A5.
- The maximum number of stacked PCB boards is 5.
- The accuracy of the drilling should be less than 0.1 mm.
- The coordinates for each hole should be entered using a keypad.
- The coordinates for up to 10 holes should be able to be keyed-in for each drilling run.
- The safety of the operator should be given high priority.

1.3 Literature Review

Since the project is related to automatic PCB drilling machines, some of the researches and journals can be referred to and have been tabulated as below:

Table 1: Past Projects of Automatic PCB Drilling Machines

No.	Authors	Title	Outcome
1	M. Alim, S. Goundar, A. Shamim, M. Pillai, R. Singh, K. A. Mamun, P. Chand and U. Mehta	Automatic PCB Drilling Machine	An automatic PCB drilling machine was built by using basic electronic components. The performance was evaluated based on different dimensions of boards and the location of holes. The user can select the different distances between holes and can be used for the same specified inputs for large-scale production. A robust performance was achieved for almost 100 operations.
2	Nguyen Huu Phuong, Ho Van Thoi	Design and build an Automatic PCB Drilling Machine	An automatic PCB drilling machine having a rigid mechanical base, robust electro–mechanical parts, and an effective control electronic circuitry has been designed. However, there are some refinements and improvements that need to be done.
3	Zulkifli Tahir, Nur Azman Abu, Shahrin Sahib, Nanna Suryana Herman	CNC PCB Drilling Machine using Novel Natural Approach to Euclidean TSP	The CNC PCB drilling machine is equipped with three-dimensional movements and is considered to produce good precision accuracy for a competitive development cost. This machine has been equipped with a novel approach of Euclidean TSP and integrated with Atmel code vision programming for protocol input-output data. The design approach gives a promising fast near-optimal solution in total tour traveling time and total distance on the PCB with an error average of less than 10% compared to the best-known solution.

4	Kajal J.Madekar, Kranti R. Nanaware, Pooja R. Phadtare, Vikas S. Mane	Automatic mini-CNC machine for PCB drawing and drilling	The setup is the combination of hardware and G-code which gives better accuracy and reduces the workload. G-code makes it easy to find the information of all stepper motors moving.
5	G.Niranjan, A.Chandini, P.Mamatha	Automated Drilling Machine with Depth Controllability	The automated drilling machine with depth controllability was designed such that the drilling depth is controlled automatically to set values by the microcontroller-based system.

The similarities of the past projects are that some of the electronic parts are the same and also working mechanisms are almost the same. However, the major difference is the controller. As we can see, all of the past projects used microcontrollers to control the movement of the PCB drilling machine. Instead of using microcontrollers, we are using the logic circuits to control the movement of the PCB drilling machine.

CHAPTER 2

METHODOLOGY

2.0 Block Diagram

For this project, we will be using block diagrams as the main idea to complete our PCB drilling machine. We have divided the block diagram into 4 parts, which are the Keypad controller, Decimal to BCD code, motor, and position sensor. Each block diagram has its own purpose for each criterion, also using block diagrams, we are able to select the suitable component for the PCB drilling machine.

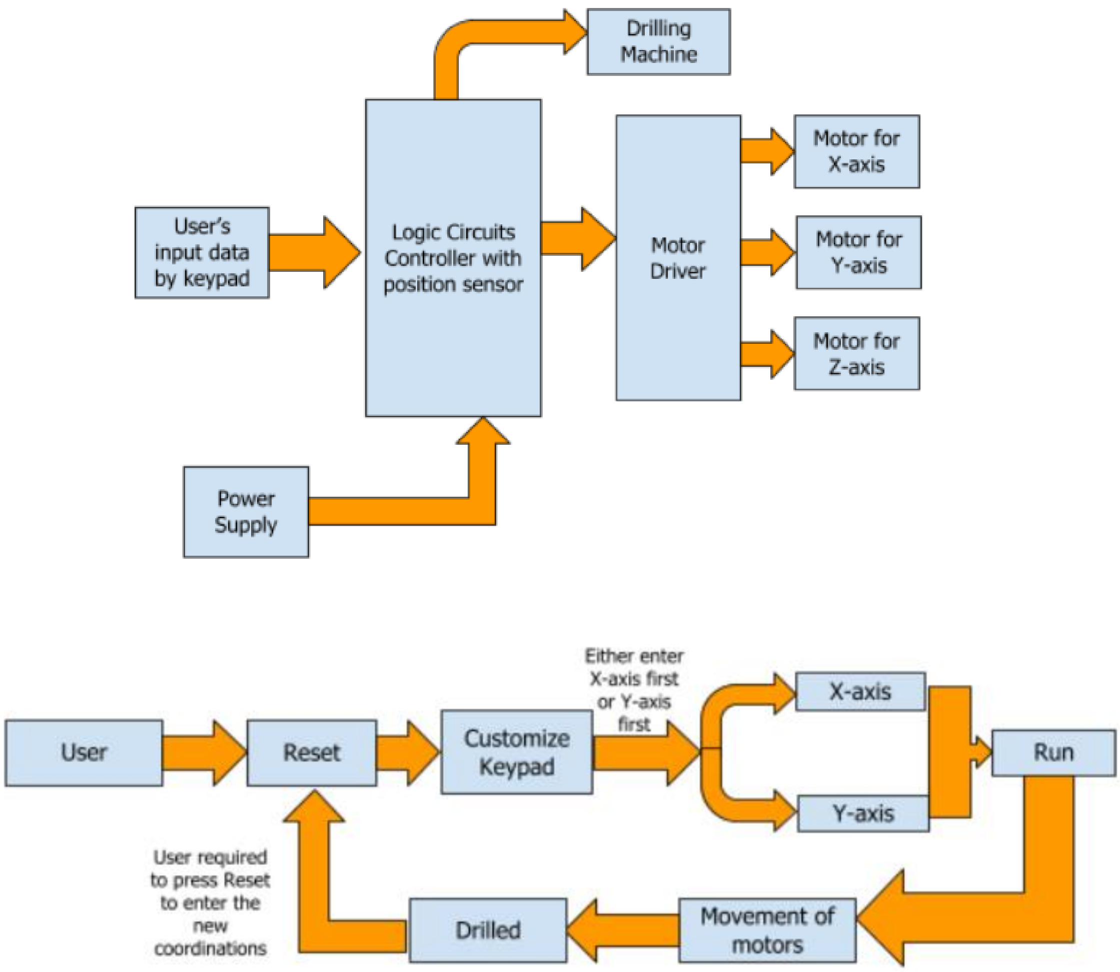


Figure 2.0.1: Overview of the Keypad controller

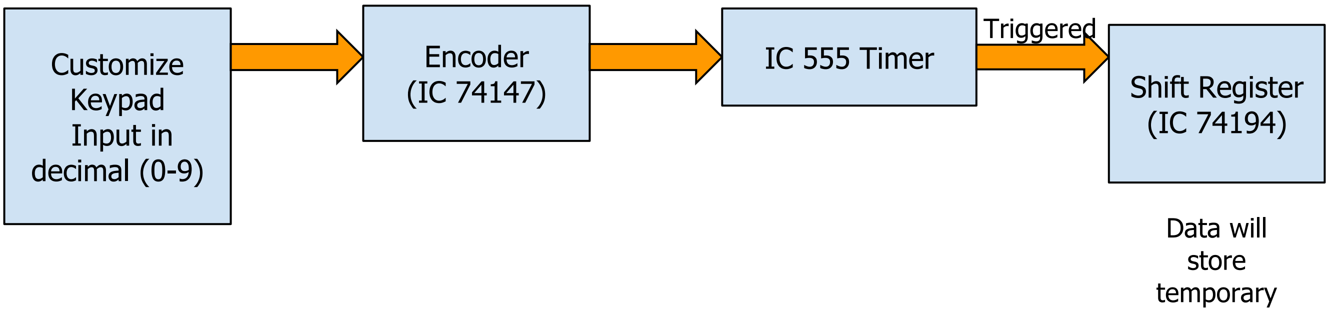


Figure 2.0.2: Decimal to BCD code

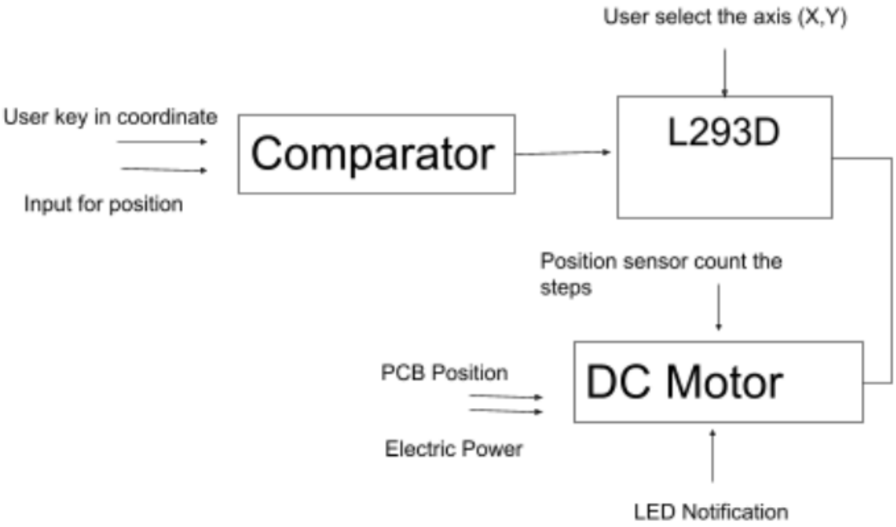


Figure 2.0.3: Block diagram for the Motor

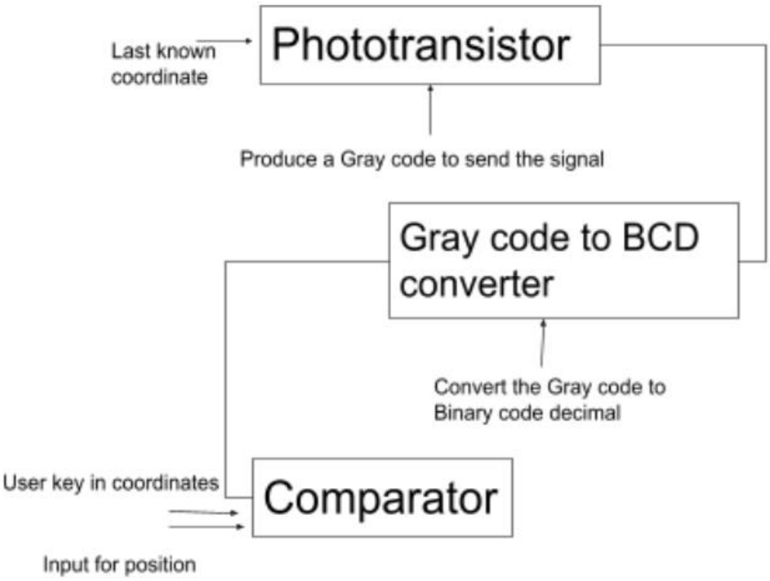


Figure 2.0.4: Block diagram of the Position sensor

2.1 Organisation Chart

Our organisation chart is based on Work Based System (WBS) which generally can divide into 3 which is Mechanical, Electronic and Report as stated below

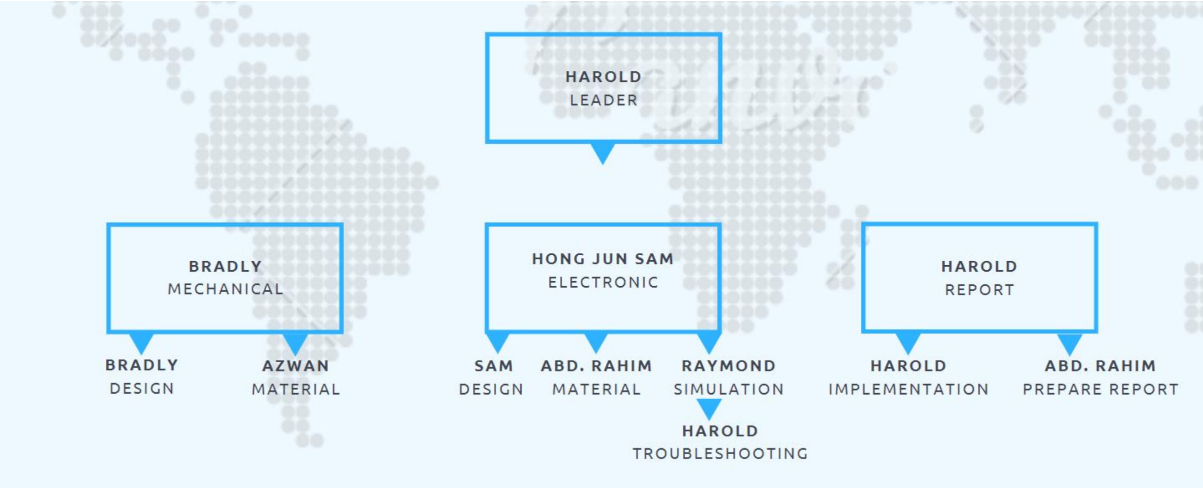


Figure 2.1.0: Organisation Chart Group 5

Table 2: Roles and tasks of members for every week along the design project is done.

Week	Event	Members' Name	Roles
1 - 2	**Course Lectures** **Team Formation** **Design Process**	Harold (Leader)	-Assigned as the leader and the electronic team -Give tasks to members to do general research on the project to let the group get the idea what to do and to expect in the project.
		Raymond Hong Jun Sam Abdul Rahim	-Assigned as the electronic team which takes care of most of the electronic designs
		Bradly Muhammad Nur Azwan	-Assigned as the mechanical team which takes care most of the mechanical design s
3 - 5	**Research and Gathering Information** **Brainstorming**	Harold (Leader)	-Call for a meeting **(1)** to gather all the information and brainstorm using the data available. -Give ideas on electronic designs.

	Conceptual Design		-Assign members to do research and preparation for different parts. -Assigned to handle the keypad and controller of the machine with the block diagram designed by the team.
		(Electronic Team) Raymond Hong Jun Sam Abdul Rahim	-Give ideas on the possible electronics concepts that can be used. -Considers all the ideas given in electronic engineers' perspectives -Provide multiple conceptual designs with block diagrams -Assigned to do research and preparation for the full detailed design on the electronics part of the machine.
		(Mechanical Team) Bradly Muhammad Nur Azwan	-Give ideas on the possible structure and mechanical designs for the project. -Provide multiple conceptual designs with concepts of mechanism. -Assigned to do research and preparation for the full detailed design on mechanical and structure of the machine
6 - 7	**Presentation** **Embodiment and Detailed Design**	Harold	-Present the results of the discussion and brainstorming. (Conceptual Designs) -Conduct a meeting **(2)** to discuss on the detailed design of the automatic drilling machine
		(Electronic Team) Raymond Hong Jun Sam Abdul Rahim	-Present a detailed design on the electronics parts with improved block diagrams. -Raymond and Hong Jun Sam were assigned to handle the motor controller. Rahim was assigned to

			handle the positioning sensor.
		(Mechanical Team) Bradly Muhammad Nur Azwan	-Bradly was assigned to handle the Solidwork schematics. Azwan was assigned to find the materials availability and dimensions for Bradly to use.
8 - 10	**Simulation**	Harold	-Call for a meeting **(3)** to discuss a full design report and start assigning members with different parts of the machine to be simulated. -Call for a second **(4)** meeting to discuss about the current situation to transition from prototype to only simulation -Call for a progress **(5)** meeting on the simulations. -Assigned to handle the keypad simulation
		(Electronic Team) Raymond Hong Jun Sam Abdul Rahim	-Raymond and Hong were assigned to handle the logic circuit of the motor driver simulation circuits. -Abdul Rahim assigned to handle the positioning sensor simulation circuits.
		(Mechanical Team) Bradly Muhammad Nur Azwan	-Assigned to handle on improving and modifying the mechanical part of the machine based on the electronic team simulation circuit. -Assigned to keep updates on the components availability and the total cost of the project.
11-12	**Finished the first simulations circuits and solid works structure** **Testing, Modification and Fixing**	Harold	-Call for progress meeting **(6)** on the simulations done for every part of the automatic drilling machine and now combine all the small parts of the simulations into one complete circuit. -Call for meeting **(7)** on the component and materials

			availability based on the current structure and electronic components needed. (Decided to proceed with only simulation due to lack of tools and materials) -Call for progress meeting **(8)** regarding the problems faced by the electronic team and suggestions on fixes. -Call for progress meeting **(9)** with the mechanical team regarding the modification needed or can be done on the structure for the fixes and improvements.
		(Electronic Team) Raymond Hong Jun Sam Abdul Rahim	-Assigned to fix any problems happening in current simulation circuits when combining all the circuits together.
		(Mechanical Team) Bradly Muhammad Nur Azwan	-Assigned to do any modification based on the simulation circuit such as the controller case and also provide input to others on the functions.
13-14	**Fixing the Final Simulations Circuits** **Full Simulations** **Report Submission**	Harold	-Call for progress **(10)** meetings with both the electronic and mechanical team regarding the problems that still persist and discuss possible fixes. -Report Submission
		(Electronic Team) Raymond Hong Jun Sam Abdul Rahim	-Assigned to finish up touches regarding the simulation circuit, so that the circuit can run as intended, and assist to complete the report.
		(Mechanical Team) Bradly Muhammad Nur Azwan	-Assigned to aid the electronic team for the simulation circuit, and assist to complete the report.

CHAPTER 3

DETAILED DESIGN

3.0 Introduction

On this chapter, we will explain about how we manage to obtained the detailed of our design project which will meet the requirements of the project.

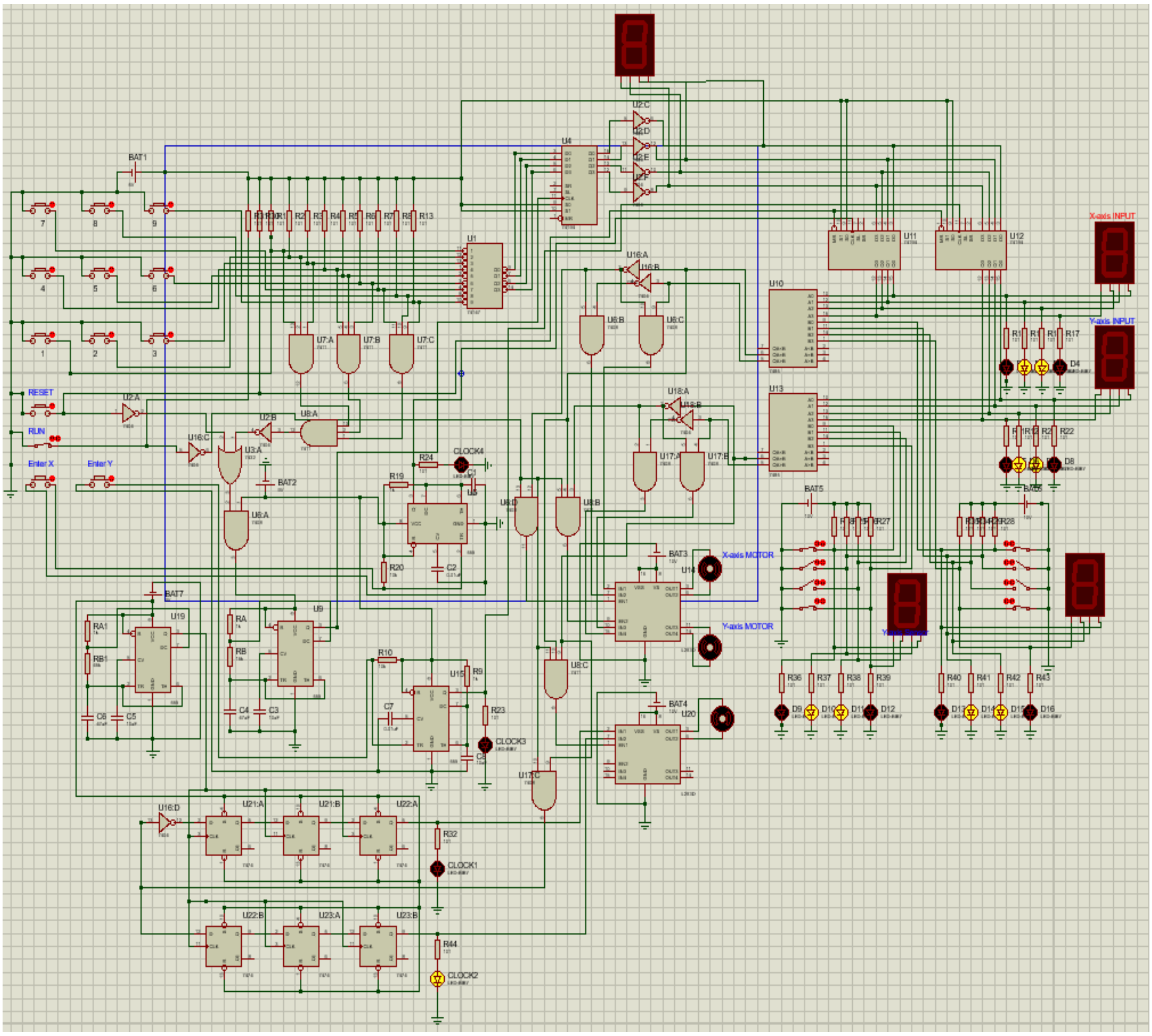
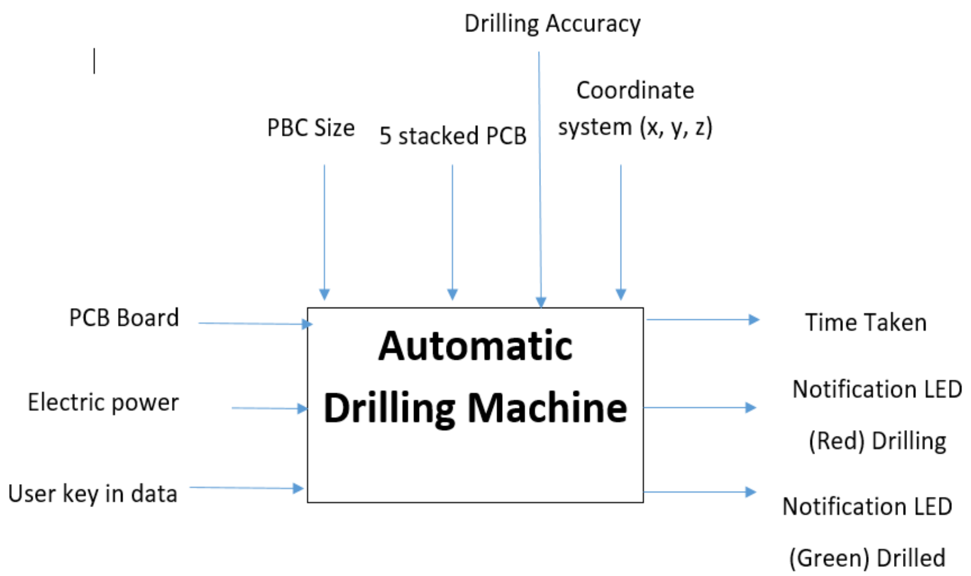


Figure 3.0.1: Full Circuit of the Drilling Machine in Proteus



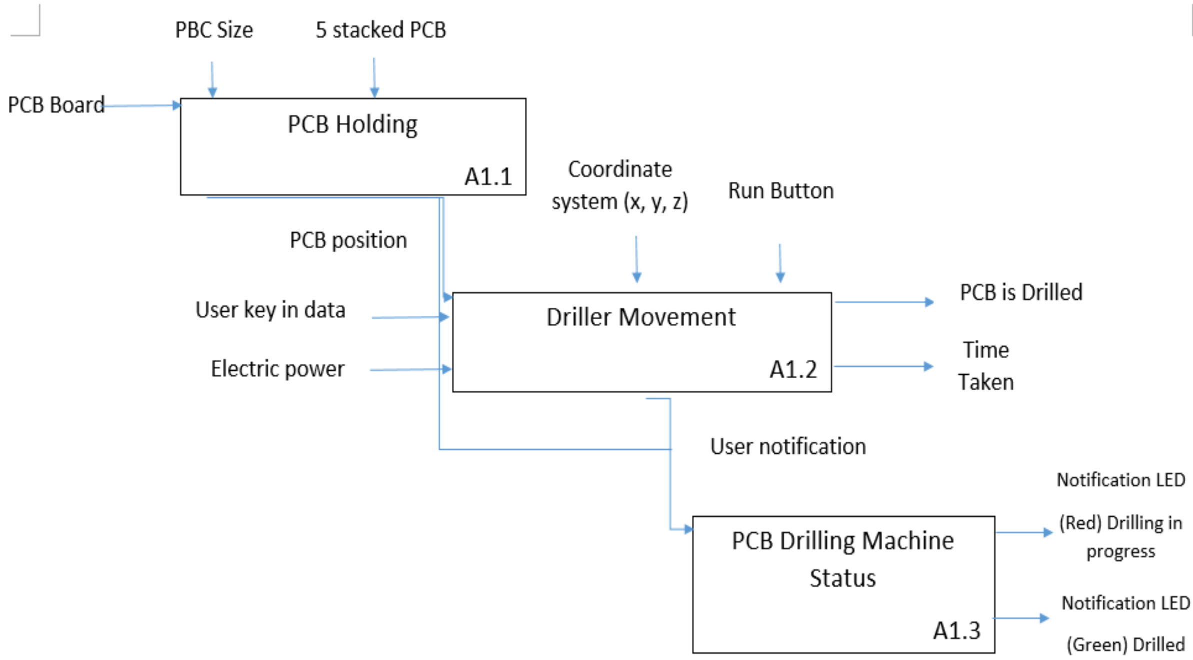


Figure 3.0.2: Functional Decomposition

3.1 Concept Selection

Mechanical Team

Concept selection is a decision process, in which design team selects one or a few products concept for further development.

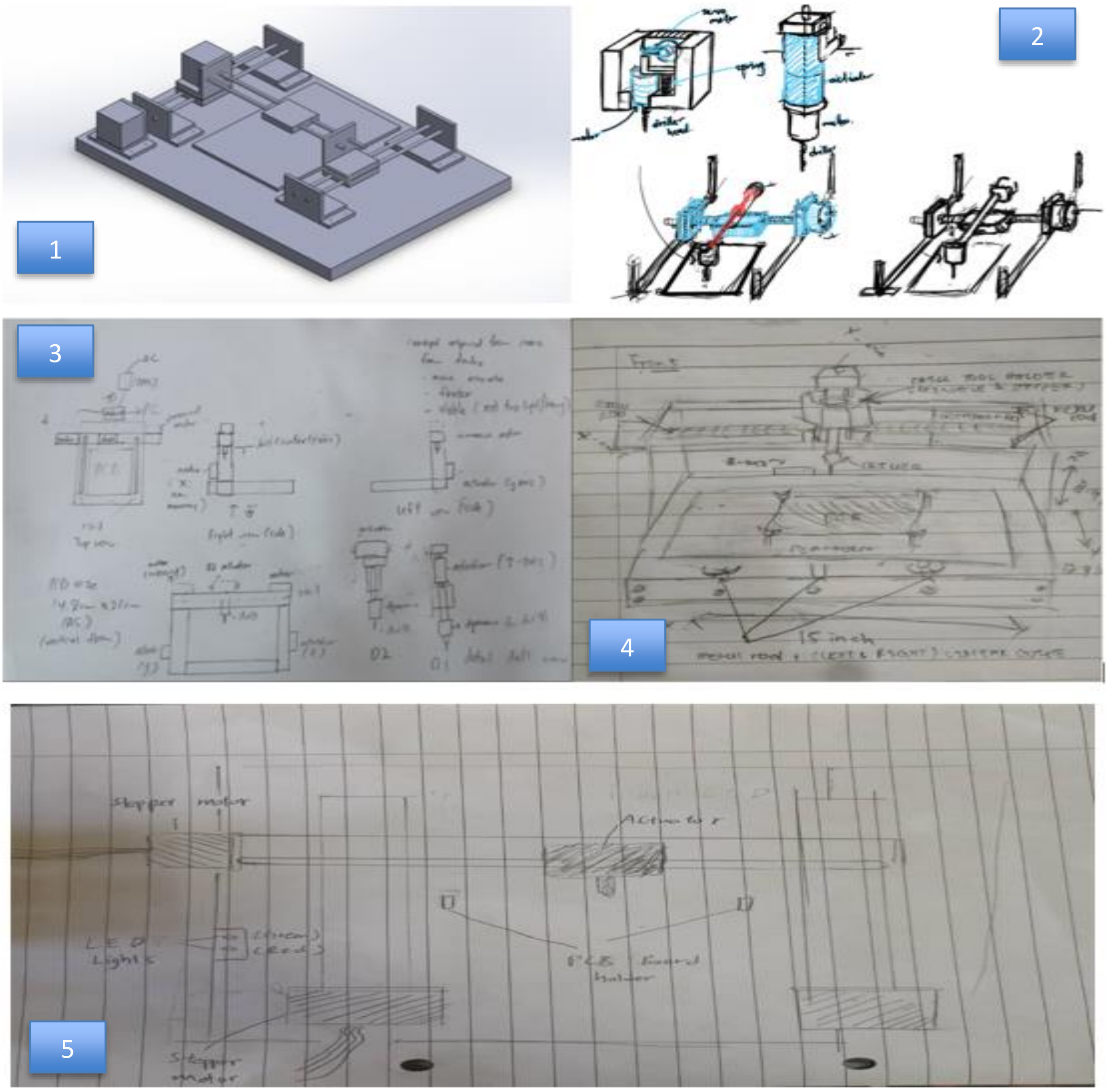


Figure 3.1.0: Conceptual Design for the Automatic Drilling Machines from each Members

Based on each member's conceptual design which evaluates the pros and cons of each design we have chosen the first design as our main design of this project. The reason we chose this design is because of ease of handling, ease of use, the accuracy of the coordinate, and better durability compares to other concept designs produce. Below is the detailed image of our main design project that has been finalized:

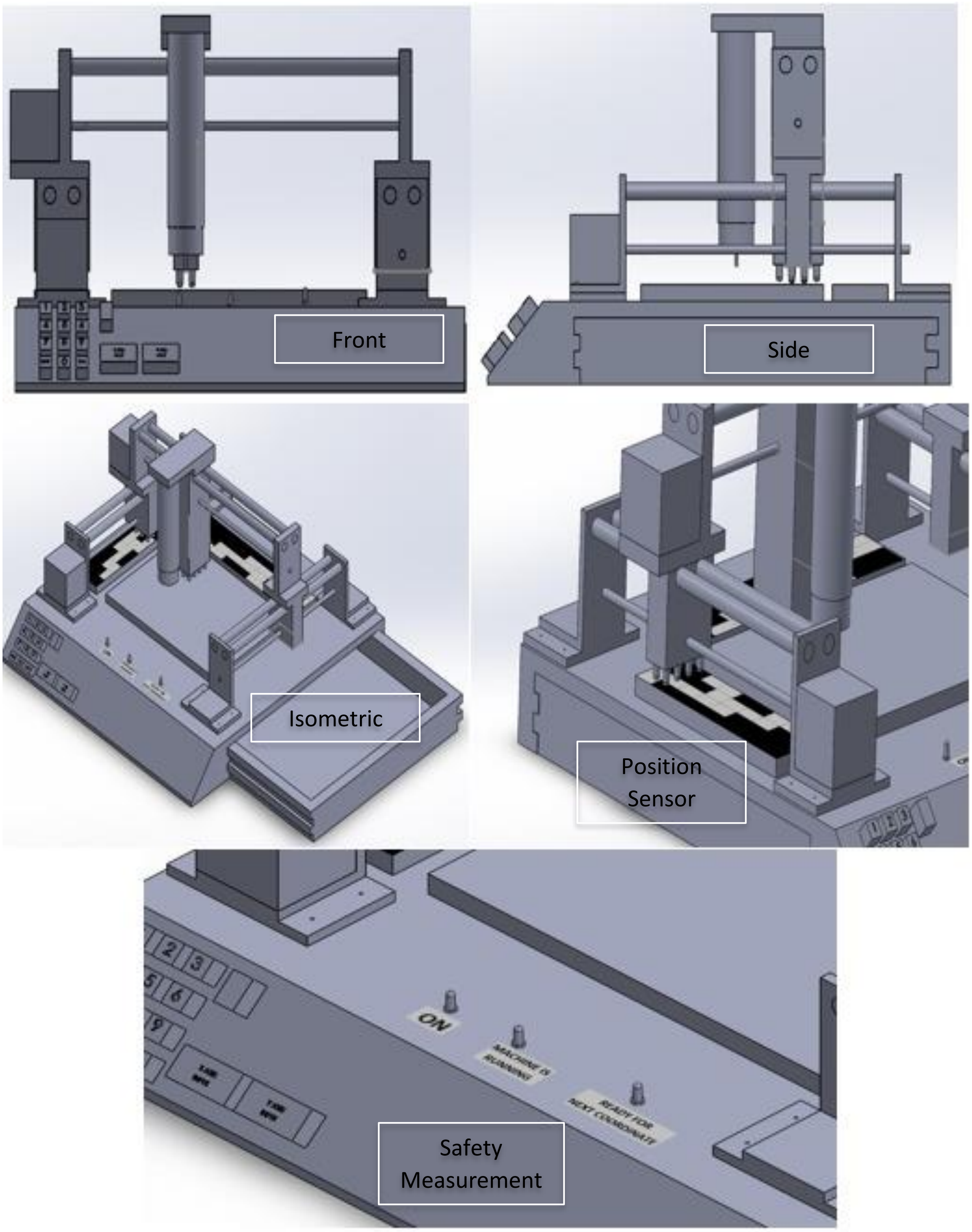
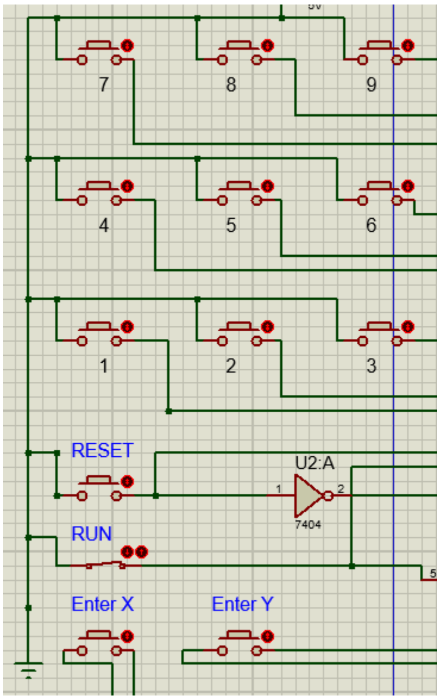


Figure 3.1.1: Different views of the PCB Drilling Machine and Safety Measurement button

3.2 Keypad

Electronics Team

The automatic drilling machine will be controlled via a custom-made keypad containing input numbers from 0 to 9, and other functional buttons such as reset, run, confirm input for the x-axis and y-axis. Users will need to reset the machine first by pressing the reset button before starting to input numbers for both the x-axis and y-axis. Users have the choice to either input x-axis or y-axis first and upon finishing inputting the desired value. Users will need to turn on the RUN switch to start the drilling process. With this few components are used to make the custom keypads which are resistors, push-up buttons, 74147 ICs- Decimal to BCD Encoder, 74194 ICs- 4-bit shift register, inverters, AND & OR logic gates. Below are the diagrams of the components for the keypads.



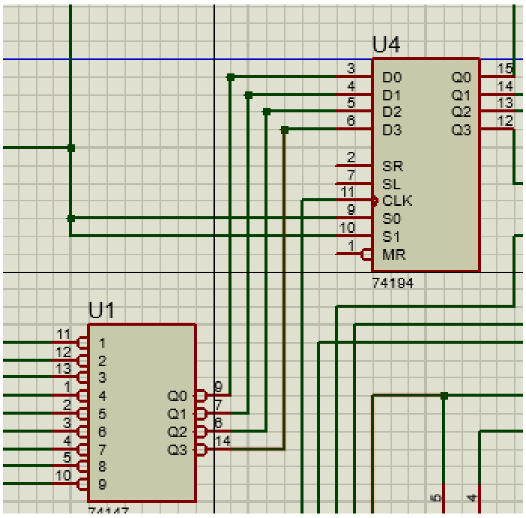


Figure 3.2.0: Decimal Input switches in Proteus	**Figure 3.2.1:** Encoder 74147 to Shift Register

As for the decimal input buttons, all of the push-up buttons will be connected onto a decimal to the BCD encoder which changes the decimal into 4-bit binaries which then will be fed onto a shift register **(Figure 3.2.1)** to store the data of what number had been pressed. The shift registers are triggered by the 555 timers that are connected together with the keypad buttons.

Meaning that every time the users pressed a button the shift register will be triggered and store the temporary data.

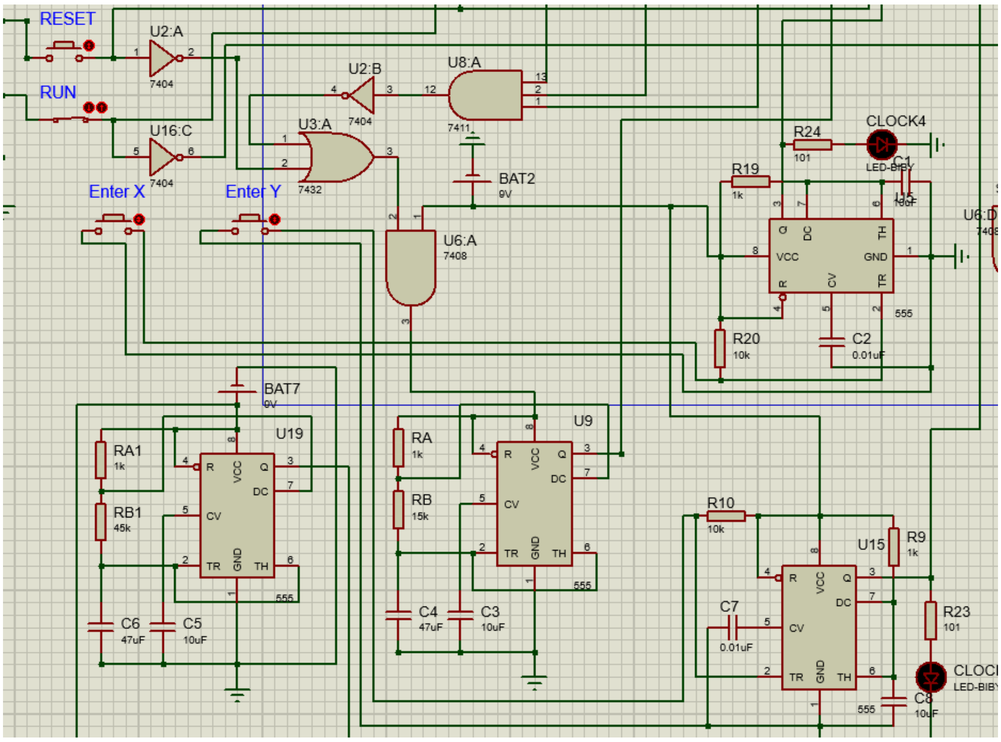


Figure 3.2.2: Reset, Run, Enter X and Y connection to 555 timer

3.2.1 Reset button

As for the reset button, it is connected to all the 555 timers that control all the shift register clocks. This will let the switch to set all the values in the shift register to be zero. This is useful to make sure that the machine starts perfectly on zero/starting coordinates. It's useful also to reset the machine if there's an issue where to happen is why running the machine.

3.2.2 Run switch

Next would be the run switch, the reasoning behind this is to make sure the machine doesn't run instantly the moment users input any values. Thus, reducing the risk of the user getting hurt by the machine since the user will have time to clear the place like for example making sure that no hand is placed on the drilling area before running the machine after inputting the values or having an unwanted object on the drilling area that would cause dangerous debris getting onto user's eyes or skin. Other than that, it allows for better control on the x-axis and y-axis motor.

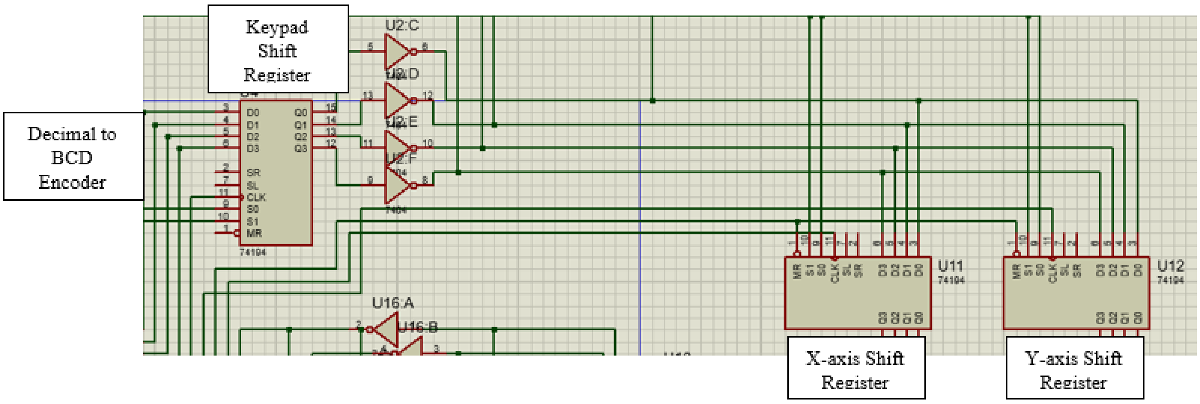


Figure 3.2.3: Shift register to another Two Shift Register

In **Figure 3.2.3**, this connection has two purposes. The first is to divide the input into two for the x-axis and y-axis separately. So when the clock of the shift register for the x-axis is triggered (INPUT X switch) then the data that the user pressed at the keypad which was stored in the first shift register to be outputted at the x-axis shift register. The second is that the encoder binary data are all inverted and therefore are inverted back using 4 inverters. To explain better, when the user presses number 1, the binary code for number 1 that was converted by the encoder will be stored in the first shift register. Then from there, the user can choose to input that number he/she pressed before as either x or y input and if the user chose to input x then it will trigger the clock for x shift register which then later sends the binary code to the comparator that handles the x-axis movement.

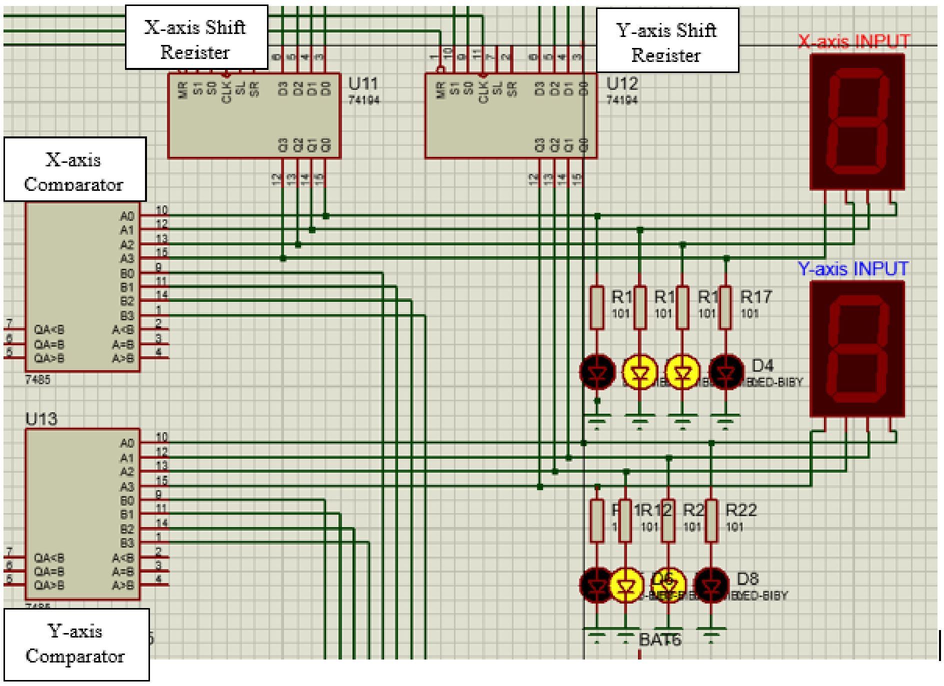


Figure 3.2.4: Connection between shift registers to comparator in Proteus

As for the connection from the shift register to the comparator which will then use the data input by the users and compare it with the position sensor data. Based on the data outputted by the comparator it can be used to act as inputs for the motor driver L293D as in **Figure 3.3.0.**

Mechanical Team

For the keypad, we decide to customize it on our own, which means we build the keypad by using push-up buttons. There are 10 push-up buttons that will label from 0 to 9 and all of these are decimal numbers. There are four more extra push-up buttons which are the Y-axis button, X-axis button, RUN switch, and RESET button. The functions of these buttons have been mentioned on the electronic part. The customized keypad will be installed at the front side of the basement of the PCB drilling machine. Other than that, there will be a 7 segment display next to the keypad. A specially designed drawer will be at the bottom of the machine, which is used to place the logic circuits.

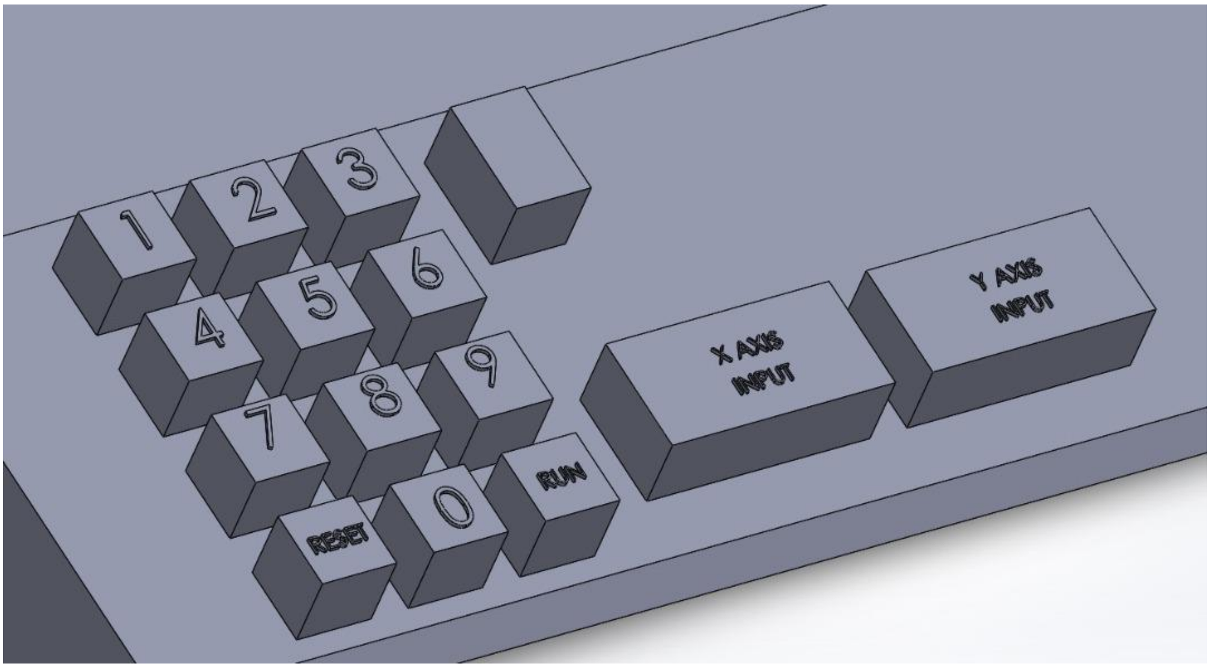


Figure 3.2.5: Customized Keypad with and a 7 segment LCD display

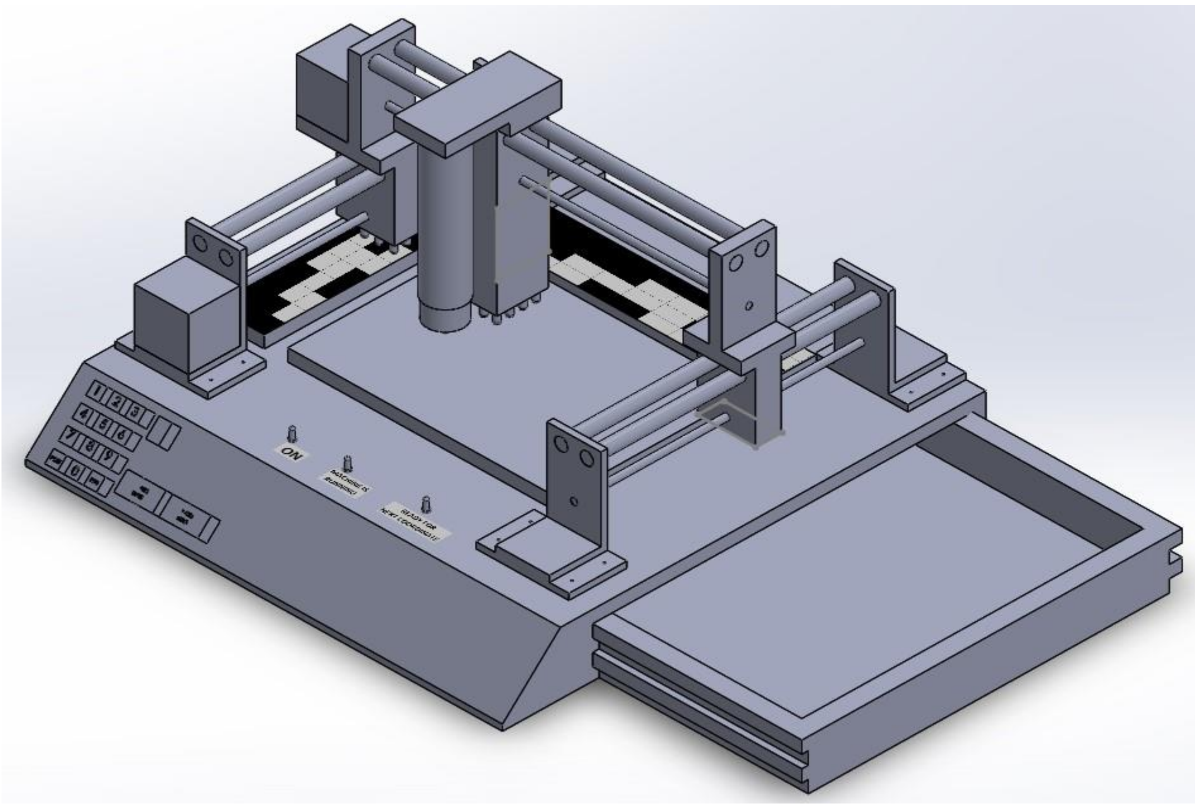


Figure 3.2.6: A special designed drawer which used to place the logic circuits.

3.3 Motors

Electronics Team

As for the motors, there are fewer choices that were being considered, and among the three types of motor which are motor, servo motor, and dc motor we choose to use a dc motor. The reason why we choose a DC motor is that it is much more simple and easier to set up. Due to the project limitation where students can only make the drilling machine using controllers, meaning any microcontrollers are forbidden. This makes the number of parameters that can be used for motors limited and if we were to use other than DC motors then the circuit will need to become more complicated and bigger. Besides that, the motor can be controlled using the position sensor which will later be explained further in the report. This makes the steps in the stepper motor to be not applicable in this situation since we can know the position of the motor using the position sensor instead of counting the steps of the motor. There will be two main dc motors that control the x-axis and y-axis movement, an actuator to control the driller by extending and pushing the driller head downward, and the last motor would be the motor used to spin the driller.

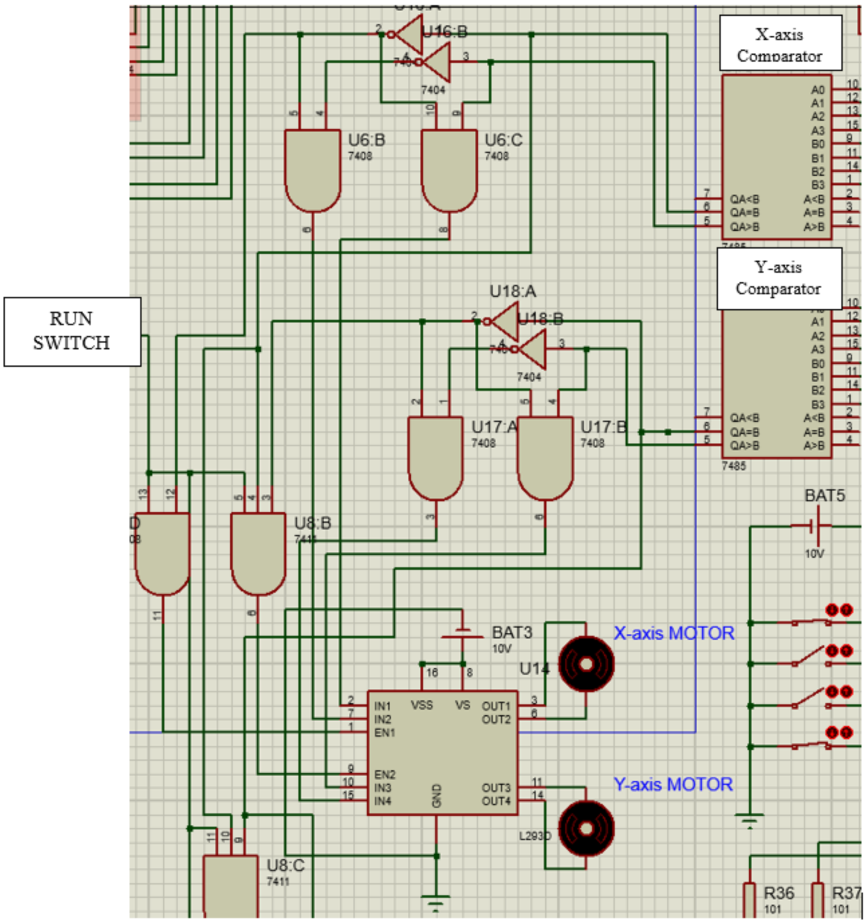


Figure 3.3.0: Logic Circuit from the Comparators' Outputs to motor driver L293D

For the X-axis and Y-axis motor, it will be controlled by a motor driver, L293D, which is connected with a few logic gates for its inputs and enable. As for the input 1 and 2, the connections are made with the output of the comparators as inputs which control the direction of the rotation of the motor. In the previous part, we mentioned that we will set a RUN switch which is used as one of the inputs for the logic circuit connecting onto the enable input. Few conditions were set for the different motors which are listed below:

- Motor x and y will move only when the run switch is on.
- Motor y will not move until Motor x has finished moving.
- Motor x will stop moving upon reaching the x coordinate.
- Motor y will stop moving upon reaching the coordinate.

With these conditions a logic table can be made out of this and then further be worked with the K-map method to find the Boolean expressions which will then be used to build the circuit in the simulation.

Table 3.0: Logic Table for the connection between comparator and motor driver L293D

Indications	A=B	A>B	A<B	Forward (clockwise) Enable 1 input in L293D	Backward (anti-clockwise) Enable 2 Input in L293D
Symbol	**A**	**B**	**C**	**Output X**	**Output Y**
	0	0	0	x	x
	0	0	1	1	0
	0	1	0	0	1
	0	1	1	x	x
	1	0	0	0	0
	1	0	1	x	x
	1	1	0	x	x
	1	1	1	x	x

Table 3.1: K-map for Output X

C \ AB	00	01	11	10
0	X	0	x	0
1	1	x	X	x

X = A′ B′

Table 3.2: K-map for Output Y

C \ AB	00	01	11	10
0	X	1	x	0
1	0	x	X	x

Y = A′ B

Mechanical Team

For the motor, we decided to put it beside the x-axis tread rod for the x-axis motor, while another motor is placed beside the y-axis base. The reason behind it is that this placement has a low centre of gravity, hence it does increase the stability of the PCB drilling machine. As mentioned above, the DC motor behind the driller is controlling the x-axis, while the motor located at the y-axis base is controlling the y-axis. All of the functions of the motor are already described in the electronic part.

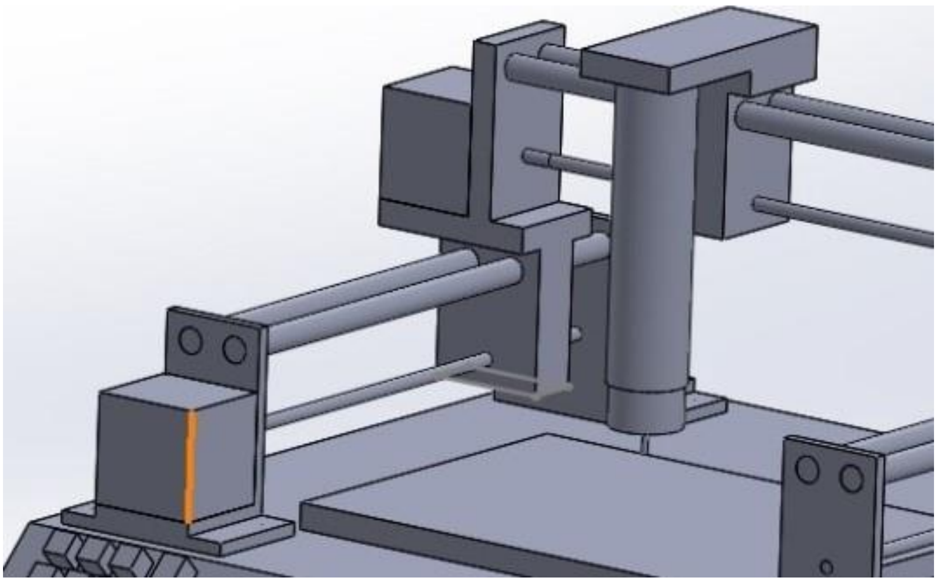


Figure 3.3.1: Motor for x-axis and y-axis (x-axis beside tread rod. y-axis with a yellow line)

We are using a metal bracket to hold both x and y-axis motors, thus it can stabilize the whole PCB drilling board, and reduce any error due to external vibration. For the driller, we will be using an actuator motor to run the driller. The actuator motors we are using are lightweight and suitable for our needs, only weighing 200g with 120N of the torque provided. For the DC motor, we will be using a Brushed DC Geared Motor for both the x and y-axis. The reason is this DC motor has enough torque for our usage, with 177mN.m, also the weight is not heavy for our platform. But most importantly, it is economical and cheap, it only costs RM45 each. Other relevant motors do cost more and are heavy.

3.4 Position Sensor

Electronic Team

For the positioning sensor, the design is by using 4 phototransistors to detect the black and white colours that we manually set up on the side of the drilling area with the Gray code pattern. With this when the phototransistor is at a certain position, we can obtain the Gray code of the current position it's on and convert it into BCD which later on will be used to compare with the coordinates imputed by the users in the comparators.

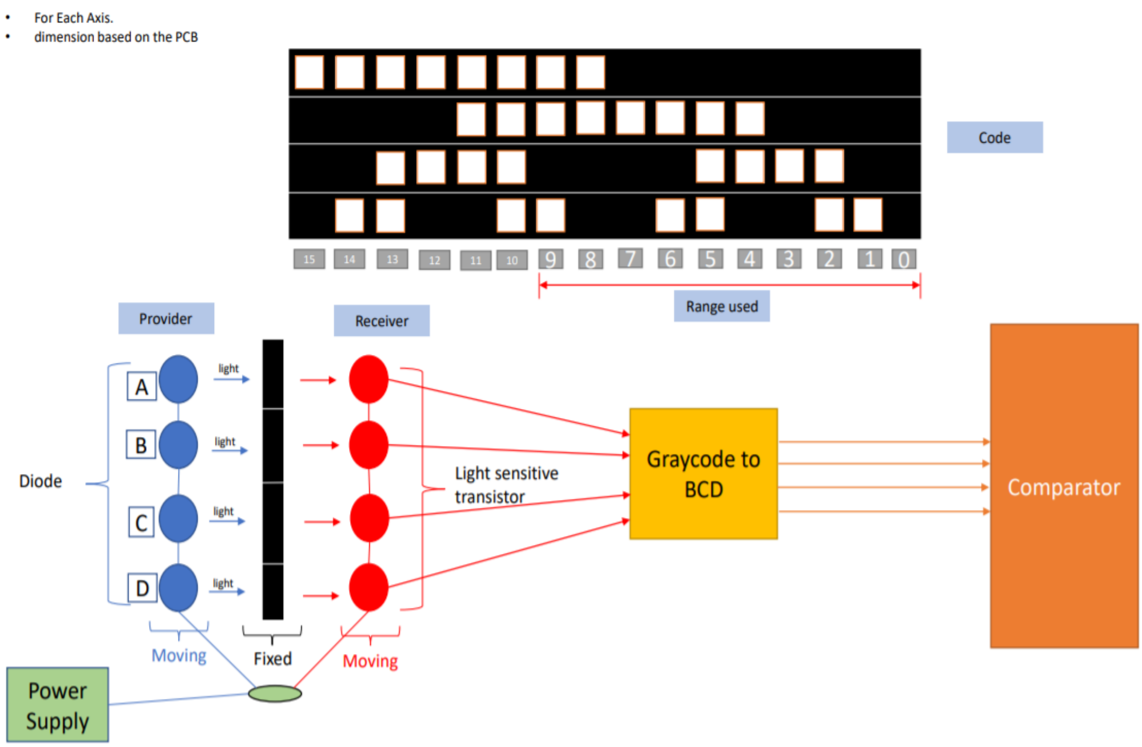


Figure 3.4.0: Electronic Design on the Position Sensor

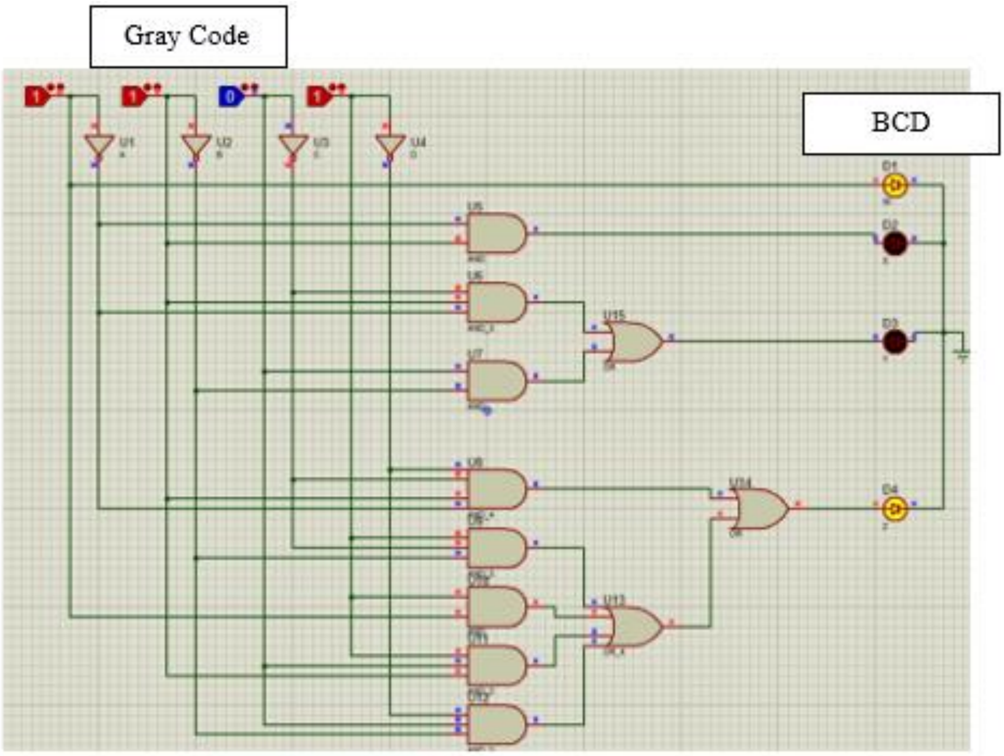


Figure 3.4.1: Gray Code to BCD Convertor circuit in Proteus

Mechanical Team

Position sensor will be placed behind the PCB drilling machine platform, since its function is to calculate the steps of the motor, so it is suitable to be placed behind it. The benefit of this placement is that it can ensure the accuracy of this drilling machine with the sensor placed near the PCB platform.

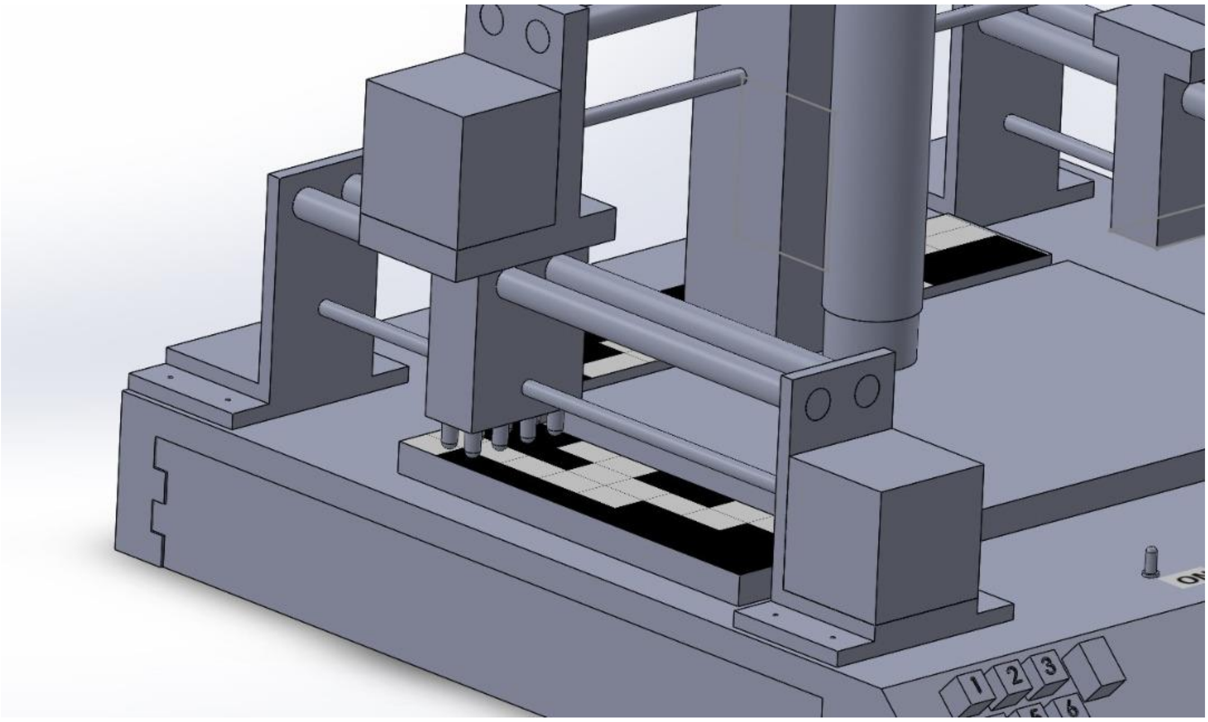


Figure 3.4.1: The placement of the position sensor located.

3.5 Sustainability of The Project

Sustainability is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. In this design project, we are not using any resources. Instead of using physical resources, we are using the virtual resources which is the simulation software, Proteus.

3.6 Societal Impact of The Project

Most of the automatic PCB drilling machines that exist in the market have a major similarity which is they are using microcontrollers to control the movement of the drilling machines. However, in our design instead of using a microcontroller to control, we are using logic circuits such as an encoder, shift register, and comparator to control the movement of the PCB drilling machine. The impact of this design project is that the microcontroller is not the only way to control the machine. But, we can also use logic circuits to build the controlling system of the PCB drilling machines.

CHAPTER 4

TESTING

4.0 Introduction

Testing is one of the most important elements in prototyping and also design projects since it's the only way for the designer or developer to check if the prototype would work just as they intended it to be. The required testing had been done to make sure that the designed simulation would meet the design requirements and were to be divided into few sections for better and detailed explanations and presentation.

4.1 Keypad Number Coordinate Input

The first thing to test in the simulation for the automatic drilling machine would be the keypad and ensuring that the output corresponds to the button we pressed in the keypad. To test this we used a 7-Segment BCD Display to show the binary being transferred across the encoder to the shift registers. Below are the figures when we input 2 on the x-axis and 6 on the y-axis.

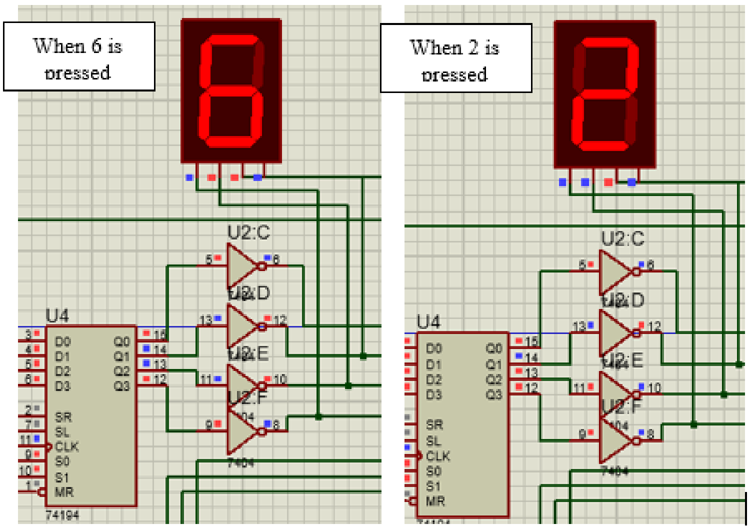


Figure 4.1.0: 7-Segment BCD Display to check the data in the keypad is stored correctly

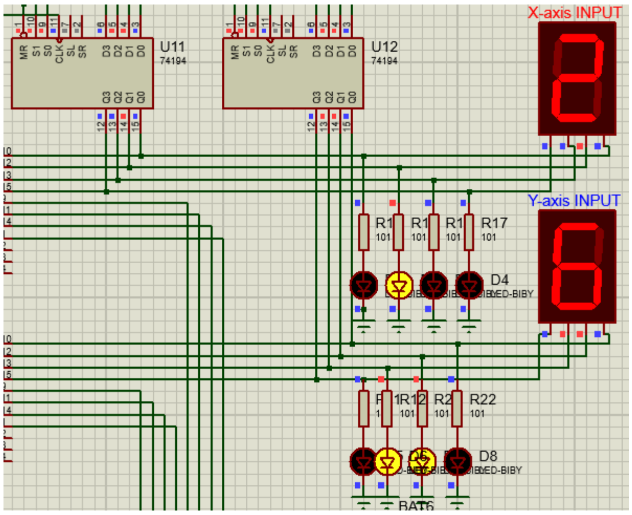


Figure 4.1.1: 7-Segment BCD Display for both x-axis and y-axis input combined with 8 LED for better visibility when testing.

4.2 Keypad Functional Switch and Buttons (Reset, Run)

Reset and Run keys are really important to make sure the machine will work or not and it's also important to have better control of the machine. For the Reset button, the way we test it is by using the same method as the previous part which is by using the 7-Segment BCD display as the indicator if we had reset the machine or not. While for the Run button, we used the rotations on the motor with an extra indication using LED at the Enables of the L293D since the way we set up the motor driver connection is that we can control the motor by the enable.

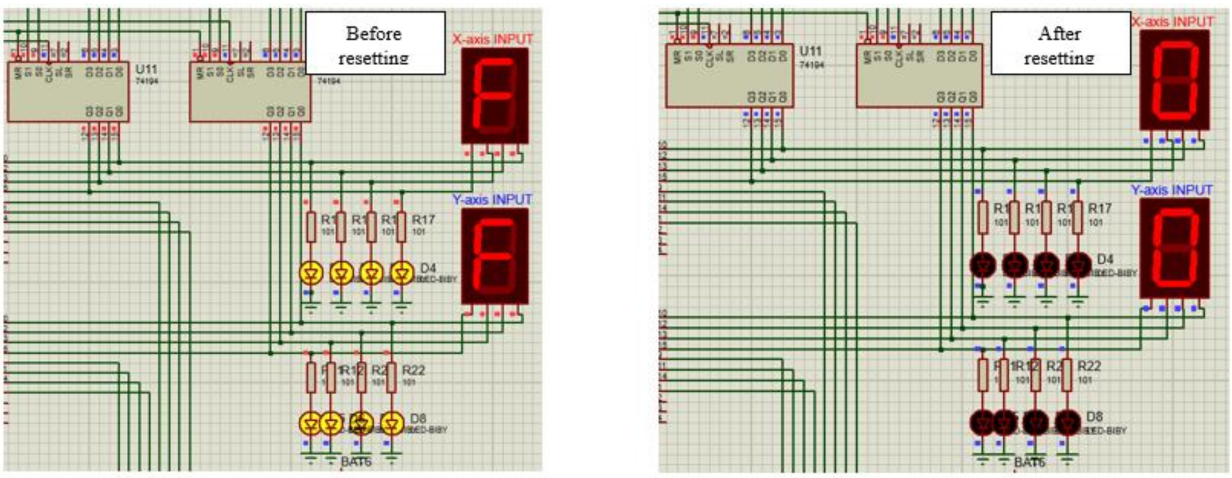


Figure 4.2.0: 7-Segment BCD Display before and after reset at the beginning of the simulation

4.3 Motor movement according to current position

The machine needs to be able to move to the desired coordinates and to test it we can use the motor rotation simulation with certain testing conditions:

- If user input is less than current position the motor will rotate clockwise
- If user input is equal to the current position the motor will stop as it has reached the desired location
- If user input is more than the current position the motor will rotate anticlockwise

As for the positioning inputs, we built our 4-bit binary generator to simulate the output of the positioning sensors when moving across the platform and used 7-segments BCD displays to indicate the number in decimal. We are aware of the problem where we can't simulate the movement of the phototransistors therefore only use the output that it will produce when it's in a certain position.

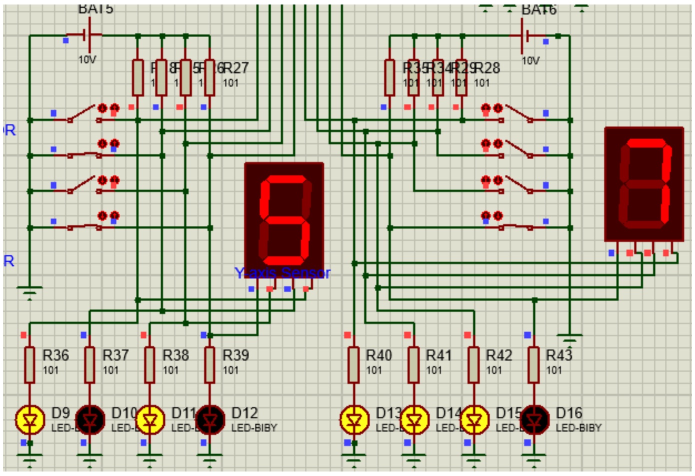


Figure 4.3.0: Positioning Sensor output simulated using 4-bit binary generator

Link 4.3.0: Simulation of the movement of the motor with the three testing conditions, https://youtu.be/c01-g2vny3A

4.4 Actuators and Drilling

The next part of the machine after finishing the axis movement is the drilling mechanism. The design that we used is by using an actuator being attached to a driller and we found out that the actuator required a certain amount of time to extend and attract itself. Therefore, we set a delay for it to fix the issue. For the drilling, the test conditions are as below:

- The actuator will extend after all axis motors had finished moving or reached the desired coordinates.
- The actuator will need a certain delay to extend and let the driller drill a hole then retract.
- The Drill motor will stop spinning after the actuator finished retracting.

The way we test the extension and retraction is by indicating it using LEDs.

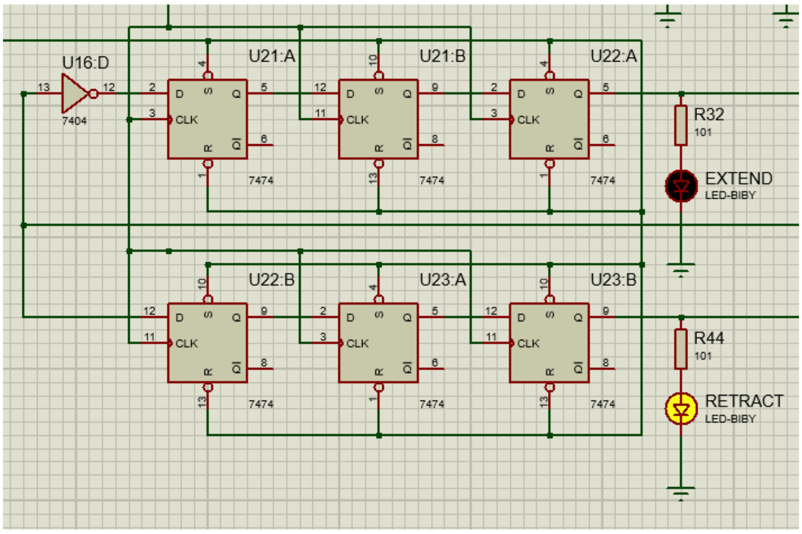


Figure 4.4.0: Delays for the extension and retraction process with D flip-flops with LED as Indicators

Video Link 4.4.0: The delay between the extension and retraction simulated in proteus, https://youtu.be/I3uREH6GrR4

4.5 Repetitiveness

The machine needs to be able to repeat the same process over and over without issue until when the machine wears down and to test it is by testing all the tests done before again for a few several times. Other than just being able to repeat the same process, we also want the repetition to be as smooth as possible, meaning there's no problem between the old task and the new task. Test conditions are as following:

- Repeatable tasks.
- After finishing, the machine can reset or continue to another coordinate.

CHAPTER 5

FULL SIMULATION

5.0 Simulation Procedures

The simulation is conducted in a certain procedure to fully indicate or represent how the machine will run in real life. Therefore, the procedures are as following:

1. Reset the machine and make sure the RUN Switch is open.
2. Input X and Y coordinates.
3. Run the drilling by closing the RUN switch.
4. Change the input from the positioning sensor to simulate the phototransistor moving.
5. After the driller finished extending and retracting, open the RUN switch.
6. Reset the machine and repeat step 1.

5.1 Link to the Full Simulation Video

Video Link: https://youtu.be/romMl09Lh24

5.2 Link to the project design

File Link:
https://drive.google.com/drive/folders/11_C0LpWSn17ZNyOkgC69lWHzUKaKrfFO?usp=sharing

REFERENCES

- G.Niranjan, A.Chandini, P.Mamatha. (2013). Automatic Drilling Machine with Depth Controllability. *International Journal of Science and Engineering Applications, 2(4).* http://www.ijsea.com/archive/volume2/issue4/IJSEA02041008.pdf

- Kajal J.Madekar, Kranti R. Nanaware, Pooja R. Phadtare, Vikas S. Mane. (2016). Automatic mini CNC machine for PCB drawing and drilling. *International Research Journal of Engineering and Technology (IRJET), 3(2).* https://www.academia.edu/download/54675591/IRJET-V3I2194.pdf

- M. Alim, S. Goundar, A. Shamim, M. Pillai, R. Singh, K. A. Mamun, P. Chand and U. Mehta. (2015). Automatic PCB Drilling Machine. *2015 2nd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE), pp 1-6.* https://ieeexplore-ieee-org.ezproxy.ums.edu.my/document/7476221/

- Nguyen Huu Phuong, Ho Van Thoi. (n.d.). Design and Build an Automatic PCB Drilling Machine. *Electronics & Computer Center University of Natural Sciences, Vietnam National University – HCM.* http://www.nsl.hcmus.edu.vn/greenstone/collect/hnkhbk/import/Dien_tu/1_SectionB/9_Nguyen%20Huu%20Phuong,%20Ho%20Van%20Thoi_DESIGN%20AND%20BUILD%20AN%20AUTOMATIC%20PCB%20DRILLING%20MACHINE.pdf

- Zulkifli Tahir, Nur Azman Abu, Shahrin Sahib, Nanna Suryana Herman. (2010). CNC PCB Drilling Machine using Novel Natural Approach to Euclidean TSP. *2010 3rd International Conference on Computer Science and Information Technology, Volume 5, pp 481-485. https://ieeexplore-ieee-org.ezproxy.ums.edu.my/stamp/stamp.jsp?tp=&arnumber=5563910*