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**DEPARTMENT OF MECHANICAL & MECHATRONICS
ENGINEERING**

THREE DIMENSIONAL PRINTER

**Graduation Project Submitted In Partial Fulfillment Of The Requirements For The
Degree Of B.Sc. In Mechatronics Engineering.**

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ABSTRACT

Mechatronics engineer's use technology to find solutions of problems concerning time and effort. Three dimensional printers are used many industrial sectors from small-scale to large companies. Three dimensional printers are very important in manufacturing applications from producing small parts to large and complicated molds. The increasing demands on the need of small biomedical parts which requires high technical and precision technology to rough food industrial applications.

So it is important to find a solution of printing parts automatically in an efficient technology taking into account effective time, production cost and accuracy within the standard limits of accuracy for purpose of design and manufacturing. Three dimensional printer could be a suitable and important solution to find the above mentioned problems.

In this report too many chapters will be discussed. The first one contain a general description about our project. The second one involves general introduction about three dimensional technologies and the chosen technology in our design. The third one discuss the selected technology and the chosen types of this technology. The fourth chapter summarizes both mechanical and electrical components of the printer. After that mechanical design of the structure and movement mechanisms will be discussed in chapter six. In addition Electrical design will be explained in chapter seventh. Chapter eight involves control design and software of the printer. Finally the last chapter conclude all report and contains a future work about the project.

In this project , the 3D printer will be constructed and tested using some applications.

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CHAPTER 1 : INTRODUCTION

1.1 Introduction

3D-printer is a technology started in 1980s as a machine that aims to create a desired shape in three dimensional space.

It's a technology that implement a software format, e.g., stereo-lithography (STL) format to create hard object through complex processes of transferring STL format starts from computer-aided-system design (CAD) to final output is done by rapid prototyping (RP) techniques.

This technology has developed through out the time to massive diverse according many factor, e.g. row material, accuracy and method of printing.

In brief the variety of 3D-printing machine technologies and characteristics of every single machine will be discussed.

Figure 1.1 shows 3D printer system.

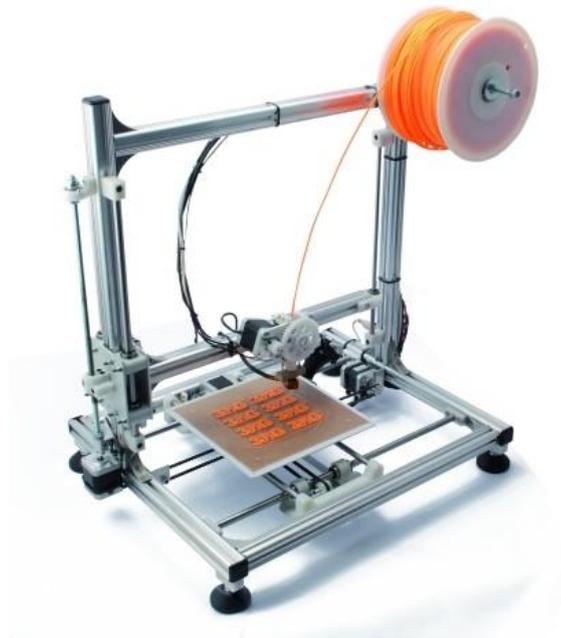


Figure 1.1 : 3D printer system.

1.2 Literature review

The reader of this project will find a combined effort to produce what is in our hands now. This project begins with the used technologies of 3D printing.

3D printer it's an instrument to make plastic printed objects. The main concepts commonly used to make a 3D printing device consist of a threaded travel mechanism, a combination X-axis and Y-axis, a precisely controlled motor (either a stepper motor or servo motor), and a controller for mechanisms for correctly positions. For each axis - X, Y, and Z – a motor is connected to the threaded travel mechanism. As the motor turns the screw, a guide on top of the thread moved left and right in a straight dimensional line. Combining the X axis motion of extruder, and the Y-axis of plate, an XY-plane is created. This allows a platform to be positioned anywhere in a 2-dimensional plane. The Z axis, either mounted as part of the XY plane or separately above it, allows for a 3rd dimension.

With the help of a controller, the medium to be print can be correctly placed in the XY-plane . The Z-axis, is used for extruder.

1.3 Chapter by chapter overview

Chapter 2 is an introduction to the main technologies of 3d printing.

Chapter 3 talks about the selected technology and its types of movement and the selection of the most suitable type.

Chapter 4 talks about one of the mechanical and electrical components which will be combined with the controller.

Chapter 5 talks about the structure design and a description for dimensions used for mechanical parts.

Chapter 6 talks about electrical design of the printer.

Chapter 7 shows the control design of the printer.

Chapter 8 describes manufacturing and testing operations due to building the printer.

1.4 Conclusion

At the end of the report, the final work of the 3D printer will be shown and also the faced problems during working to build the printer will be shown.

CHAPTER 2 : 3D PRINTING TECHNOLOGIES

2.1 Introduction

In this chapter the technologies of three dimensional printers will be studied and one of these technologies will be chosen for the project.

2.2 Stereo-lithography (SLA) Technology

Starting from the bottom layer to the top layer. Later, the definition was extended to any material capable of solidification or alteration of its physical state. Stereo-lithography is an additive manufacturing process that works by focusing an ultraviolet (UV) laser on to a vat of photopolymer resin. With the help of computer aided manufacturing or computer-aided design (CAM/CAD) software, the UV laser is used to draw a pre-programmed design or shape on to the surface of the photopolymer vat. Photopolymers are sensitive to ultraviolet light, so the resin is photo chemically solidified and forms a single layer of the desired 3D object[1]. Then , the build platform lowers one layer and a blade recoats the top of the tank with resin. This process is repeated for each layer of the design until the 3D object is complete. Completed parts must be washed with a solvent to clean wet resin off their surfaces[2].

2.3 Selective Laser Sintering (SLS)

It's a 3D printing technique that uses high power CO₂ lasers to fuse particles together. The laser sinters powdered metal materials (though it can utilize other materials too, like white nylon powder, ceramics and even glass). Selective laser sintering (SLS) is a powder-based fusion technology that uses a laser beam to locally sinter polymer powder to build parts layer by layer.

A bin of the powder material is heated to an elevated temperature. A recoating blade deposits a very thin layer of the powdered material (typically 0.1 mm) onto a build platform. After deposition of a layer, a laser beam starts to scan the surface. The laser beam selectively sinters the powder and solidifies a cross-section of the part. When the entire cross-section is scanned, the building platform moves down one layer thickness in height. Unsintered powder remains in place to support subsequent layers eliminating the need for support structures. The recoating blade deposits a new layer of powder on top of the scanned layer and the laser beam starts to sinter the successive cross-section of the part onto the previously solidified cross-sections. This process is repeated until all parts are fully manufactured. The result is a container filled with powder and consolidated products. Since multiple products can be produced simultaneously the process can be used for small series production. When the printing process is complete and the powder container and product have cooled down, the powder container is unpacked. The solid products are parted from the unsintered powder and cleaned with compressed air and a blasting medium. The remaining (unsintered) powder is collected and reused. The parts are then ready to use or are post processed to improve mechanical properties or appearance.

2.4 Digital Light Processing (DLP) Technology

It's similar to SLA given that it also works with photopolymers. The liquid plastic resin used by the printer goes into a translucent resin container. There is, however, one major difference between the

two, which is the source of light. While SLA uses ultra violet light, DLP uses a more traditional light source, usually arc lamps.

This process results in pretty impressive printing speeds. When there's plenty of light, the resin is quick to harden (we're talking seconds). Compared to SLA 3D printing, DLP achieves quicker print times for most parts. The reason it's faster is because it exposes entire layers at once. With SLA printing, a laser has to draw out each of these layers, and this takes time.

2.5 Electron Beam Melting (EBM) Technology

This is a 3D printing technology similar to SLM in that it uses a powder bed fusion technique. The difference between the two is the power source. The SLM approach above uses high-powered laser in a chamber of noble, or inert gas. EBM, on the other hand, uses a powerful electron beam in a vacuum. Aside from the power source, the remaining processes between the two are quite similar. EBM's main use is to 3D print metal parts. Its main characteristics are its ability to achieve complex geometries with freedom of design. EBM also produces parts that are incredibly strong and dense in their makeup.

Here are a few of EBM's other impressive features:

- Doesn't need extra auxiliary equipment for the 3D printing process.
- Has increased efficiency using raw materials.
- Lessens lead times resulting in parts getting to market faster.
- Can create fully functional, durable parts on demand for wide-ranging industries.

The printing process starts like most others in that the user has to first create a 3D model, or computer-generated digital file.

2.6 Fused Deposition Modeling (FDM) Technology

It uses production grade thermal plastic materials to print its 3D objects. It's popular for producing functional prototypes, concept models, and manufacturing aids. It's a technology that can create accurate details and boasts an exceptional strength to weight ratio.

Before the FDM printing process begins, the user has to slice the 3D CAD data (the 3D model) into multiple layers using special software. The sliced CAD data goes to the printer which then builds the object layer at a time on the build platform. It does this simply by heating and then extruding the thermoplastic filament through the nozzle and onto the base. The printer can also extrude various support materials as well as the thermoplastic.

For example, as a way to support upper layers, the printer can add special support material underneath, which then dissolves after the printing process. As with all 3D printers, the time it takes to print all depends on the objects size and its complexity.

Like many other 3D technologies, the finished object needs cleaning. Raw FDM parts can show fairly visible layer-lines on some objects. These will obviously need hand sanding and finishing after printing. This is the only way to get a smooth, end product with an even surface. FDM finished objects are both functional and durable. This makes it a popular process for use in a wide range of industries, including for mechanical engineering and parts manufacturers. BMW uses FDM 3D printing, as does the well-known food company Nestle, to name just a couple.

2.7 Selective Laser Melting (SLM) Technology

SLM also uses a high-powered laser beam to form 3D parts. During the printing process, the laser beam melts and fuses various metallic powders together. The simple way to look at this is to break down the basic process like thus:

Powdered material + heat + precision + layered structure = a perfect 3D object.

As the laser beam hits a thin layer of the material, it selectively joins or welds the particles together. After one complete print cycle, the printer adds a new layer of powdered material to the previous one. The object then lowers by the precise amount of the thickness of a single layer. When the print process is complete, someone will manually remove the unused powder from the object. The main difference between SLM and SLS is that SLM completely melts the powder, whereas SLS only partly melts it (sinters). In general, SLM end products tend to be stronger as they have fewer or no voids[3].

A common use for SLM printing is with 3D parts that have complex structures, geometries and thin walls. The aerospace industry uses SLM 3D printing in some of its pioneering projects. These are typically those which focus on precise, durable, lightweight parts. It's a costly technology, though, and so not practical or popular with home users for that reason. SLM is quite widespread now among the aerospace and medical orthopedics industries. Those who invest in SLM 3D printers include researchers, universities, and metal powder developers. There are others too, who are keen to explore the full range and future potential of metal additive manufacturing in particular.

2.8 Laminated Object Manufacturing (LOM) Technology

LOM is a rapid prototyping system that works by fusing or laminating layers of plastic or paper using both heat and pressure. A computer-controlled blade or laser cuts the object to the desired shape. Once each printed layer is complete, the platform moves down by about 1/16th of an inch, ready for the next layer. The printer then pulls a new sheet of material across the substrate where it's adhered by a heated roller. This basic process continues over and over until the 3D part is complete[4].

2.8.1 LOM printing works as follows:

1. Sheet is adhered to a substrate with a heated roller.
2. Laser traces desired dimensions of prototype.
3. Laser cross hatches non-part area to facilitate waste removal.
4. Platform with completed layer moves down out of the way.
5. Fresh sheet of material is rolled into position.
6. Platform downs into new position to receive next layer.
7. The process is repeated.

2.9 Binder Jetting (BJ) Technology

The Massachusetts Institute of Technology (MIT) first invented BJ 3D printing. **It also includes :**

- Powder bed printing.
- Inkjet 3D printing.
- Drop-on-powder.
- Binder jetting (BJ). This is the most popular name and the one we'll use to refer to it.

BJ is a 3D printing process that uses two types of materials to build objects: a powder-based material (usually gypsum) and a bonding agent. As the name suggests, the “bonding” agent acts as a strong adhesive to attach (bond) the powder layers together. The printer nozzles extrude the binder in liquid form similar to a regular 2D inkjet printer. After completing each layer, the build plate lowers slightly to allow for the next one. This process repeats until the object reaches its required height.

The four popular materials used in BJ printing include:

1. Ceramics.
2. Metals.
3. Sand.
4. Plastics.

It’s not possible to get super high-resolution or overly rugged 3D objects with BJ printing, but there are other advantages. For example, these printers allow you to print parts in full color. To do this, you simply add color pigments to the binder, which typically include black, white, cyan, yellow, and magenta. This technology is still advancing, so expect more great things to come in the future. At the time of writing, some applications of BJ 3D printing include rapid prototyping, and various uses in the aerospace, automotive, and medical industries.

2.9.1 Material Jetting (MJ) Polyjet and Wax Casting Technology

Material Jetting referred to as wax casting. Unlike other 3D printing technologies, there isn’t a single inventor for MJ. In fact, up until recent times it’s been more of a technique than an actual printing process. It’s something jewelers have used for centuries. Wax casting has been a traditional process where the user produces high-quality, customizable jewelry. The reason it gets a mention here is because of the introduction of 3D printing. MJ 3D printers produce high-resolution parts, mainly for the dental and Jewelry industries , For jewelers who want to experiment with various casts as most jewelers do MJ is now their leading 3D technology.

Once the 3D model (CAD file) is uploaded to the printer, it’s all systems go. The printer adds molten (heated) wax to the aluminum build platform in controlled layers. It achieves this using nozzles that sweep evenly across the build area. As soon as the heated material lands on the build plate it begins to cool down and solidify (UV light helps to cure the layers). As the 3D part builds up, a gel-like material helps to support the printing process of more complex geometries. Like all support materials in 3D printing, it’s easy to remove it afterward, either by hand or by using powerful water jets. Once the part is complete you can use it right away, no further post-curing necessary.

There are also Polyjet MJ 3D printers, which use photopolymer-resins rather than synthetic waxes. Polyjet technology also offers very good resolution. Unlike digital wax printers, people use Polyjet devices to create parts for a wide range of industries.

2.10 Conclusion

In this chapter several 3D-printing technologies have been studied. In this graduation project, the FDM-printing technology is chosen for the proposed 3D-printer. The FDM technology has several benefits, such as it is clean, simple-to-use and office-friendly. Moreover it supports production-grade thermoplastics to be mechanically and environmentally stable and it can be used make complex geometries and cavities that would otherwise be have problems without the FDM technology.

CHAPTER 3 :FDM TECHNOLOGY

3.1 Introduction

In this chapter the movement of 3D-printer working with FDM-technology will be studied, and suitable movement will be chosen for the proposed printer .

3.2 Cartesian 3D printer

Cartesian 3D printers are named after the dimensional coordinate system — the X, Y, and Z-axis which is used to determine where and how to move in three dimensions.

Cartesian 3D printers typically have a print bed which moves only in the Z-axis. The extruder sits on the X-axis and Y-axis, where it can move in four directions on a gantry.

There are variations, for example, instead of moving the print-head purely in XY space, one of the axes are changed by moving the print bed itself. This is a mechanically simpler design, and therefore easier to maintain, but at the sacrifice of printing speed.

This type has a square base can move x-y plane , the extruder can also move in x-y plane , the extruder handle moves in z direction. Figure 3.1 indicates the Cartesian 3D printer.

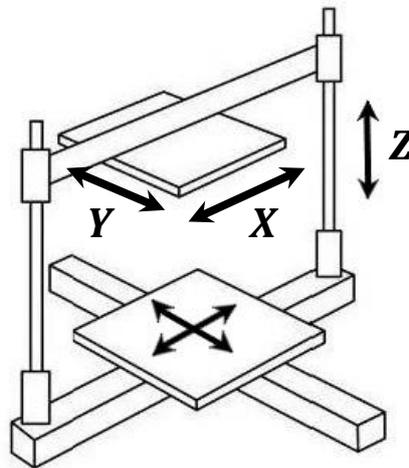


Figure 3.1 : Cartesian 3D printer

3.3 Delta 3D printer

FDM-technology has another type which called Delta 3D printer, it also work within the Cartesian plane.

Identifying characteristics start with the circular print bed. The extruder is suspended above the print bed by three arms in a triangular configuration, thus the name “Delta”.

However, it’s sometimes argued that this category of printer is not as detailed or as precise as its Cartesian sibling.

This technology has a rotating disk and vertical rallies moves in different distances in z direction to make the extruder move in x-y plane.

Figure 3.2 presents the delta 3D printer.

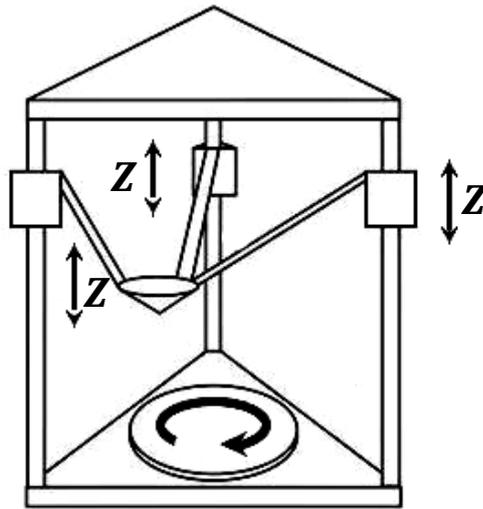


Figure 3.2 : Delta 3D printer

3.4 Polar 3D printer

This category uses a polar coordinate system. It's similar to the Cartesian, except that the coordinate sets describe points on a circular grid rather than a square, all of which means that you can have a printer with a spinning bed, plus a print head that can move up, down, left and right.

The big advantage of a polar 3D printer is that the printer can function with only two stepper motors. Compare this to a typical Cartesian 3D printer which requires a minimum of one stepper motor for each axis usually at least four .

Moreover, Polar 3D printers can have a greater build volume within a smaller space, lacking the requirement of a XYZ framework to move around.

The motion is quite hypnotic to watch. It may not seem as, intuitive *as* other designs, but the end results are exactly the same.

This type has a rotating plate which can move in x direction , θ for rotating plate , and the extruder moves in z direction.

Figure 3.3 : presents the Polar 3D printer

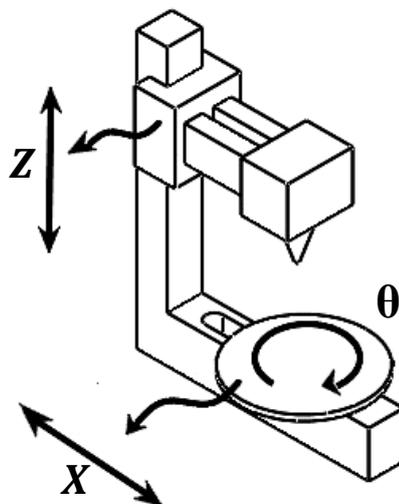


Figure 3.3 : Polar 3D printer

3.5 Scara 3D printer

The Selective Compliance Assembly Robotic Arm (Scara) is a very precise system with a tiny footprint. A Scara 3D printer looks and moves much like an industrial robot on a car assembly line might, but this is purely in the service.

This technology has two links separated by two revolute joints rotate with θ_1 and θ_2 , the two links move linearly in z direction. Figure 3.4 represents the Scara 3D printer.

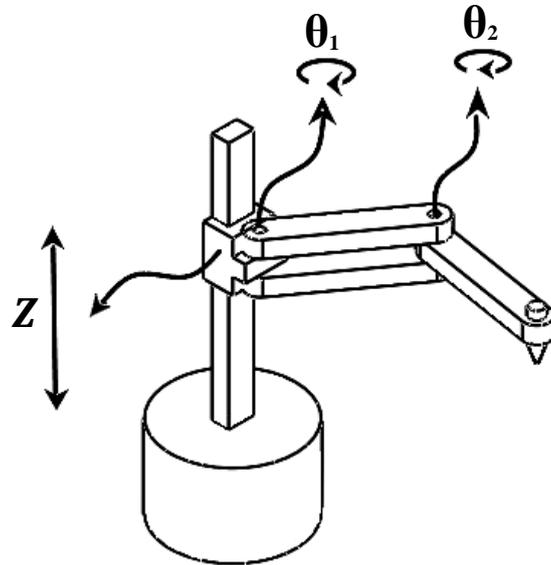


Figure 3.4 : Scara 3D printer.

3.6 Conclusion

In this chapter several types of FDM-technology have been studied . In this graduation project , Cartesian 3D printer will be chosen for the proposed 3D-printer.

The chosen printer in the Cartesian system will have the following movements, due to stability and rigidity :

- The bed moves in y direction.
- The extruder move in x direction.
- Base of the extruder moves in z direction.

Figure 3.5 shows Cartesian 3D printer

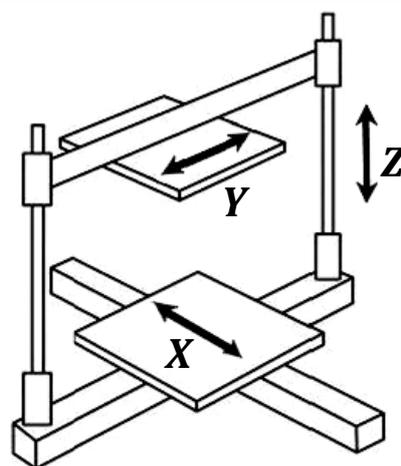


Figure 3.5 : Used cartesian 3D printer

CHAPTER 4 : MECHANICAL AND ELECTRICAL COMPONENTS

4.1 Introduction

In this chapter mechanical and electrical parts of 3D-printer will be studied and suitable components will be chosen for the design of the 3D printer.

4.2 Mechanical components

The mechanical part of 3D-printer consists of multiple section. The first is base which is the mechanical structure that will be discussed in the next chapter. The second is the rails which represented as smooth rod. the third is threaded rod. Fourth is belt and pulley. Fifth will be couples and bearings. Also there is heated bed. Lastly there will be the extruder which is the most important part.

4.2.1 Smooth rod and Heated bed

A smooth rod is a metal rod usually used on the axis for components such as most commonly used diameter is 8 mm, but 10 mm and 12 mm are seen in more rigid designs as well. Stainless steel is a pretty hard steel, and doesn't rust, making them ideal to slide bushings on.

Figure 4.1 shows Smooth rod.



Figure 4.1 Smooth rod

4.2.2 Threaded rod

Threaded rod is a fastening bar or a rod threaded along its length. Thread direction is an important specification to consider. Choices include right hand, left hand, or both right hand and left hand.

Right hand threads are configured so that clockwise rotation tightens the threaded rod to a fastener. Left hand threads are less common, but well-suited for applications in which motor vibration would cause right handed threads to loosen. When thread direction is not specified, the default direction is usually to the right. Left hand threads are usually listed explicitly. Figure 4.2 shows Threaded rod.



Figure 4.2: Threaded rod

4.2.3 Belt and Bully

A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts may be used as a source of motion, to transmit power efficiently or to track relative movement. Belts are looped over pulleys and may have a twist between the pulleys, and the shafts need not be parallel. In a two pulley system, the belt can either drive the pulleys normally in one direction (the same if on parallel shafts), or the belt may be crossed, so that the direction of the driven shaft is reversed (the opposite direction to the driver if on parallel shafts). As a source of motion, a conveyor belt is one application where the belt is adapted to carry a load continuously between two points.

A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of belts, or transfer of power between the belts. In the case of a pulley supported by a frame or shell that does not transfer power to a shaft, but is used to guide the cable or exert a force, the supporting shell is called a block, and the pulley may be called a sheave. Figure 4.3 Shows belt. Figure 4.4 shows pulley.



Figure 4.3: Belt



Figure 4.4: Pulley

4.2.4 Shaft Coupling

Shaft couplings are actually the mechanical device that connects or couples the two drive element or shaft together for transmitting the power from one end to another. Couplings do not allow any shaft interruption during operation. Anyway, with the torque limiting couplings can disconnect when the limit of the torque is exceeded. Shaft Coupling has a common advantages such that it transfers the power from one end to another end , it provides connectivity of shaft with the other units that are manufactured such as motor and generators , it provides shaft misalignment and mechanical flexibility , it decreases the shock load transmission from shaft one end to another , provide protection against overload , adjust the rotating unit vibration characteristics and it connects the driving part[5].

Figure 4.5 shows shaft coupling.



Figure 4.5 : Shaft coupling tool

4.2.5 Bearing

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads applied to the parts.

Figure 4.6 shows Bearing.



Figure 4.6 Bearing.

4.2.6 Extruder

By relocating the extruder, its motor and mounts away from the hot end, we can significantly reduce the weight of the moving parts, leaving only the hot end to be pushed to and fro. This decreased weight, should, in theory, result in more accurate prints, particularly at higher speeds: there is less momentum to overcome when changing directions. In other words Extruders should be able to print faster, but it turns out there are a lot more factors to achieve speed than just the extruder [6].

Figure 4.7 shows Bowden Extruder.

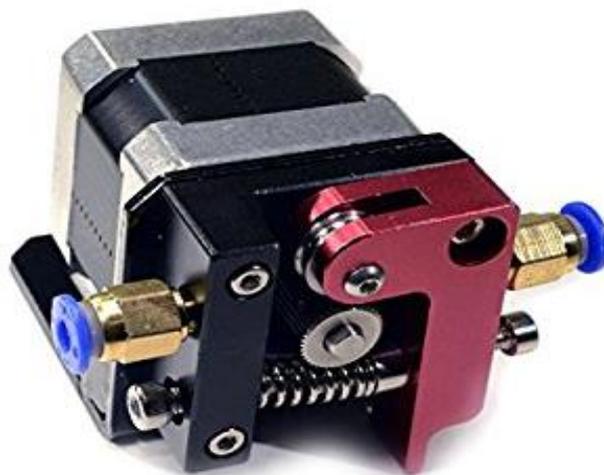


Figure 4.7: Bowden Extruder

4.2.7 Heated bed

A heated build platform (**HBP**) improves printing quality by helping to prevent warping. As extruded plastic cools, it shrinks slightly. When this shrinking process does not occur throughout a printed part evenly, the result is a warped part. This warping is commonly seen as corners being lifted off of the build platform. Printing on a heated bed allows the printed part to stay warm during the printing process and allow more even shrinking of the plastic as it cools below melting point. Heated beds usually yield higher quality finished builds with materials such as **ABS** and **PLA**. A HBP can also allow users to print without rafts.



Figure 4.8 shows Heated Bed

Figure 4.8 : Heated Bed

4.3 Electrical components

Electrical and actuation system of a 3Dprinter consists of multiple sections. The first is the actuator (Motors), which are used to move the axes of the 3Dprinter . Second is the controller. Third is the motor driver, which is used to make interface between the motors and the controller. Lastly, is the power supply, which is used to power the machine. Mechanical system represented by the components which are responsible on the movement of the mechanism of the printer.

4.3.1 Stepper Motor:

The stepper motor is one kind of electric motor used in the robotics industry which converts electrical pulses that are provided by a stepper motor driver into discrete mechanical movements. Stepper motors are the most important part of 3D printers , since they are used to move the extruder or the build platform along the x,y, and z axis. The extruder assembly also has a stepper motor used to pull the filament into the extruder. Stepper motors come in a variety of sizes : NEMA 17 , MEMA 23...etc.

Where NEMA is : a measurement standardized by the National Electrical Manufacturers Association (NEMA) and refers to the frame size of the motor[7].

Figure 4.9 shows the stepper motor.



Figure 4.9 : stepper motor.

4.3.2 : Types of Stepper Motor :

There are three main types of stepper motors, they are:

4.3.2.1 Permanent Magnet Stepper Motor:

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.

Figure 4.10 shows permanent Magnet Stepper Motor

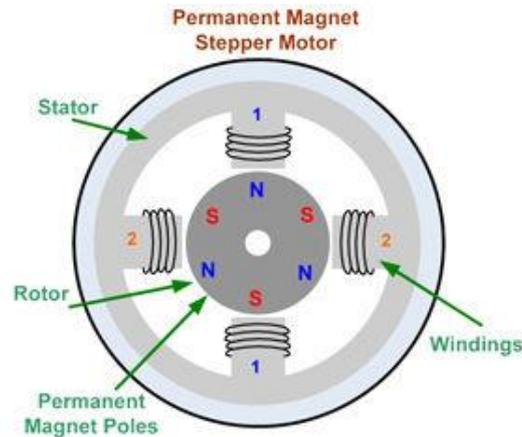


Figure 4.10 : Permanent Magnet Stepper Motor

4.3.2.2 Variable Reluctance Stepper Motor:

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.

Figure 4.11 shows the variable Reluctance Stepper Motor

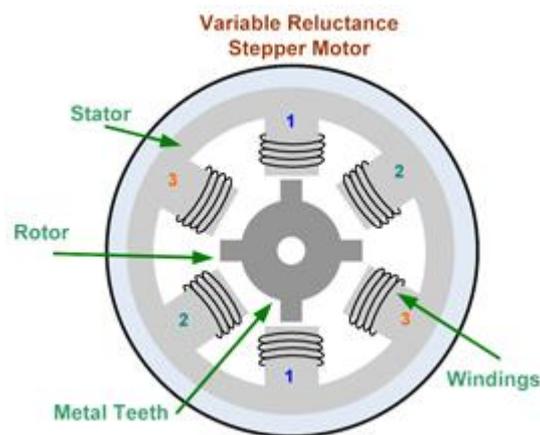


Figure 4.11 : Variable Reluctance Stepper Motor

4.3.2.3 Hybrid Synchronous Stepper Motor:

Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in a small package size.

Figure 4.12 shows the hybrid Synchronous Stepper Motor

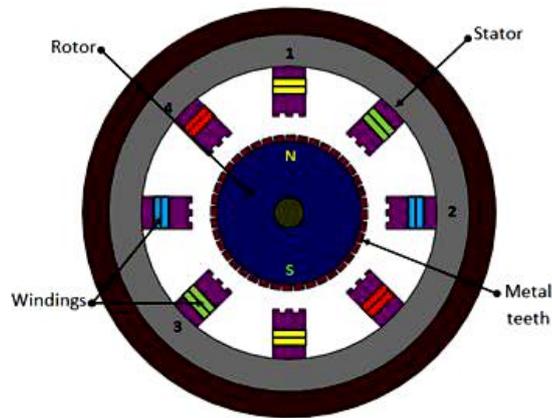


Figure 4.12 : Hybrid Synchronous Stepper Motor

The two most commonly used types of stepper motors are the permanent magnet and the hybrid types. Both of them has a different step angle .

Typical step angles for the hybrid stepper motor range from **3.6° to 0.9° (100 – 400) steps per revolution .**

Typical step angles for permanent magnet stepper motor range from **7.5° to 15°. (48 – 24) steps/revolution**

The step angle can be calculated by :

$$\text{Step angle} = \frac{360^\circ}{\text{Number of poles}}$$

4.3.2 Power supply

Is a component that supplies power to at least one electric load. Typically, it converts one type of electrical power to another,

This takes the 220V AC electricity from the wall and converts it to low voltage DC power for your printer to use

The used power supply is the same power supplies used in desktop computers. It had been repurposed for use in many printers. They are very beefy and efficient, and have separate lines that provide power at a variety of voltage (12V, 5V, 3.3V).

Figure 4.13 shows the power supply.



Figure 4.13 : Power supply

4.3.3 Hardware end stops

Stepper motors must know when they have reached the limits of an axis. The end stops are a limit switches used on every moving axes of a 3D printer, so the hardware of end stops is connected electrically to the end stop ports of the printer control board and will provide a signal when the end stop condition is met [11]. Figure 4.14 shows components of end stops.

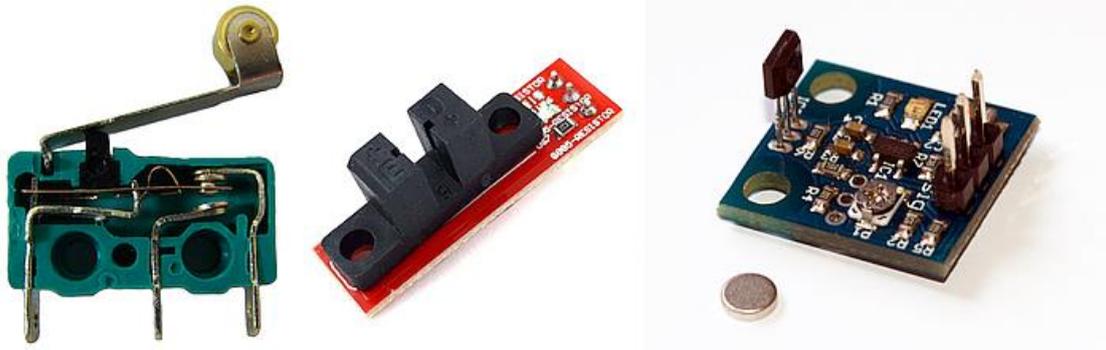


Figure 4.14 : Components of end stops.

4.4 Conclusion

For bed movement (x- axis movement) the belt is chosen instead of the screw , since screw will result a backlash in returning. In z-axis movement screw is chosen for this purpose since backlash is negligible due to the weight of the extruder. In y-axis movement the belt is chosen for the same reason as in x-axis movement.

Two stepper motor in type of " Nema-17 " is chosen due a suitable torque which handle in the bed movement (x-axis movement). One stepper motor is used for both z and y and movement of the extruder.

CHAPTER 5 : MECHANICAL STRUCTURE DESIGN

5.1 Introduction

In this chapter mechanical structure of the printer will be shown and discussed with all components of the printer together.

3D-printer must be designed with consideration of mechanical and electrical components will work sufficiently. Mechanical structure is made as shown in figure 7.1 to provide high stability for printing and reducing some errors which need for some type of usual calibration, so this design is needed [10].

5.2 Mechanical design

In this project of 3D-printer building , mechanical design for structure includes all mechanical components had been done using *Solid Works* program.

The printer movement design has a three degrees of freedom , such that the table moves in the x direction , the extruder moves in z direction using power screws and in the y direction using rails.

For the required workspace of printing , the dimensions of the printer were put to form a complete design of the printer.

Figure 5.1 shows a complete design of the 3D-printer.

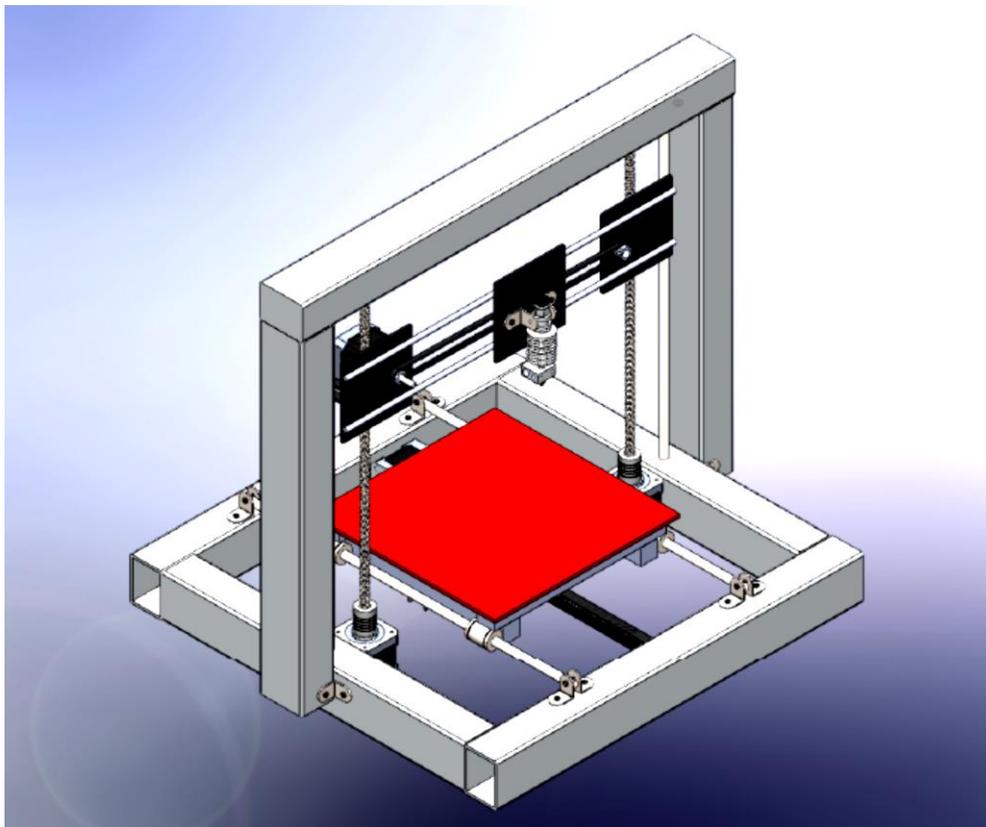


Figure 5.1 : A complete design of the 3D-printer.

5.3 Parts specifications

3D-printer is constructed from mechanical , electrical components and control devices. In this section specifications of mechanical components are concerned to be shown.

5.3.1 Mechanical components specifications

Figure 5.2 shows the mechanical components.

- 1- Aluminum structure channel
- 2-extruder holder (6mm)
- 3-Screws (M3)
- 4-Nuts (M3)
- 5- Acrylic sheet (3mm)
- 6-Lead screw (8×300mm)
- 7-Smooth rod holder (6mm)
- 8-Bearings(SC8UU)
- 9-Hotend (E3D)
- 10- Timing belt for x direction (GT1)
- 11- Heat bed MK2B (20×20 cm)
- 12- Bearings (LM8UU)
- 13- Extruder (MK8).
- 14- Timing belt for y direction(GT2)
- 15- Pulley (GT2)
- 16- Couplers (5×8mm)
- 17- Smooth rod (8mm)
- 18- Angle brackets (2mm).

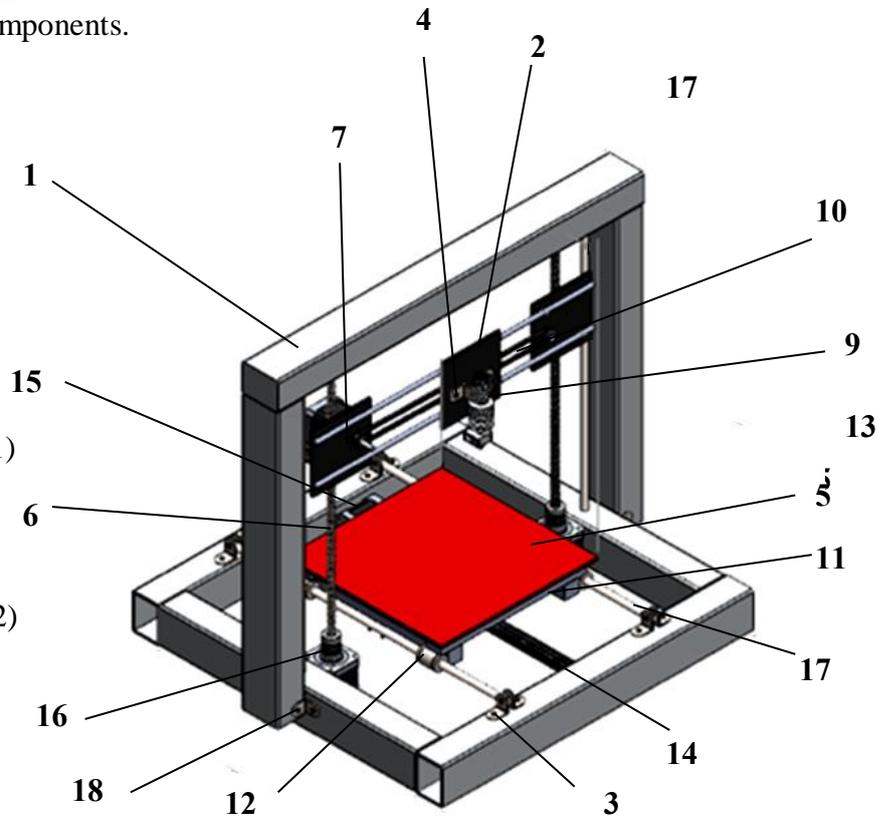


Figure 5.2 : Mechanical components

5.3.2 Electrical components specifications

Electrical components had been discussed in chapter 4

- 1- Power supply (240-watt)
- 2- Stepper motor (NEMA 17).
- 3- Stepper motor driver (A49AA).
- 4- LCD display (optional).
- 5- Endstops (3 axis)
- 6- Wires.

5.3.3 Control systems components specifications

Control components had been discussed in chapter 5

- 1- Arduino Mega.
- 2- Ramps 1.4 Shield .
- 3- Current limiter.

5.4 Structure dimensions

The following figures shows the projections of the printer design with specific dimensions. The chosen dimensions depend on the workspace area for 3D printing which is $20 \times 20 \text{ cm}^2$.

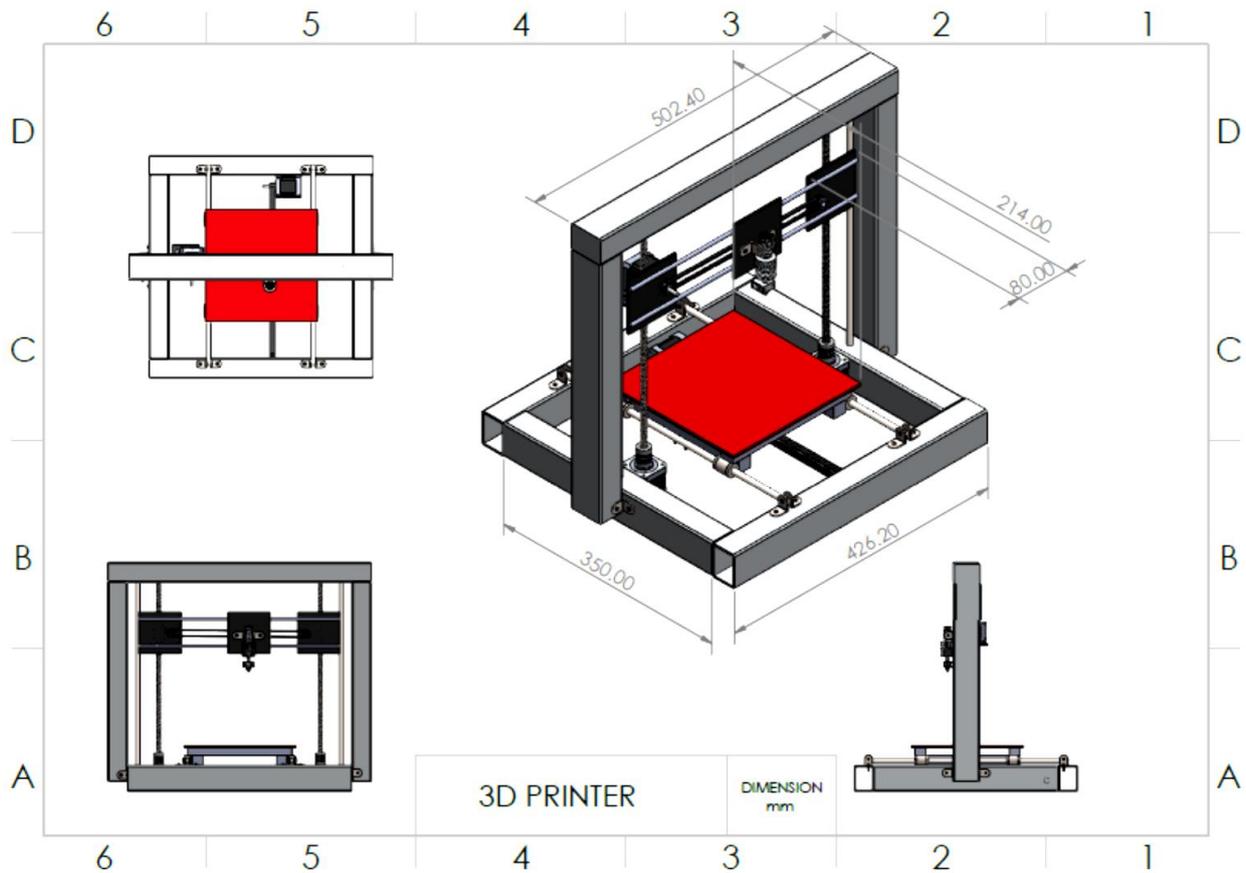


Figure 5.3 : Structure design projections

5.4.1 Top view

Top view shows the movement of the hot table in y direction and the extruder in the x direction. Figure 5.4 shows the top view.

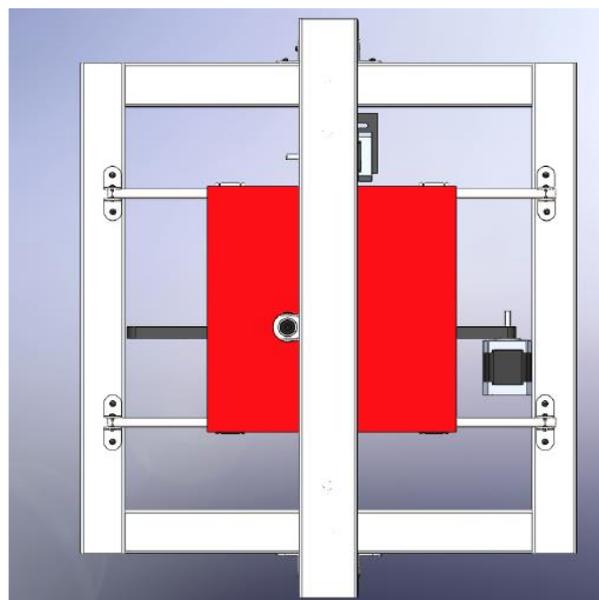


Figure 5.4 : Top view of the printer

5.4.2 Side view

Side view shows the movement of the extruder in the z direction and shows how can the table move in the y direction. Figure 5.5 shows the side view.

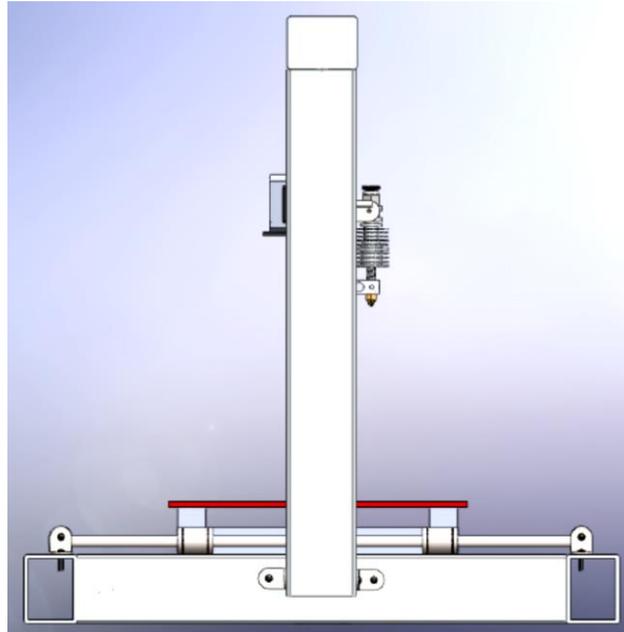


Figure 5.5 : Side view of the printer

5.4.3 Front view

Front view shows the movement of the extruder in both x and z directions. Figure 5.6 shows the front view.

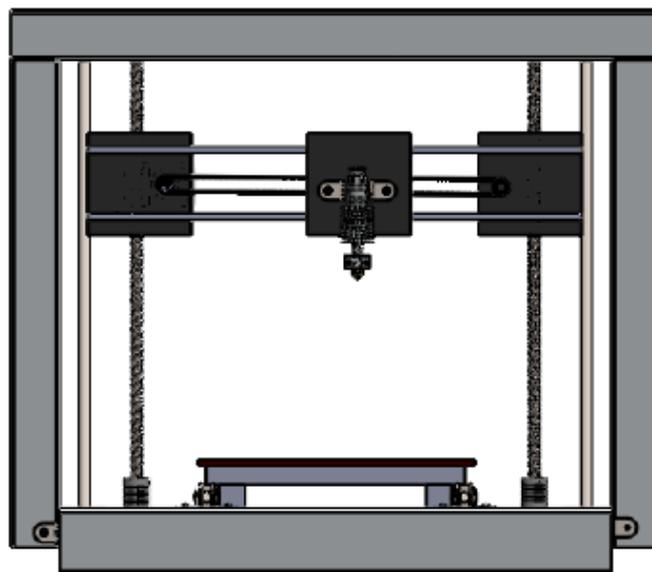


Figure 5.6 : Front view

5.5 Conclusion

The design of the 3D-printer had been chosen with its specific dimensions. Then the 3D-printer will be constructed and all its components will be installed to the printer to tested for satisfying results during graduation project 2.

CHAPTER 6 : COMPONENTS FOR CONTROL SYSTEM

6.1 Introduction

In this chapter the components of control systems will be studied for the 3D-printer such that a suitable components for control system will be chosen. Also the electrical design for the components discussed in the previous chapter and wiring diagram will be discussed.

The 3Dprinter controller is the brain of a 3D printer system. A controller completes the all-important link between a computer system and the mechanical components of a 3D printer .The controller's primary task is to receive conditioned signals from a computer or indexer and interpret those signals into mechanical motion through motor output. There are several components that make up a controller and each component works in unison to produce the desired motor movement.

6.2 Choosing suitable arduino for the printer.

Arduino Mega is high-end series of arduino controller. the Mega2560 comes with a 54 digital I/O (input/output) ports (of which 14 can be used as PWM output), 16 analog input ports and 4 UART (hardware serial ports), using a 16 MHz crystal oscillator. Open-sourced software and hardware platform, large interacted community, easy development environment and strong control ability, all together making the Arduino become the most popular electronic product development tool currently[8].

Figure 6.1 shows arduino Mega description.

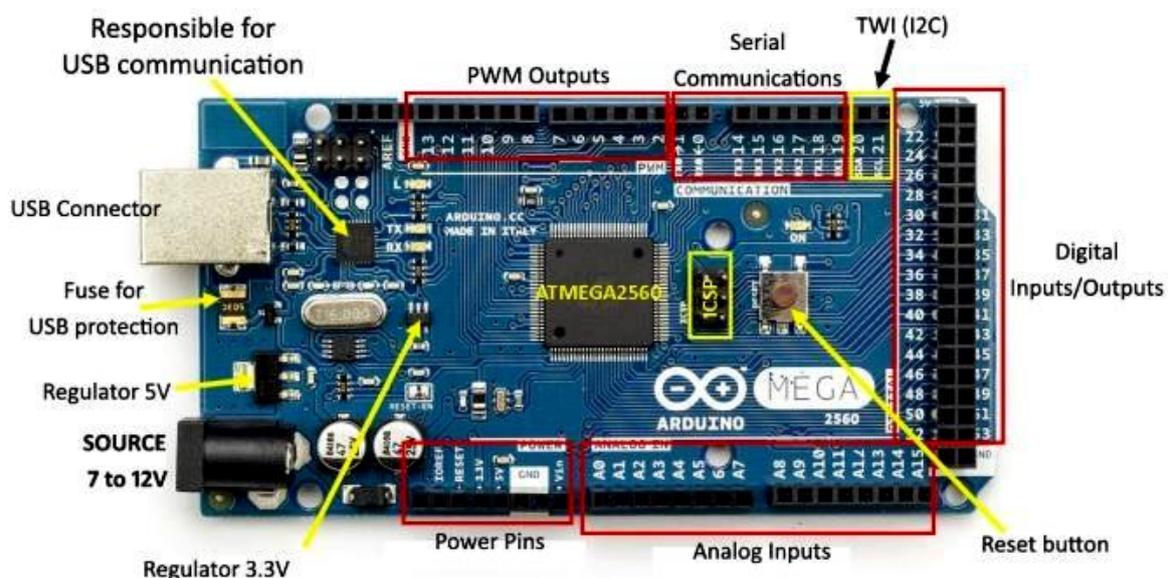


Figure 6.1 : Arduino Mega description

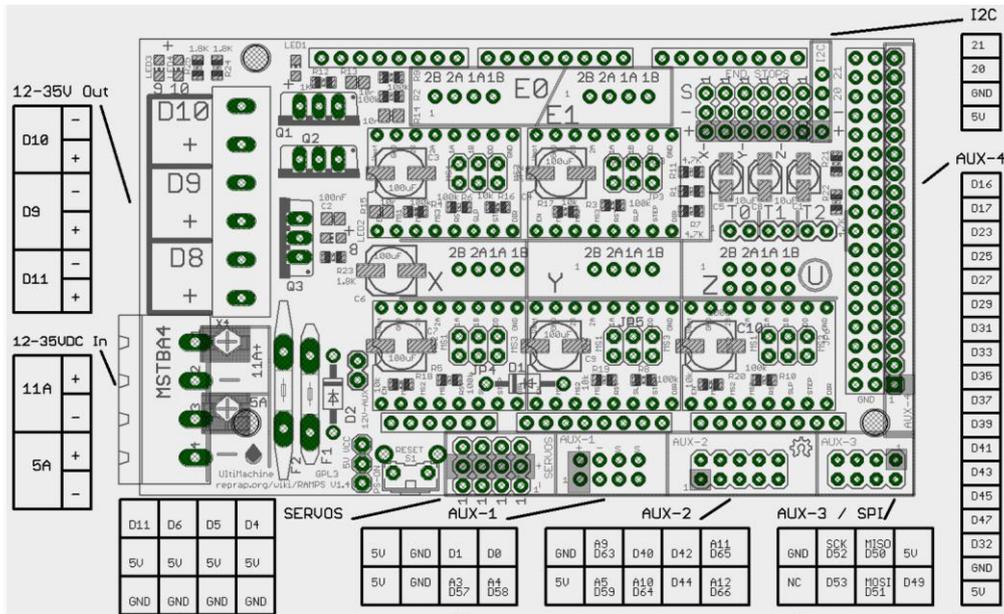
6.3 Shield RAMPS 1.4

It is an Open-Hardware daughter board which act as an interface between the Arduino Mega 2560 and different devices such as Stepper motors. often used to drive 3D printers, CNC machines, Robots etc...

Figure 6.2 shows schematic diagram of the shield ramps 1,4

It supports:

- stepper motor drivers (A4988 or DRV8825)
- 3 Thermostats
- end stops
- 4 servos outputs
- 1 LCD display connector



6.2 : schematic diagram of shield ramp 1.4

6.4 Stepper motor drivers

These chips are responsible for running the stepper motors. They fire the coils of the motor in sequence, causing it to move in increments.

Many motherboards have the stepper drivers built in, but some also have them in modules that can be unplugged. By balancing the power fed to each coil, the driver is also able to divide steps up into further increments, and allows more precise control over the motor than is normally possible. The stepper driver also controls how much electrical current is fed to the motor. More power makes the motor stronger, but also makes it run hotter. Figure 6.3 shows the stepper motor drivers.

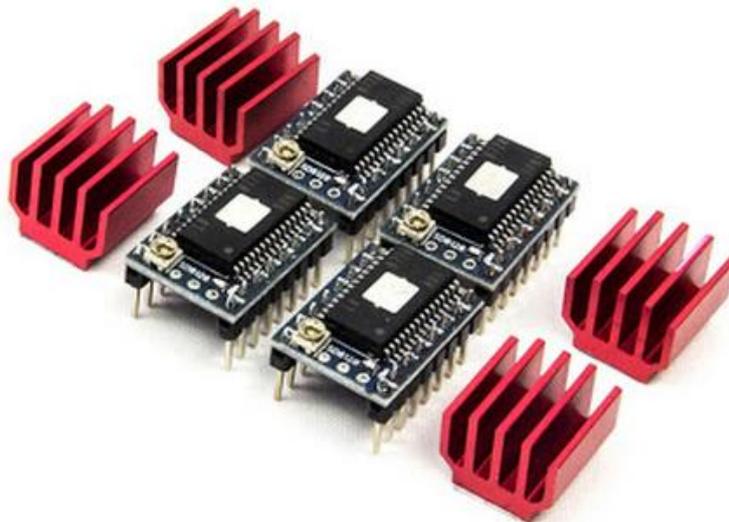


Figure 6.3 : Motor driver

Figure 6.4 shows the arduino mega with the shield and motor drivers

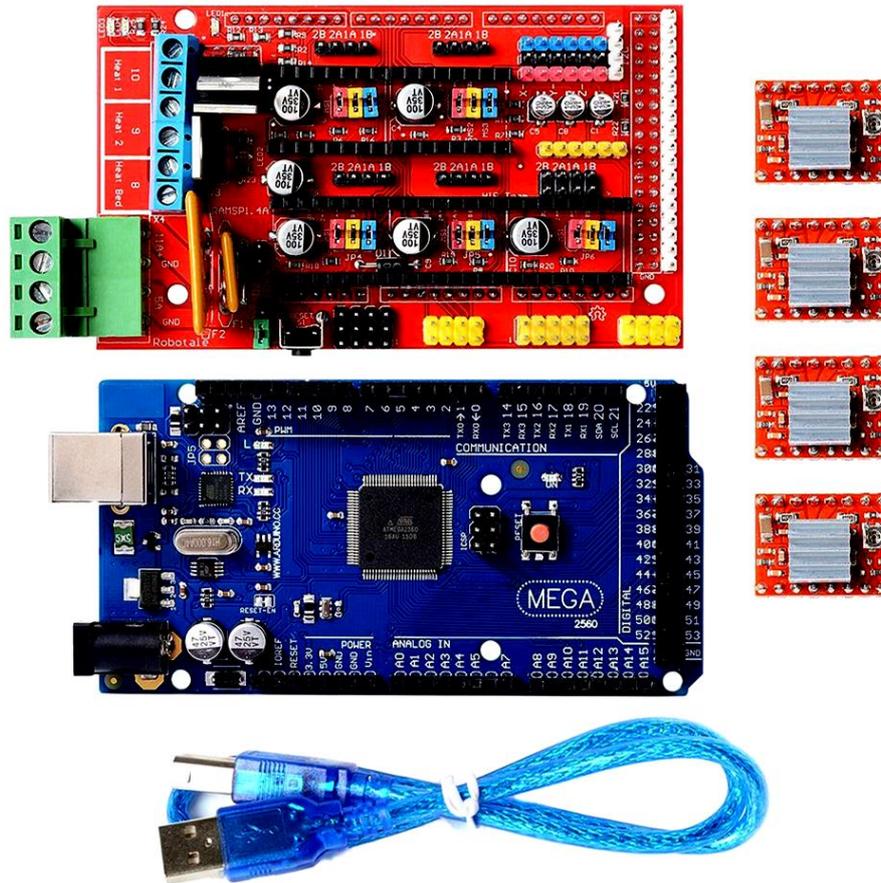


Figure 6.4 : Arduino Mega with stepper motor driver and shields.

6.5 Electrical diagram

In order to drive the stepper motors, they must be connected to the shield ramp, which contains the drivers. In addition the limit switches are also connected to the shield at their home position. The heated bed is also connected to the shield. Fans and the LCD is connected to it.

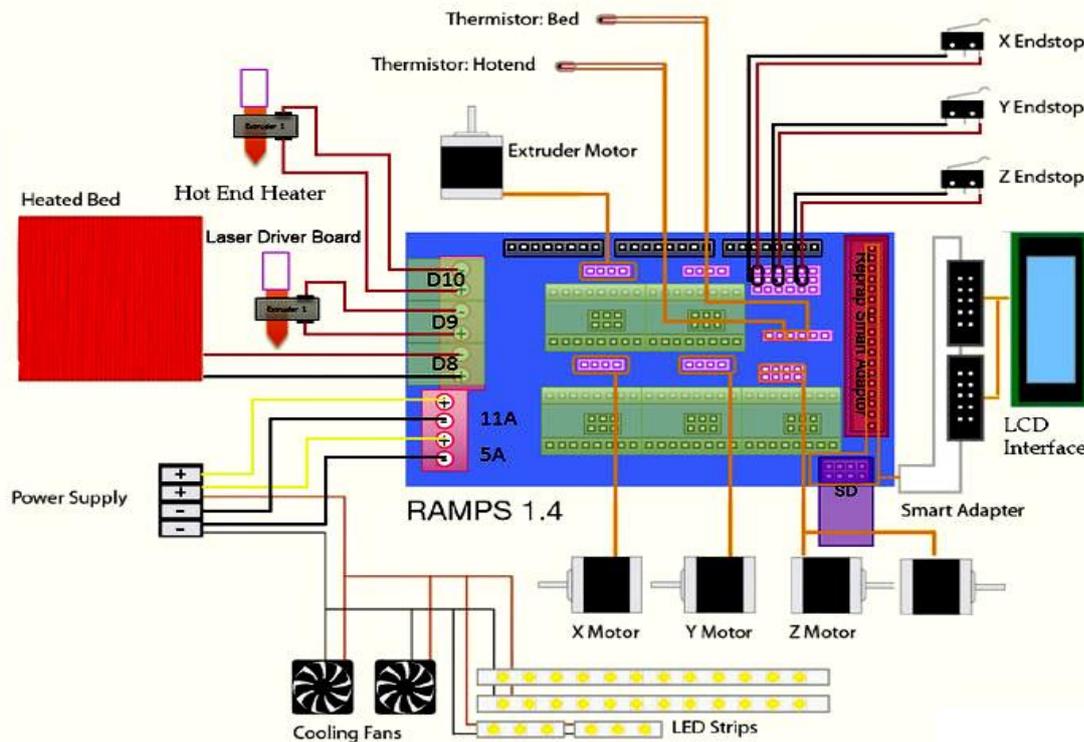


Figure 6.5 : 3D-printer wiring controller diagram

6.6 LCD screen

The use of the LCD screen is important since it achieves the purpose for the user to control the positions before printing and to select the desired sketch to be printed from the SD card inserted with it.

Figure 6.6 shows the LCD screen.



Figure 6.6 : LCD screen.

6.7 Software program

Using software program for the arduino "*Arduino 1.8.0*" and CAD programs such as "*Solid Work*" for designing the desired work parts and "*Quora*" to translate the design into machine language in order to be ready for printing on the printer. These programs will be discussed in the next chapter

6.8 Conclusion

The final design and implementation is concluded by selection mechanical and electrical and control system components.

CHAPTER 7 : SOFTWARE AND CONTROL DESIGN

7.1 Introduction

3D printing technology is a well-known application of additive manufacturing. The essence of 3D PRINTERS is their operating software which control every stage of workflow from scratch .

Design the 3D model with the help of computer-aided-design (CAD) is where the journey begins and through multiple process the physical product is ready. In this chapter the main stage of the process will explained and by the finish of this chapter the reader will have a brief knowledge in 3D printer operating system. Figure 7.1 shows the 3D-printer operation flow command

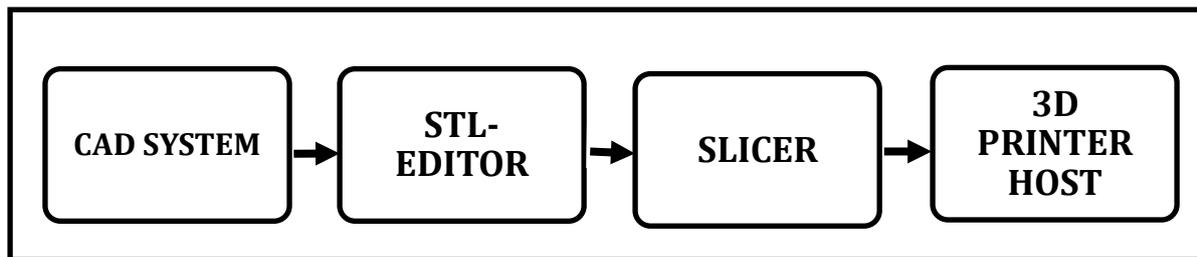


Figure 7.1 : 3D-printer operation flow command

7.2 D design software (CAD)

CAD is the designing and analyze of an object with the use of computer system. 3D shape could introduce and many other complex shape. This software isn't about to design the physical geometry but also its offer a choosing of material, dimension and tolerances. Simulation is an important feature in CAD system which help the user to determine whether if the design attain an objective or not. Multiple commercial product is introduced which provide a simple and practical use. in 3d printer the desired format file is stereo-lithography (STL). STL files describe only the surface geometry of a three-dimensional object without any representation of color, texture or other common CAD model attributes. The STL format specifies both ASCII and binary representations. Binary files are more common, since they are more compact. CAD software pushes the additive manufacturing forward and keep the designing process on hand.

7.3 STL-format software

STL-format software deal with the files imported from CAD software. Work as STL file viewing, editing and repairing 3D printing software. in general, not all stl file is compatible with 3d printing process which lead to poor output product. This software makes sure that the 3D model has no Defects .

7.3.1 Boundary edges

Boundary edges are detected if some edges of the STL file are not connected to only one face. This essentially means that the model has holes and does not represent a closed surface.

7.3.2 Intersecting faces

Intersecting faces are detected when two surfaces collide with each other. This error is commonly encountered when multiple bodies are occupying the same space, intersecting faces usually lead to failures during slicing, as the software cannot recognize which areas are "inside" the model and which are "outside".

7.3.3 Non-manifold edges

Non-manifold edges are detected when more than two faces are connected to the same edge. There are two instances of this type of error. An extra surface may be defined in the interior of the model.

7.3.4 Over-refined mesh

A mesh is "over-refined" when the total number of triangles of the STL mesh is larger than required. This will not lead to any errors during 3D printing, but it will unnecessarily increase the size of the STL file, making it more difficult to handle. Usually, the tiny details that are represented by an over-refined mesh cannot be 3D printed, as they exceed the capabilities of most systems (in terms of accuracy and minimum feature size).

7.4 Slicer software

Like any NC machine (e.g. milling machine) 3D printer is need a series of instruction to follow. G-code is the common name for the most widely used numerical control (NC) language, they tell the machine how to act due alphanumeric commands. Slicer software job is to chop up the 3D model into a numerous number of 2D layers represented by a specific G-code instruction. Better instructions mean better prints. In fact, more than 90% of experts agree that 3D printing software has the greatest impact on print quality, even more so than the 3D printer itself[8]

7.5 3D printer host

Last stage in the whole process is to connect the computer to 3D printer and monitoring the communication between the two devices by transmitting the G-code. 3D printer host provide such function.

7.6 Use of firmware

Every programmer is human and not vice-versa. 3D printer firmware is useful stage dedicated to the user; Its provide the user the capability to adjust their own machine depending on a various parameter. Firmware has developed over years because of a plenty of manufacturer and technologies. Every manufacturer use to use different dimensions, sensors and technologies. For the sake of variety firmware has sort of flexibility and it always on the user's hand.

7.7: Firmware

Firmware is a software program permanently etched into a hardware device such as a keyboards, hard drive, BIOS, or video cards. It is programmed to give permanent instructions to communicate with other devices and perform functions like basic input/output tasks. Firmware is typically stored in the flash ROM (read only memory) of a hardware device. It can be erased and rewritten. Basically it is the bridge between the hardware and software of a computer system. When software sends commands to the hardware of a computer system, the firmware interprets and translates the software commands into a form that is recognizable by the hardware. when 3D printer host sends G-code to 3D printer, the firmware translates the G-code commands into specific electrical signals that are sent to the motors, heaters, fans and other components on the 3D printer.

7.8 Firmware levels

Firmware in CAM systems can be classified into three levels.

7.8.1 Low Level Firmware

Low Level Firmware is found in ROM, OTP/PROM and PLA structures. Low level firmware is often read-only memory and cannot be changed or updated. It is sometimes referred to as hardware.

7.8.2 High Level Firmware

High Level Firmware is used in flash memory for updates that is often considered as software.

These subsystem have their own fixed microcode embedded in flash chips, CPUs and LCD units. A subsystem is usually considered part of the hardware device as well as high level firmware.

7.9 Firmware configuration

This configuration for **marline firmware** as example and the rest of other product are pretty same.

7.9.1 Configuration.h

Contains the core settings for the hardware, language and controller selection, and settings for the most common features and components. The core and default settings of Marlin live in the Configuration.h file. Most of these settings are fixed. Once you compile Marlin, that's it. To change them you need to re-compile. However, several items in Configuration.h only provide defaults -factory settings- that can be changed via the user interface, stored on EEPROM and reloaded or restored to initial values.

7.9.2 Configuration.adv:-

serves up more detailed customization options, add-ons, experimental features, and other esoteric.

Figure 7.2 shows the integration of the 3D printing system

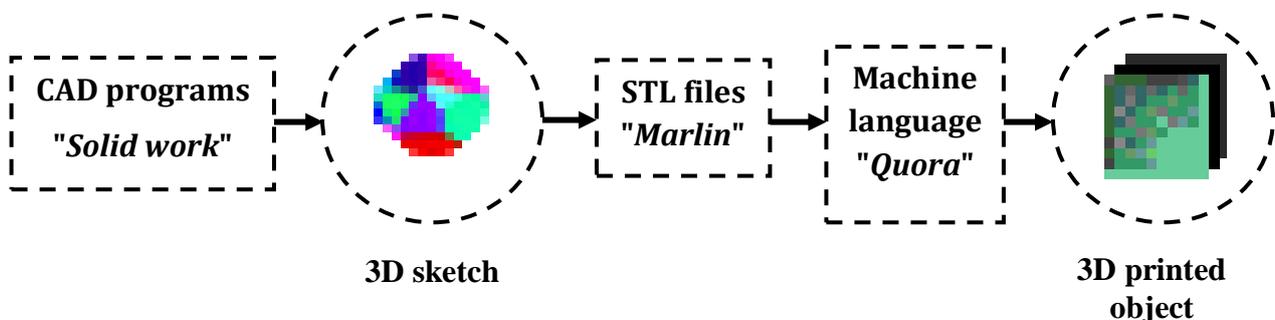


Figure 7.2 : The integration of the 3D printing system

7.10 conclusion

The firmware function as interpreter which is the bridge between software and hardware. But like everything else user should interfere to adjust the software to hardware characteristics size, types and so on.

CHAPTER 8 : BUILDING PROCESS

8.1 Introduction

In this chapter the process for building the 3D printer machine will be discussed in a steps.

8.2 Cutting structure

After mechanical structure had been designed as in chapter 5 , the Aluminum profile had been cut into seven pieces with their specified dimensions in order to form the structure.

8.3 Structure assembly

After aluminum pieces had been cut , then they drilled and assembled together using bolt and angle brackets.

8.4 Installing mechanical components

After building structure , mechanical components were added to the structure using bolts as designed. Figure 8.3 shows mechanical components on the structure.

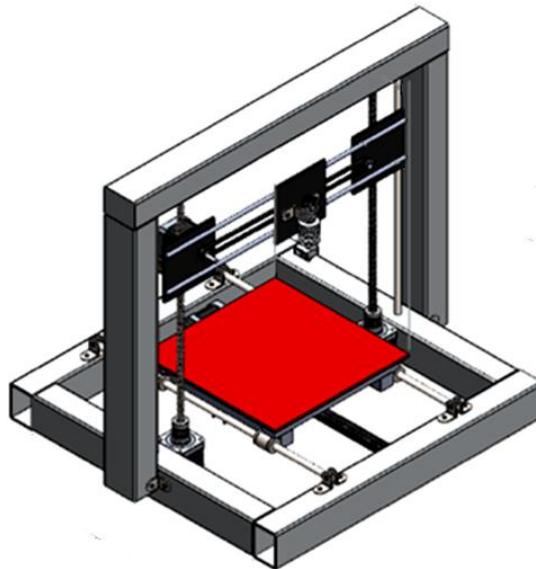


Figure 8.1 : Mechanical components on the structure.

8.5 Installing electrical components

In this step all electrical components are added to the printer mechanisms in order to be controlled and energized by the power supply..

Figure 8.3 shows electrical components on the printer mechanism.

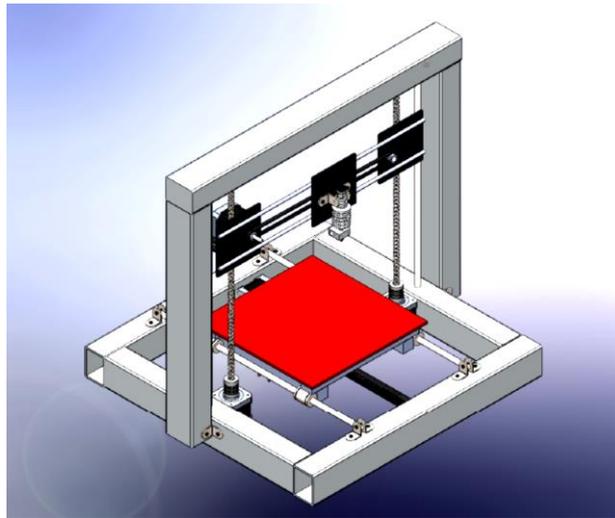


Figure 8.2 : Installation both electrical components on the printer mechanism.

8.6 Installing software program

Using software program for the arduino "*Arduino 1.8.0*" and CAD programs such as "*Solid Work*" for designing the desired work parts and "*Quora*" to translate the design into machine language in order to be ready for printing on the printer.

8.7 Printer testing

Figure 8.4 shows a specimens of printed pieces



Figure 8.3 : specimens of printed pieces

8.8 Conclusion

In this chapter the practical steps for building the designed 3D printer were shown.

CHAPTER 9 : CONCLUSION

9.1 General conclusion

Additive manufacturing, has impact on multiple industry, its provide many useful products, applicable for various goods from food to medical supplies. 3D PRINTER is typical machine for implement such technology. 3D PRINTERS have wide spread because of their performances and simplicity. The main concept of 3D PRINTER is the same. Different printers use different materials and different binding processes, but generally a powder of ceramic, nylon, or even metal is used as the base material and fused together into the pattern for the layer currently being created. After the completion of a layer, the machine moves on to the next layer until it is completed.

Figure 9.1 shows the final project of 3D printer system.

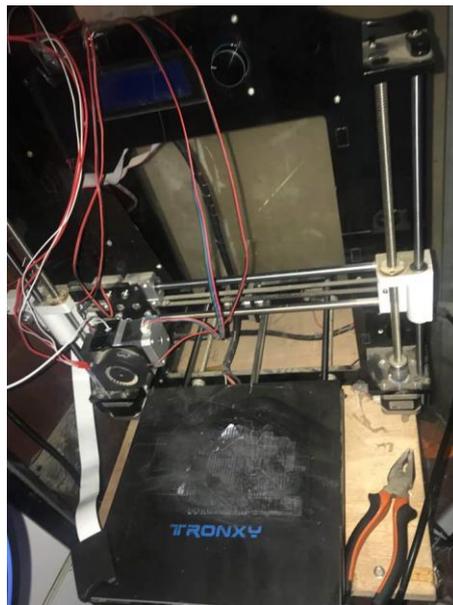


Figure 9.1 : finished 3D-printer system.

9.2 Problem faced

In this project there were some trouble which had been faced , such as:

- Preparing some of mechanical parts such as extruder handle.
- Controlling the position and the direction of the extruder.
- Calibration the electrical part.
- Installing and active the programs.
- The surface finish of the product which had been printed , it has some dimensional tolerance.

9.3 Future of work

3D printer became very known in several industrial operations. This kind of machines is very important and required. This offers to make the desired shape for objects directly without making cast process or a huge manufacturing for large quantities.

It can be also add a protection cover on the printer as a type of safety. It also be more than extruder with different colors for printing objects with more professional process in modern industries.

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