



An-Najah National University

Pick & Place SMT Machine

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Abstract:

Our project is about pick-and-place machines for placing surface mount devices like capacitors, resistors, integrated circuits onto the printed circuit board which are in turn used in computers, consumer electronics as well as industrial, medical, automotive, military and telecommunications equipment. In general, the SMT pick and place machine uses an end effectors to pick and place the component on the PCB and a controller is used to control the movement of the stepper motors using Open PNP . Our SMT pick and place machine was designed with a Cartesian configuration, and the BIGTREETECH SKR V1.3 controller controls the stepper motors. The end effectors use a vacuum suction pen to pick and place the components and a belt mechanism is used in the z-axis for up-down motion. Our machine is well suited for small scale industries. Our project satisfies one important sustainable development goal - industry, innovation, and infrastructure

Chapter 1:

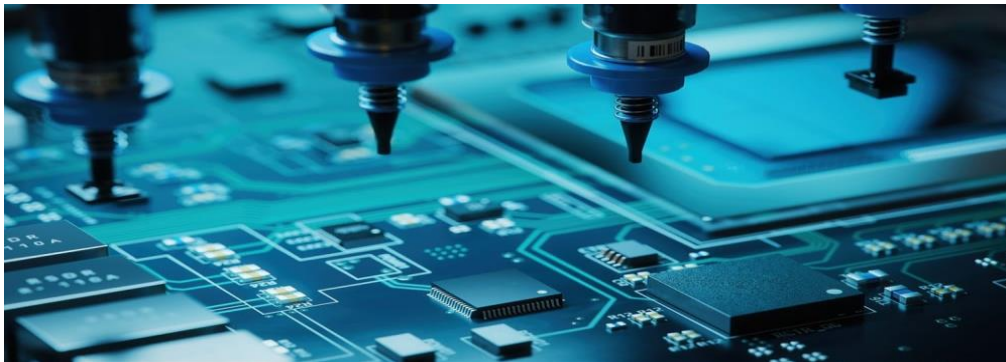
Introduction

Concept of the project:

1.1 Definition of Surface-Mount Technology

Surface-Mount Technology, or SMT, is a method for attaching electrical components directly onto the surface of a printed circuit board, or PCB. This process allows for automated production to complete more of the required assembly to create a working board. It lowers the cost of production and increases the maximum output by eliminating bottlenecks on the assembly line.

SMT has another big advantage over the former 'through-hole technology' method. In the older method, electronic components were mounted to a circuit board through specifically cut holes in the board for the component. ([1])



1 Figure1.1. : Surface-Mount Technology

1.2 Definition of PCB board

An electronic device's printed circuit board (PCB), which connects its component parts, is a board with layers of circuitry. There is at least one PCB in almost every electrical gadget. As a result, the PCB assembly business is crucial to the production of practically all types of electronic products. ([2])



Figure (2) 1.2. : PCB board

1.2.1 Evolution of PCBs

Over time, PCBs have evolved as an easy tool for optimizing the manufacturing of electronics products. What was once assembled easily by human hands soon gave the way to microscopic components which required the precision and efficiency of machinery.

1.4 Project scope:

The goal of this project is to design, program, and use an SMT pick and place machine to assemble electrical components that have been placed in certain locations and move them to the correct locations on PCB boards.

After defining the project constraints and assumptions, the mechanical architecture of the processor will be designed for the console design and simulation, and the best controller for such a task will be chosen. The first stage involves gathering all the project components and tools that are required. Each electrical component's position in relation to the frame of reference will be determined by the machine vision system, and the path diagram will be created based on these positions to show the processor the proper path to take.

1.5 objective of the project:

When humans manually pick and place surface mount components onto a printed circuit board (PCB), there are problems with human accuracy and time efficiency. A pick and place surface mount device (SMD) is an automated device that can populate a printed circuit board (PCB) with surface mount components (resistors, capacitors, and IC chips) by referencing a Gerber file. The SMD pick and place machine will be able to pick the surface mount components up and place the components down at the correct location until the board is finished. The objective of this project is to create a pick and place SMD machine. ([3])

1.5 Project goals:

The machine is not designed to be the fastest or cheapest option available, with the main goal being to reduce manual labor strain and boost productivity. The objective is to create a select and place device that is dependable, adaptable, and simple to operate.

Consequently, the following are the goals we hope to accomplish with this project:

1. Creating and choosing the best control system for the machine so that it operates with accuracy and speed.
2. Select the tools and parts with the best performance at the lowest cost.

1.6 Literature review:

In order to demonstrate many forms of tiny form electronics for practical use, IBM introduced the idea of SMT electronics in the 1960s. A compact surface-mounted button device for timepieces had been created at the same time by the European Philips corporation. Although it took some time to gain traction, 10% of the market was its by 1986. The technology was initially known as "Planar Mounting," and most of the necessary parts were created by IBM.

Planar mounting changed into SMT during the course of three steps. The first phase lasted from 1970 until 1975. The IBM prototype's use in the 1960s for computer systems on spacecraft sparked interest in its advancement.

SMT underwent its second main stage of growth between 1976 and 1985. The size of components had been drastically decreased, enabling the development of electronics with multiple uses. SMT was much helped by this for usage in headset radios and photography.

The automation of SMT production in factories was also reaching a new level at the same time. The groundwork for even quicker developments in SMT had been laid as the production machinery developed. ([4]) ([5])

Chapter 2:

SMT and SMD

2.1: SMT

2.1.1 What Is SMT?

A novel design used to organize components printed on a circuit board is called SMT, or surface mount technology. On earlier iterations, board components were mounted on the circuit via holes in the board. This approach requires careful planning to guarantee that all leads were formed using the appropriate procedure and fit different boards. Additionally, a large board with room for several circuits is needed. ([6])



Figure (3) 2.1. : SMT

The likelihood of error increases while working with tiny components, yet with SMT, errors may be quickly corrected using molten solder. The usage of SMT indicates that radiation levels will be lowered compared to the previous visions, when rectifying faults took a long and difficult time. Because there are no holes drilled in the board and the wire attachment is low, it is appropriate for today's technological age.

The absence of leads and the short length of any leads that are present are characteristics of SMT. The principal component and solder junction are both located on the same PCB side in SMT.

2.1.2 The actual process of SMT

1-Firstly, a PCB stencil is aligned on the surface of the boards and solder paste is applied using a squeegee to ensure the pads are coated with a uniform and controlled amount of solder paste.

2-Secondly, via a pick and place machine or hand placement, the components are mounted onto the boards in their respective locations. The wet solder paste will act as a temporary adhesive but it is still important to ensure that the boards are moved gently to prevent misalignment.

3-Thirdly, the boards are passed through a reflow oven which subjects the boards to infrared radiation, melting the solder paste and forming solder joints. Then the boards are passed through an AOI machine, or Automatic Optical Inspection machine which runs a number of quality checks on the boards visually, such as component alignment and checking for solder bridges. The boards then proceed to further testing.

2.2 SMD

2.2.1 What is SMD?

Surface mounted devices (SMDs) are the physical components that are installed on printed circuit boards. To satisfy the needs of a world that requires components that are speedier, more versatile, and more inexpensive, SMDs have undergone significant transformation. Modern SMDs use pins that may be soldered directly onto PCBs instead of leads to link them to a circuit board. There are various advantages of using pins rather than leads. For instance, the same task can be accomplished with less parts. A smaller circuit board might therefore include more components on it, boosting functionality. In addition, since no holes need to be bored into the board, installation is speedier and less expensive. ([7]) ([8])

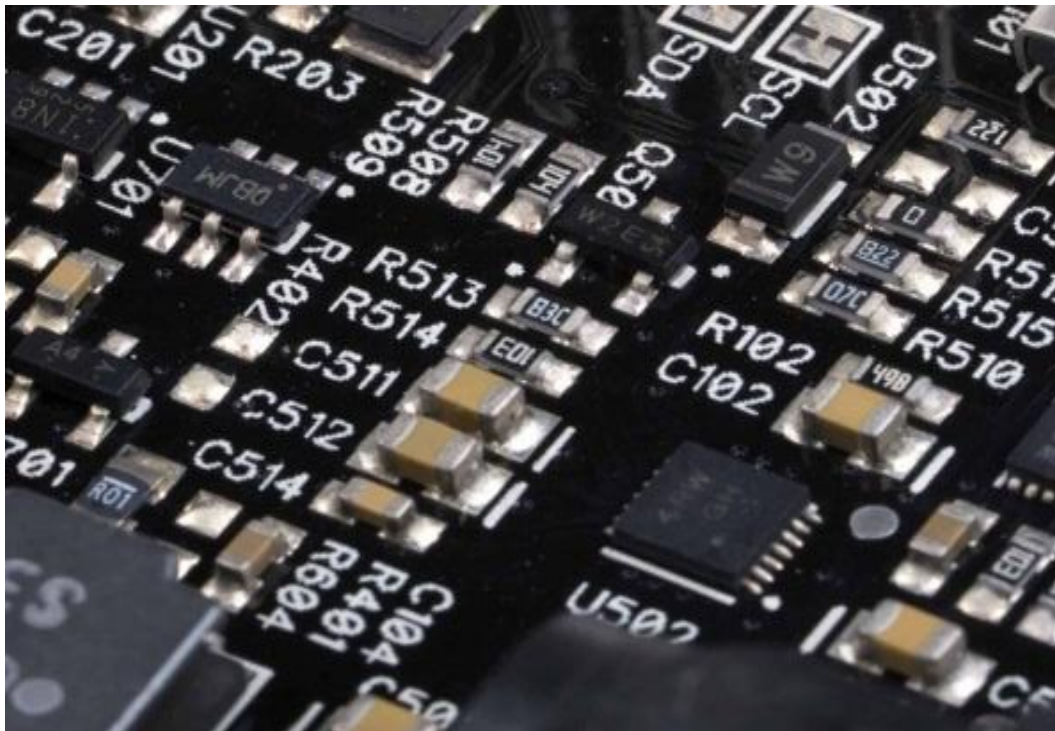


Figure (4) 2.2. : SMD

For the creation of a working device, the proper SMD selection is crucial. Thinking carefully about what would fit precisely into a PCB and the mounting method or arrangement that will serve your desired device the best would be the finest course of action. SMDs have come a long way since they were first manually soldered (by hand) onto electrical boards. Resistors, ICs, and other similar components can all be automatically put on the surface of PCBs using modern SMDs. By using the right layout technique, SMDs can perform at exceptionally high levels for longer periods of time.

2.3 What Distinctions Exist Between SMT and SMD?

The PCB will need mounting and soldering surfaces, and SMT leverages this mounting method. The usage of the SMD, on the other hand, refers to the use of an electronic component that may be attached to a PCB using SMT equipment. The method employs components that are soldered using soldering paste onto the PCB.

SMT is one that is frequently used in production since it is economical. Additionally, SMT will provide stronger connections, perfect for stressed components and advantageous for prototyping. ([9])

2.3.1 Features of SMT:

- Components have no leads or only short leads;
- The main body of the component and the solder joint are on the same side of the PCB;

2.3.2 Features of SMD:

- miniaturization;
- No lead (flat or short lead);
- Suitable for surface assembly on PCB;



Figure (5) 2.3. : SMD Components

2.3.3 How does SMT make SMDs more effective ?

There are many places where SMT and SMD overlap, despite the fact that the main distinction between the two is that one term relates to the mounting procedure and the other to real components. For instance, the main method of SMT is the appropriate selection and placement of SMDs. SMT assembly is a process or approach for handling SMDs more successfully.

Your prototypes can be significantly improved by using the appropriate method. For instance, automated SMT machines are able to quickly mount thousands of SMDs onto electrical boards. Additionally, the effectiveness of a complete SMT will depend on the SMDs used in the manufacturing process. The SMT and SMD overlap can also be seen as a space-and-time phenomenon. SMT is the timely placement of these components on the board itself, whereas SMDs determine the physical capacity of an electronic board (area).

2.3.4 Different Types of SMD Components

There are different types of surface mount devices (SMDs). SMDs need to withstand high soldering temperatures. Therefore, you must carefully select, place, and solder them in order to achieve great manufacturing results. The two major types of surface mount electronic components are passive and active components. ([10])



Figure (6) 2.4. :Types of SMD Components

2.3.5 Passive SMD Components:

- Passive surface mounting has a more straightforward environment. The main components of passive SMD include thick film resistors, tantalum capacitors, and monolithic ceramic capacitors. The forms are often cylindrical and rectangular. The components' mass is roughly ten times less than that of their through-hole equivalents.
- To satisfy the requirements of various applications in the electronics sector, surface mount resistors and capacitors are available in a range of case sizes. Although case sizes are generally getting smaller, larger case sizes are also an option if capacitance requirements are high.
- **Surface mount discrete resistors :**

Surface mount discrete resistors are available in two main types which are thin and thick film. Also, the construction of thick film resistors involves screening resistive film on a high purity alumina substrate surface. Thin film resistors have a resistive element on a ceramic laminate with protective coating solder cable terminations. These terminations feature an adhesion layer on the ceramic substrate.



Figure (7) 2.5. :Resistor

- **Surface mount tantalum capacitors**

The dielectric of the surface mount capacitor might be either tantalum or ceramic. Excellent capacitance-voltage output is provided by tantalum surface-mount capacitors per unit volume. On wrap-under lead capacitors, the polarity indication is also a lead rather than a termination. It is not difficult to position and solder the molded plastic tantalum capacitors.

There are two case sizes available for these capacitors: extended range and normal range. These capacitors' capacitance values differ as well. Additionally, these capacitors can be produced to order based on the specifications of the application.

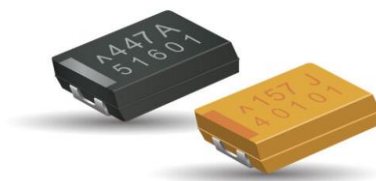


Figure (8) 2.6. : Tantalum Capacitor

- **Surface mount ceramic capacitors**

Due to the lack of leads, surface mount capacitors are appropriate for high frequency applications. Additionally, the most typical packaging for ceramic capacitors is 8mm tape and reel. Frequency control and decoupling capacitors are perfect applications for surface mount ceramic capacitors. Additionally, the volumetric efficiency of multilayer monolithic ceramic capacitors has been improved.



Figure (9) 2.7. : MLCC Capacitor

2.3.6 Active SMD components

Surface mounting offers more types of active and passive packages than through-hole technology.

- **Plastic leaded chip carriers (PLCC)**

Leads from PLCC provide the compliance needed to withstand the stress at the solder junction. As a result, the solder junction is protected from breaking. The ceramic chip carrier is significantly more expensive than PLCC. Additionally, PLCCs with high die-to-package ratios may be more susceptible to package breaking due to moisture absorption. They need to be handled properly as a result.



Figure (10) 2.8. : Surface Mount QFJ (PLCC)

- **Fine pitch SMD packages**

These surface mount packages have several leads and a very fine pitch. Additionally, fine pitch packages need smaller land pattern patterns and thinner leads.

- **Leadless ceramic chip carriers (LCCC)**

Leadless chip carriers feature no leads. Rather, they feature groove-shape terminations that offer shorter signal paths that enable higher operating frequencies. Leadless ceramic chip carriers are in different families based on the pitch of the package. The 50 mil family is the most common. However, there are other families like 20, 25, and 40 mils.



Figure (11) 2.9. : Leadless ceramic chip carriers (LCCC)

- **Small outline Integrated Circuit (SOIC)**

SOIC is a shrink package that features leads on 0.050 inch centers. Also, the small outline integrated circuit helps to house larger integrated circuits. SOIC comprises leads on two sides that are created outward. This is generally known as gullwing lead. Also, SOICs need careful handling to avoid any lead damage. SOICs are available in two different body widths which are 150 mils and 300 mils.



Figure (12) 2.10. :Small outline Integrated Circuit (SOIC)

- **Small outline J packages (SOJ)**

Pins are present on just two sides of the SOJ packaging. The SOIC and PLCC are combined to create the compact outline J package. Additionally, the SOJ packages combine the handling advantages of PLCC with the space economy of SOIC. High density DRAMs frequently employ SOJ packages.



Figure (13) 2.11. : Surface Mount SOJ

2.5 Advantages and Disadvantages of Surface Mount Technology

Advantages

- **Reduced board size**

When employed in the production of PCBs, SMT aids in greater space savings. Additionally, this technique makes it possible to place more components on a PCB. SMT has enabled PCB producers to create tiny and intricate boards. Advanced electrical gadgets are then produced using these boards.

- **High frequency and signal transmission**

SMT supports high density on multilayer boards. Also, SMD components feature short leads or no lead. Therefore, it reduces RF interference. In addition, SMT offers more resistance to vibration.

- **Automated production**

The use of automation makes the SMT assembly process easier. Also, the pick and place machine makes component placement easier.

- **Reduced material cost**

SMT doesn't require drilling of holes. Drilling holes on a circuit board is a time consuming and costly effort. Also, SMD components are less expensive than through hole components. Therefore, all these help to reduce the cost of manufacturing. Also, there is reduced cost as regards handling and packaging since surface mount assemblies are smaller.

- **PCB flexibility**

Regarding PCB design and material, surface mount technique offers more freedom. The PCB surface is directly soldered with surface mount electrical components. As a result, this gives PCB boards a lot of versatility. ([11]) ([12])

Disadvantages:

- **Difficult to inspect**

SMD components are very small and have several solder joints. Therefore, this can make PCB inspection difficult. BGA packages have solder joint problems that can be difficult to inspect. Several solder joint types make inspection difficult to perform.

- **High cost**

SMT is a very costly process. Also, it requires large investment in equipment and high training costs. Most SMT equipment is very expensive. In addition, these pieces of equipment need to be handled by a professional due to their technical complexity.

- **Prone to damage**

SMD components are prone to damage when they drop. Therefore, these components need proper care when handling and packaging them.

Chapter 3

3d printers motherboards

3.1 Motherboards :

3.1.1 Overview

All the electrical components will be connected to the printer motherboard, which houses the microcontroller. It's the microcontroller's job to enact the code from the 3D printer software to ultimately produce a 3D printed object. This job includes not only barking orders, like telling the stepper drivers when and in what direction to move the motors, but also requires the microcontroller to listen and respond to various inputs like the extruder temperature or the state of the limit switches. It is the motherboard's responsibility to provide the physical connectors for these outputs and inputs. The number of stepper motors, heaters, sensors and buttons that are supported is often a deciding factor when purchasing a motherboard. However, there are many other features, such as the presence or absence of a certain type of stepper driver, that will weigh into your decision to go with one motherboard over another. ([13])

3.1.2 Motherboard quality-of-life Features :

- **24V Input Voltage** - 24V is the unofficial new standard for powering stepper motors, extruders, and heated bed over the old 12V standard. Purchasing a motherboard that supports 24V will allow for smaller gauge wire to be used when connecting all the components and for better stepper motor performance .
- **32 Bit Processor** - Most motherboards have an 8-bit microcontroller that runs all the electrical components of the printer, but this processor can struggle to keep up with all tasks required to make a 3D printer run properly. High end motherboards use 32-bit processors that can quickly calculate complex motion paths, resulting in quieter and better prints.
- **Internet Connectivity** - The presence of a wifi or ethernet module on the motherboard will allow for remote monitoring of your prints. Throw in a wireless camera and you can cancel failed prints while away, saving filament and possible injury to the printer.

- **Spare IO Pins** - Motherboards with accessible and unused IO pins opens up the ability to seriously customize your printing experience. These IO pins can trigger a camera to take a picture of the print after each layer or they could be used to turn on LEDs after the print is finished so you can inspect your part.

3.1.3 The best 3D printer controller boards :

1- Smoothie board v1:

It's a 32-bit board boasting a 120-MHz processor, way ahead of the older ATmega chips that only clock 8 MHz.

The v1 comes with built-in stepper drivers (A5984) and there are a few versions to choose from, varying according to the number of drivers: the Smoothieboard 3X has 3 drivers, the 4X has 4 etc .The number of drivers is the only significant difference between versions.

Smoothieboards have its own firmware which has been developed by the manufacturing company, this firmware is as capable as Marlin but easier to configure.

Microcontroller: LPC1769

Connections: USB, Ethernet, microSD card

Input power: 12 to 24 V

Built-in drivers: Yes (A5984)

([14])

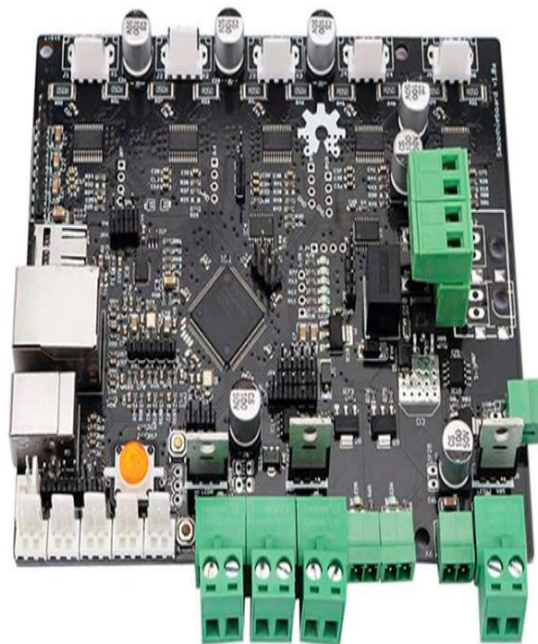


Figure (14) 3.1. : Smoothieboard v1

2- BIGTREETECHSKR V1.4:

BIGTREETECH SKR V1.4 motherboard is R&D by Shen Zhen Big TreeTechnology CO.,LTD. .The BIGTREETECH SKR V1.4 motherboard is not only with a high cost-effective but especially suitable for small and medium-sized 3D printers. It's a great performance using 32-bit main frequency 100MHz ARM level Cortex-M3 series LPC1768main control chip. it's a fully compatible with open source firmware Marlin2.0 andSmoothieware

Microcontroller: NPX LPC1768

Input power: 12 to 24 V

([15])

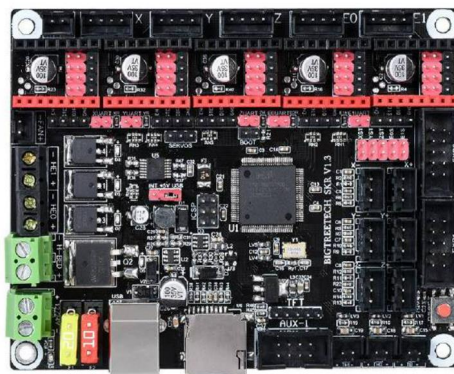


Figure (15) 3.2. : BIGTREETECHSKR V1.4

3- SKR Mini E3:

Developed by the good folks of BigTree Technology in Shenzhen, China, the SKR Mini E3 board was specifically designed as a drop-in replacement and upgrade board for Creality 3D printers like the Ender3 . And it's quite a replacement, with a 32-bit microcontroller and super-quiet onboard TMC2209 drivers capable of sensorless homing.

Another advantage of upgrading your Creality printer to this board is that firmware flashing would be much simpler than what it is today. The V2.0 version also features dual Z-ports for printers with two motors on the Z-axis and dedicated 5-V circuits for accessories like an auto bed leveling sensor, TFT screen, and LED lights. But perhaps the best thing about this controller board is the cost: around \$46 for 32-bit and integrated drivers is a steal.

Microcontroller: STM32F103RCT6
Connections: Micro-USB, microSD card
Input power: 12 to 24 V
Built-in drivers: Yes (TMC2209)
([16])

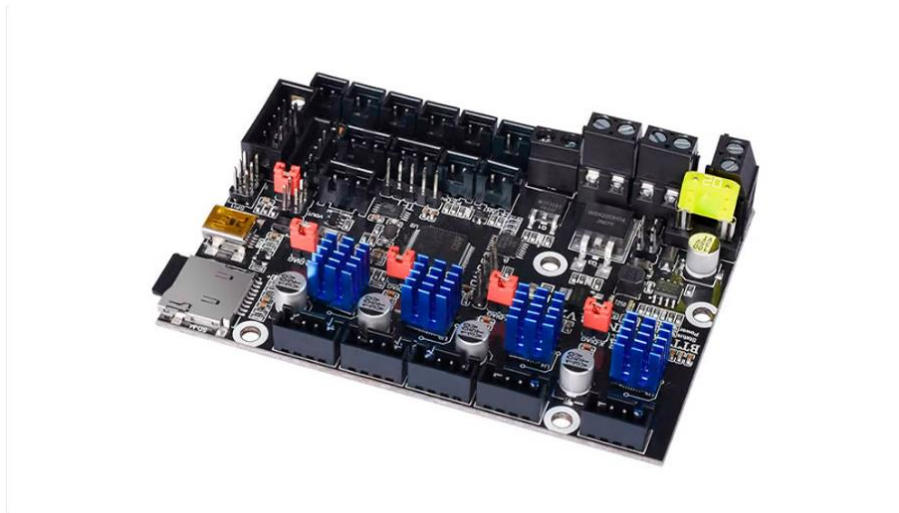


Figure (16) 3.3. : SKR Mini E3

4- SKR 2.0 :

The SKR 2.0 is the Mini E3's older brother and the successor of the SKR 1.4 Turbo. Now, instead of the 120 MHz microprocessor, the 2.0 version comes with an ARM Cortex-M4 series with a core frequency of 168 MHz and a few other improvements like two extra PWM controllable fan outputs (three in total) and a USB port for memory sticks.

This board offers full UART support for Trinamic drivers (not included) and dual extrusion right off the bat. Wi-Fi is supported as well but requires an expansion module that can be purchased separately. The 2.0 version also comes with extra protection circuits for thermal runaway prevention and jumpers for TMC drivers that allow sensorless homing without the need to cut out driver pins.

Finally, the SKR 2.0 runs on Marlin 2.0, enabling all the new advanced features offered by open-source firmware. While some users have reported reliability issues with some BigTreeTech boards, the SKR 2.0 has one of the most attractive prices in the market for high-quality 32-bit boards.

Microcontroller: STM32F407VGT
Connections: 2 x USB, microSD card
Input power: 12 to 24 V

Built-in drivers: No
([17])

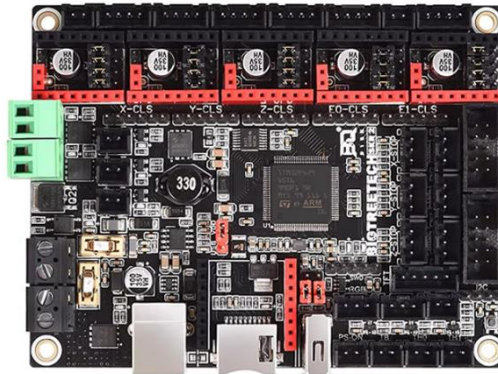


Figure (17) 3.4. : SKR 2.0

5- SKR Pro 1.2 :

The SKR Pro is BigTreeTech's ultimate solution for high-level 3D printing. It boasts the same ARM 32-bit Cortex-M4 chip as the SKR 2.0, which clocks at 168 MHz. However, it offers more hardware capabilities than any other BigTreeTech board.

Starting with the numbers, it allows for six motors, three extruders, three controllable fans, two displays, and supports dual Z-ports. It also offers 20 expansion ports for PWM, ADC, UART, and other protocols for peripherals, plus the conventional Wi-Fi expansion port.

Additionally, the 12- to 24-V power is supplied in separate lines: one for the motors, one for the heated bed, and another for the board itself.

- Microcontroller: STM32F407VGT
- Connections: 2 x USB, microSD card
- Input power: 12 to 24 V
- Built-in drivers: No

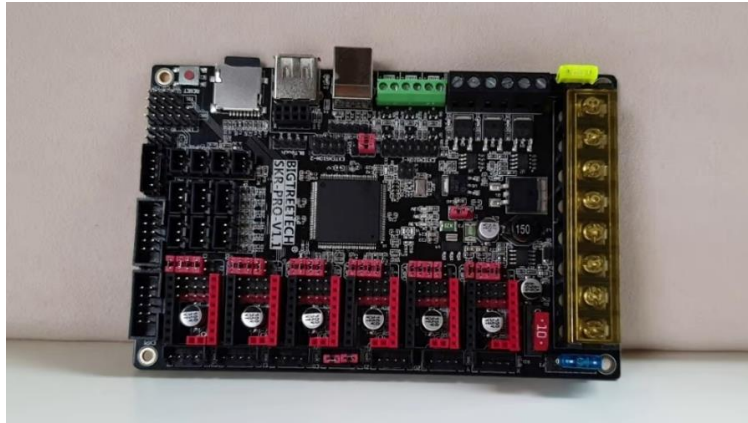


Figure (18)3.5. : SKR Pro 1.2

6- Duet 2 Wifi :

By now, you're probably seeing a pattern with the boards in this list: 32-bit ARM chip, great drivers, connectivity options, and so on. What can possibly get better? Well, how about a built-in Wi-Fi connection and impressive 1/256th microstepping? The Duet 2 Wifi has got you covered.

It comes with super-quiet built-in TMC2660 drivers capable of delivering up to 2.8 A motor current. Yet, this board is perhaps best known for its unique RepRapFirmware. This firmware supports an impressive array of movement systems, including the Hangprinter and multiple independent axes from the likes of the BCN3D Sigma. Depending on the mechanics of the machine you want to power, this could be the only controller board that'll fulfill your demands.

For those looking for extra hardware capacity, the Duet 3 Mainboard 6HC might be a good alternative. It ships with six high-current TMC5160 drivers and 10 PWM outputs capable of handling a heated bed, three additional extruders, and six fans. It also comes with nine IO expansion ports for end-stops, probes, and sensors.

Microcontroller: Atmel SAM4E8E

Connections: Wi-Fi, microSD card, Micro-USB

Input power: 12 to 24 V

Built-in drivers: Yes (TMC2660)

([18])



Figure (19) 3.6. : Duet 2 Wifi

3.2 Motion controller

The motion controller is the interface between OpenPnP and the hardware. It translates OpenPnP's movement commands into electrical signals that control the motors.

The term motion controller can be a little confusing, and it means a few different things. It can mean the actual board which is installed in the machine, or it can mean the software (or firmware) that runs on the board. It can even mean a completely computer based system .

When we say motion controller we just mean "whatever OpenPnP sends commands to to make the hardware move." ([19])

3.2.1 Choosing a Motion Controller:

This is a very important decision. The motion controller will determine how fast the machine moves, how many motors it can control, how many outputs are available for things like solenoids and pumps, etc.

In general, the most important decision is to pick a motion controller that supports as many motors as the machine needs.

A basic pick and place machine has 4 motors or axes. They are X, Y, Z and C, which is also called Rotation. X and Y move the head around, Z moves the nozzle up and down and C rotates the nozzle. More complex machines may have multiple Z axes and multiple C axes. These are referred to as Z2, Z3, C2, etc.

Another important consideration is making sure that the motion controller has enough outputs to control your various peripherals. The most basic PnP will have one output; usually a nozzle vacuum solenoid.

3.2.2 Types of motion controllers

There are a lot of motion controllers available and here is some of the recommended models:

1- Smoothie:

Smoothie is an Open Source motion controller firmware that runs on a variety of affordable, all in one boards. It's easy to configure, well documented and works great with OpenPnP. Here is some Smoothie based boards that are known to work with OpenPnP

- **Smoothieboard:**

The Smoothieboards are numerical fabrication controllers designed to run the Open-Source Smoothieware firmware, by a community of volunteers. They come into a range of different versions, with different feature sets and advantages.

All Smoothieboards are designed to run on the most powerful hardware in their price range at the time of their conception, to be easy to expand for new and adventurous uses, to be easy to develop on, and to be simple to use for normal users.

- **Rapid Starboard:**

Designed specifically for SMT pick and place machines run by OpenPNP, the Rapid Star Board is an all-in-one solution to run a multi-nozzle pick and place machine on Smoothieware firmware.

Available in two versions:

- A) Full TMC2208 drivers for all 6 axis
- B) Encoder setup where TMC2208 is populated for all drivers, while X and Y have DIR/STEP/EN & Motor VIN output for encoder connection.

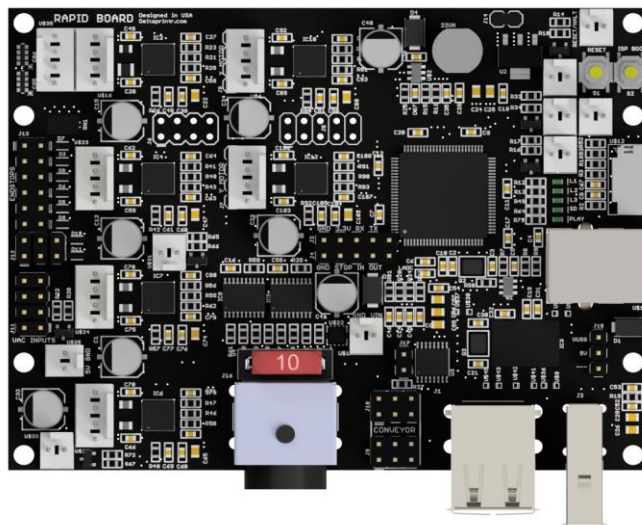


Figure (20) 3.7. : Rapid Starboard

- **Cohesion3D Remix:**

This board is designed with PnP in mind and has up to 6 stepper drivers and 6 MOSFET outputs. This board is great for larger, more complex machines.

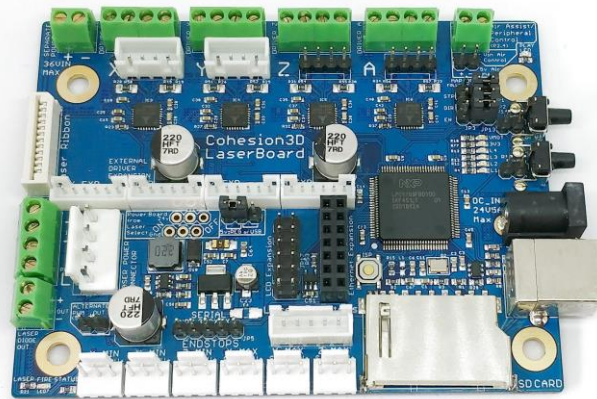


Figure (21) 3.8. : Cohesion3D Remix

- **Re-Arm:**

RE-ARM is a 100Mhz, 32-bit ARM controller with the popular Arduino MEGA footprint. It's a plug-in replacement for the Arduino Mega in your RAMPS setup for a quick and easy upgrade to 32-bit goodness. It runs Smoothieware and Marlin 2.0 firmwares.

What are the benefits of using Re-ARM?

- More powerful processor. Faster feed rates!
- Runs Smoothieware.
- Easy configuration using a text file on SD card, no need to upload firmware every settings change
- SD card appear as a drive in windows. Easy drag and drop new firmware or edit config file.
- Capable of running smaller micro-step stepper drivers. Like the 1/128 micro-stepping SD6128 driver.
- Available Ethernet RJ45 add-on Module
- Run graphic LCDs with your Deltas without hiccups.
- Run 2 SD cards, one for settings and firmware(on board) and the other for file loading (on LCD).
- 5V tolerant pins, except for analog inputs which are at 3.3V

- Filtered endstop inputs.
- Able to run CNCs, Laser cutters and 3D printers.

([20])

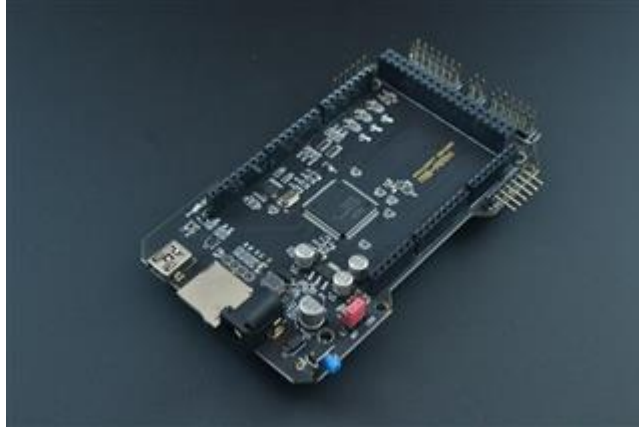


Figure (22) 3.9. : Re-Arm

2- Rep Rap:

RepRap Firmware is a comprehensive motion control firmware with uses in CNC and laser engraving/cutting in addition to operating 3D printers. It is not designed for outdated 8-bit processors with low CPU power, like most other 3D printer firmware's; rather, it is exclusively compatible with current 32-bit CPUs. Therefore, it is built to implement complex features while making effective use of the power of current, low-cost ARM processors. On an SD card plugged into the printer electronics, it is configured with human editable files. As a result, common users do not need to install any development tools or assemble the software.

The software is capable of receiving G-Code from the USB port, serial port, SD card, Ethernet or Wi-Fi interface via http, and Ethernet interface via Telnet.

3- TinyG:

TinyG is another great Open Source motion control platform. It supports up to 6 axes and is one of the only ones to support S-curve acceleration. This makes its motion very smooth and can allow for faster accelerations without

losing steps. The TinyG board only has 4 stepper drivers, but if that's all you need then it's an excellent choice.

4-Grbl:

Grbl is an Open Source motion control system for the Arduino platform. Grbl can run on any boards that have an ATmega328-based microcontroller and it is very easy to get up and running and can be considered the cheapest option, but it only supports 3 axes by default. which makes it not ideal for pick and place machines since it leaves you without an option to rotate the nozzle.

5-Marlin:

As we know every 3D printer is by definition at least a 4 axis machine and this makes 3D printer firmware tempting for pick and place motion control. The most popular of the bunch is Marlin. Marlin can be used with OpenPnP but it has some inherent limitations based on its focus on 3D printing. It can be difficult to get acceleration and maximum velocity set up correctly since these are often tied together on a 3D printer. In addition, configuration is complex because we have to remove a lot of the 3D printing functionality so It's not recommended to use 3D printer firmware with OpenPnP.

Chapter 4

SMT Pick and Place Machine

4.1 Definition

A machine used to attach surface mounted components to printed circuit boards is referred to as a PnP machine for SMT.

The goal of the surface placement system is to provide a productive assembly procedure for PCB installation utilizing surface mount technology. All electronics components are picked up and carefully installed with great accuracy onto the PCB as part of an elaborate machinery that supports the entire operation. In a single day, hundreds or even thousands of finished PCBs can be produced and utilized for a variety of equipment, including medical, industrial, automotive, and military applications. ([21])

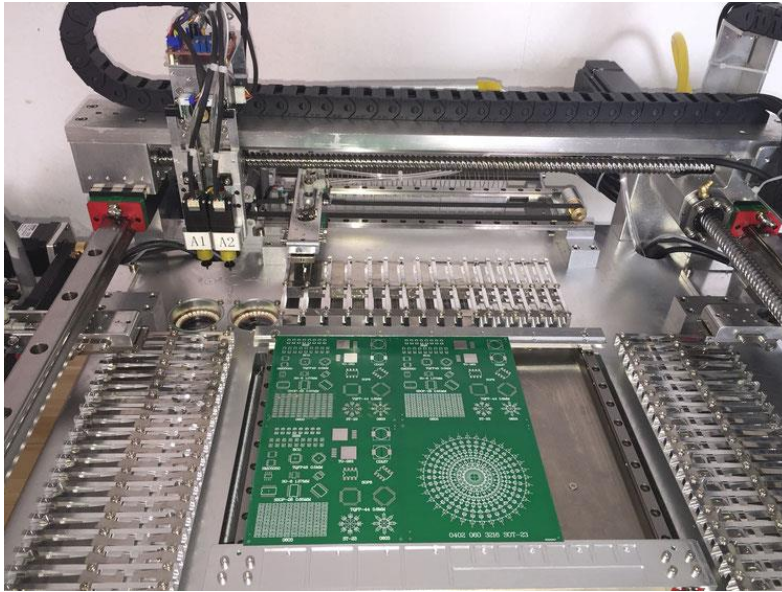


Figure (23) 4.1. : SMT Pick and Place Machine

4.2 Why is it important to build SMT Pick and Place Machines?

Flexibility and time are essential things to have. Using SMT we can mount SMD components on the bottom and top side of the PCB. This means that we don't need to drill holes into the PCB. Also, this will give us a smaller and more lightweight PCB design. ([22])

4.3 Methods of Pick and Place Centering ([24])

1- Mechanical centering jaws

This method involves picking the component and moving in its center position in the Y and X axes on the head. Also, this is an easy method that is repeatable within ± 0.01 inch accuracy. This centering method is common in low to middle range machines. However, it touches the component physically and this isn't ideal for some types of parts.

2- Vision centering

The two types of vision centering are look-up and look-down. Before taking up a component to determine its placement, look down vision frequently scans the top of the object. It then calculates the center and compares it to the database-stored photo file. The look-down vision systems are capable of handling fragile and unusually shaped parts.

The look-up vision technique is incredibly precise. In this technique, the machine transports the surface-mount components to a camera station after picking them up from the pickup position. This camera station determines the center location and examines the component's bottom.

3- No centering mechanism

This method doesn't depend on the pick-up point for placement of the component. This means that after the tool head picks up the component, the part isn't physically centered. Therefore, this method is not accurate for placing components since there is no tolerance. Also, this method is commonly used by instructors or hobbyists.

4- Laser centering

Picking up the component in line with a laser beam constitutes laser centering. This laser beam pinpoints the component's center location on the tool head. The zero point of the component is then recalculated depending on its location along the Y and X axes.

4.4 Components of SMT Pick and Place machine :

1- PCB :

The components are placed on PCB to make a circuit. ([23])

- **Types of Printed Circuit Boards:**

- a) Single Sided Board**

It is a straightforward printed circuit board with just one layer. On one side, all of the electrical parts and components are fixed, while on the other, copper traces are formed.

b) Double Sided Board

It is the most typical sort of PCB, with components and pieces mounted to both sides. On both sides, there are connecting traces.

c) Multi Layered Board

comprises of insulation between various substrate layers. The most popular multilayer boards have four, six, eight, and ten layers. However, there are more than 42 layers in all that can be produced. These boards are utilized in incredibly intricate electronic circuits.

2- Motherboard :

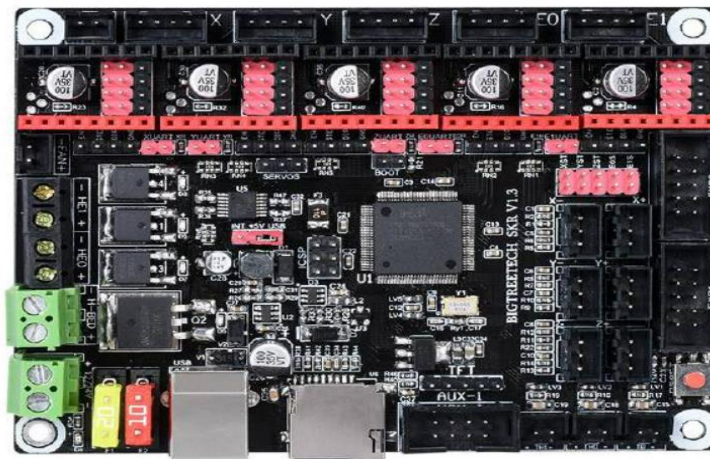


Figure (24)4.2. : BIGTREETECHSKR V1.3

3- Motors :



Figure (25) 4.3. : NEMA 17 Stepper Motor

4-Pneumatic system:

The Pneumatic system works as follows:

A vacuum pump is a crucial part of a pick and place machine because it produces the suction force required to retain and move components throughout the handling process. Here is a description of how a pick and place machine's suction pump works:

1. Component Pickup: To generate suction, the vacuum pump creates a vacuum or negative pressure. Components are grabbed and taken out of the feeder or component tray using this suction force. The component is firmly held in place by the pump, which generates a pressure differential between the component and the nozzle.
2. Component Release: The vacuum pump can be turned off or turned around to release the component after the pick and place device has arrived at the appropriate point on the PCB. The component is separated from the nozzle and positioned onto the PCB by removing the suction force.
3. Suction Control: The suction force may be adjusted and controlled by the vacuum pump. This is crucial because various components could need various amounts of suction power to be kept firmly. The suction force must be sufficient to retain the component securely without being too powerful to harm it. ([25])

Figure (26) 4.4. : Spark fun vacuum pump



Figure (26) 4.4. : Spark gun vacuum pump

5- vacuum ejector(Solenoid Valve):

is a device used to generate vacuum or negative pressure. It utilizes compressed air or gas to create suction by entraining or drawing in the surrounding air. The vacuum ejector assembly typically consists of an ejector body, nozzle, diffuser, vacuum port, and control valves. ([26])



Figure (27) 4.5. : Solenoid Valve

5- V-Slot Linear Actuator:

A form of linear motion system that is frequently utilized in a variety of applications, such as CNC machines, 3D printers, and pick and place machine systems, is the V-Slot linear actuator. It offers accurate, fluid linear motion along a laid-out route.

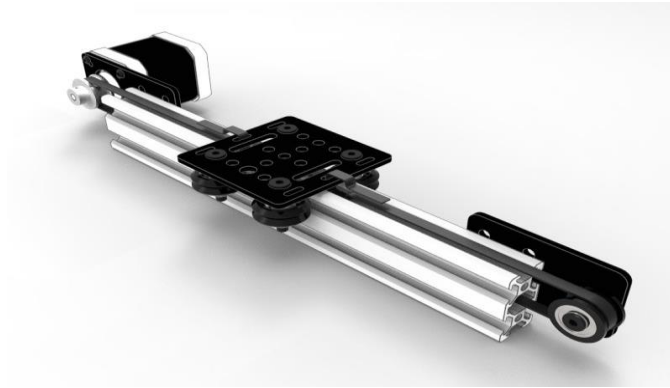


Figure (28) 4.6. : V-Slot Linear Actuator

6- Head and nozzle:

the elements in charge of picking up and attaching electronic components to printed circuit boards (PCBs).

Head: During the component placement process, the head is the assembly that holds and places the nozzle(s) and is in charge of overall movement and control. In order to correctly place the nozzle over the desired spot on the PCB, it is often positioned on a gantry system and is mobile in three axes (X, Y, and Z).

The head may include a number of smaller parts, including as motors, linear guides, and control systems, that enable the nozzle to be moved and aligned precisely throughout the insertion process. A vision system is often included in the head to assist in identifying component locations and correctly aligning the nozzle.

Nozzle: The area of the head that directly communicates with the electrical parts is the nozzle. It is made to safely remove components from their storage location, such a feeder, and set them down in the appropriate spot on the PCB.

To accommodate diverse component types, the nozzle is available in a variety of forms, dimensions, and arrangements. Vacuum nozzles, mechanical grippers, and customized nozzles for certain component packages are

examples of common nozzle types. The size, shape, weight, and needed handling manner are only a few examples of the variables that affect the nozzle selection.

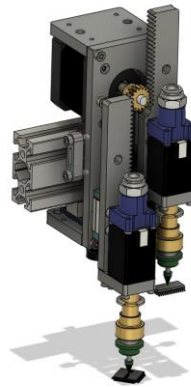


Figure (29) 4.7. : Head and nozzle

7- Feeders:

Feeders are specially designed to feed the components to the machine. SMT machine is to pick up the components in the feeders through command to a specified location specified by coordinates.

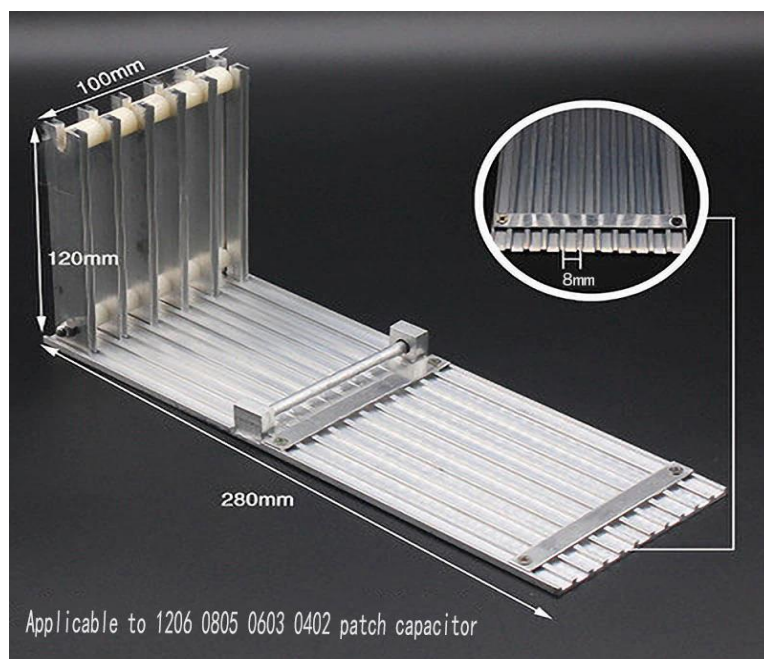


Figure (30) 4.8. : Five slots SMT component placement feeder

8- Limit switches :

A limit switch is an electromechanical device used to detect the presence or absence of an object or to monitor the position of a moving part. It is commonly used in various industrial and automation applications where precise positioning, safety, or control is required.

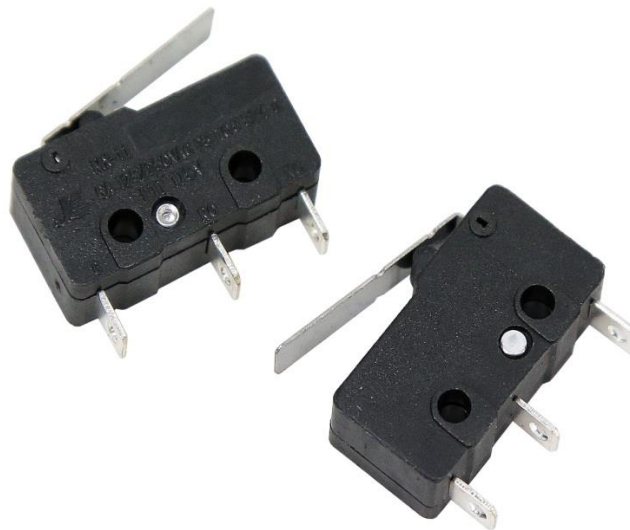


Figure (31) 4.9. : Limit switch

9- Vision system:

A normal machine has two cameras. The down looking camera is primarily used for targeting and setup, and it is also used for fiducial location when finding the orientation of a board. The second camera is up looking and is used to improve alignment of parts before placing them.

1-Up looking-Cam : ELP-USBFHD01M 6mm focal length.

2-Down looking-Cam: ELP-USBFHD01M 8mm focal length.

1-Up looking-Cam : camera that is used for vision inspection and alignment during the component placement process. Here's a breakdown of its function:

1. Component Inspection: Images of components put on the nozzle of the pick and place machine or in the placement area are taken using the Up looking-Cam. The

components' existence, positioning, and alignment are then confirmed by analysis of these photographs.

2. Alignment: The camera aids in precisely aligning the components with the desired PCB (Printed Circuit Board) placement. The equipment may adapt to guarantee exact placement by comparing the acquired photos with the anticipated position.

3. Vision Recognition: The Up looking-Cam employs algorithms for vision recognition to recognize and categorize components based on their visual characteristics. This enables the system to distinguish various component kinds and treat them appropriately.

4. Verification and Quality Control: The camera aids in confirming the precision and high caliber of component implantation. Defects such as missing parts, an improper orientation, or misalignment can be found, and the device can either inform the operator or start repair procedures.

5. The Up looking-Cam may also be utilized for calibration and calibration verification. The camera has the ability to calibrate the location and alignment of the pick and place machine's whole vision system by examining recognized reference patterns or features on the PCB.

2-Down looking-Cam: is used for vision inspection and alignment during the component placement process.

PCB Alignment: The Down Looking-Cam aids in aligning the pick and place machine with the PCB (Printed Circuit Board). Fiduciary markings and other reference elements on the PCB are photographed, and their positions are compared to those that are anticipated. Before component insertion, the machine can precisely position and align the PCB using this information.

Component existence and alignment are confirmed by taking pictures of the components on the PCB with the camera. It examines the photos to find the components and checks that they are positioned and orientated appropriately for installation.

Vision Recognition: The Down looking-Cam makes use of vision recognition algorithms to recognize various elements and categorize them in accordance with their visual characteristics. As a result, a range of components may be handled by the machine, and precise placement is guaranteed.

After components are positioned on the PCB, the placement accuracy is checked using a down-looking camera. In order to check for any misalignment or placement mistakes, it takes pictures of the components that have been installed and compares them to the desired location. This examination contributes to the assembly process's high level of quality.

Quality Control and Defect Detection: Using a camera, the PCB and the attached components are examined for any flaws, such as bent leads, missing or misaligned components, or soldering problems. To maintain quality control, it spots possible problems and sets out alarms or remedial measures.



Figure (32) 4.10. : Open PNP Camera

10- power supply:

A device that converts AC power from the mains into a constant DC voltage output of 24 volts with a maximum current output of 15 amps is known as a 24V and 15A DC power supply. Applications that call for greater power levels, such industrial machinery, motor control, LED lighting systems, and certain electrical gadgets, frequently employ this kind of power supply.

1-Voltage Output: A consistent output voltage of 24 volts direct current is offered by the power supply. This guarantees a steady power source for equipment and parts that need this amount of voltage.

2-Current Output: The power supply's maximum current output is 15 amps. This indicates that it can supply up to 15 amps of current to circuits or connected devices that need that amount of power.

3-Protection Features: High-quality power supplies frequently come with safety features including thermal protection, short circuit protection, overcurrent protection, and overvoltage protection. In the event of electrical problems or overloads, these protections aid in preventing harm to connected equipment and the power supply itself.

4-Cooling and Ventilation: Due to the substantial amount of power that a 24V and 15A power supply can produce, it is crucial to guarantee enough cooling and ventilation in order to avoid overheating. To effectively dissipate heat, some power supplies include fans or heat sinks built right in.



Figure (33) 4.11. : 24V DC Power Supply

11- Drag chain: An element used in pick and place machines to handle and safeguard the cables, wires, and hoses that supply power, signals, and control to different moving sections of the machine is a drag chain, often referred to as a cable carrier or cable chain.

a description of how a pick and place machine uses a drag chain:

1. Cable Protection: The drag chain's main purpose is to shield the cables and hoses from harm brought on by rubbing, bending, or exposure to the environment. It gives the cables a safe place to be housed, eliminating snagging, twisting, or crushing while the machine is in motion.

2. Cable Management: The drag chain maintains and arranges the cables, keeping them neatly structured and avoiding their tangling with other machine

parts. This encourages effective wire routing, lessens clutter, and makes maintenance and problem-solving easier.

3. Motion transfer: While the machine's moving components, such as the pick and place head or gantry, are in motion, the drag chain enables the smooth transfer of cables and hoses. It allows for the cables' motion, ensuring that they may flex and stretch without being hindered.

4. Flexibility and Range of Motion: The drag chain is designed to be flexible and have a broad range of motion. It has several bends and pivot points, allowing the cables to follow the machine's many axes of motion. This guarantees that the wires won't be stressed or stretched as they travel to their intended locations.

5. Cable Lifespan and Reliability: The drag chain helps increase the cables' lifespan and assures their dependable performance by shielding them from excessive bending, abrasion, or other stress. It lessens the possibility of cable damage leading to power loss, signal interference, or cable failure.

6. Simple Maintenance: The drag chain makes it simple to examine, maintain, and replace the cables as required. It may be opened or dismantled to provide easy access to each cable in the chain, making maintenance work simpler.

([27]) ([28]) ([29])



Figure (34) 4.12. : Drag chain

Chapter 5

Stepper motor

Motor:

5.1 Stepper motor

5.1.1 Introduction:

In contrast to many other common types of electric motors, stepper motors don't simply revolve continuously for an undetermined number of spins until the DC voltage passing to them is turned off.

Stepper motors, on the other hand, are a category of digital input-output apparatus used for precise starting and stopping. They are made to be powered on and off quickly in succession by a number of coils that are placed in phases and are hit by the current flowing through them. These discrete, preset phases are what we refer to as "steps," and they enable the motor to revolve through a quarter of a rotation at a time.

A stepper motor's function is to divide a single full rotation into several somewhat smaller (and about equal) part-rotations. These can be used to command the stepper motor to rotate through specific angles or degrees for practical purposes. ([30]) ([31])

5.2.1 Stepper Motor Working Principles:

Stepper motors, like other electric motors, contain a stationary component (the stator) and a moving component (the rotor). While the rotor is either a permanent magnet or an iron core with variable reluctance, the stator has teeth on which coils are strung. Figure 5.1 is a drawing of the motor's section with a variable-reluctance iron core as the rotor.

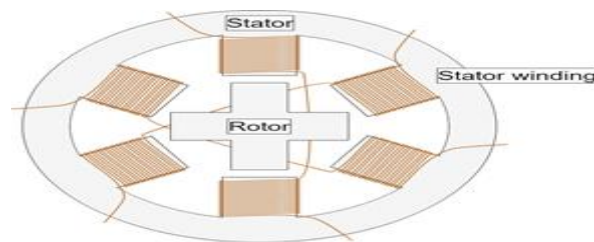


Figure (35) 5.1. : Cross-Section of a Stepper Motor

The stepper motor's fundamental operating principle is as follows: The current flowing in the coil creates a magnetic field by activating one or more of the stator phases, and the rotor aligns with this field. The rotor can be rotated by a particular number of turns to reach the desired final position by delivering various phases in the proper order. An illustration of the working concept is shown in Figure 5.2. The rotor is initially aligned with the magnetic field created by coil A when it is first powered up. The rotor turns 60 degrees clockwise to line up with the new magnetic field when coil B is powered on. The same thing occurs when coil C is powered on. The stator teeth's colors in the images show the stator winding's generated magnetic field's direction.

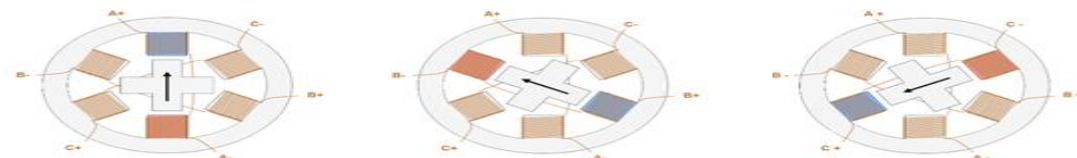


Figure (36) 5.2. : Stepper Motor Steps

5.3 Stepper Motor Types and Construction

Construction details have an impact on a stepper motor's performance in terms of resolution (or step size), speed, and torque. These characteristics may also have an impact on the motor's controllability. In actuality, since there are several rotor and stator configurations, not all stepper motors have the same internal structure (or construction).

For a stepper motor, there are basically three types of rotors:

5.3.1 Permanent magnet rotor:

The brushless Permanent Magnet Synchronous Motor (PMSM) provides a very high level of dependability and efficiency. It also offers a strong torque with a small frame size and no rotor current thanks to its permanent magnet rotor. Permanent magnets are installed to create a spinning magnetic field rather of needing winding for the rotor. These kinds of motors are very basic and inexpensive because there is no supply of a DC source. The permanent magnet synchronous motors are AC synchronous motors with a sinusoidal back EMF waveform and permanent magnet field excitation. The PMSM can produce torque at zero speed thanks to the permanent magnets. This motor operates with excellent efficiency and needs an inverter with digital control.

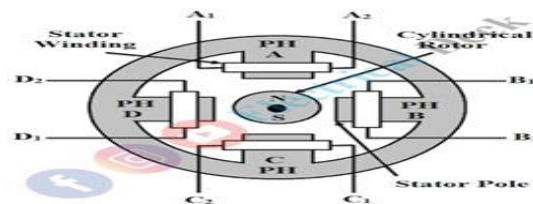


Figure (37) 5.3. :Permanent magnet rotor

- **Construction:**

The permanent magnet synchronous motors, like any rotating electric motor, consist of a rotor and a stator. The permanent magnet synchronous motor construction is similar to the basic synchronous motor, but the only difference is with the rotor. In this type of motor, the permanent magnets are mounted on the rotor and the rotor doesn't have any field winding.

The permanent magnets are used to create field poles. The permanent magnets used in the motor are made up of samarium-cobalt and medium, iron, and boron because of their higher permeability. The most widely used permanent magnet is neodymium-boron-iron because of its effective cost and ease of availability.

- **Working Principle :**

The permanent magnet synchronous motors working principle is similar to the synchronous motor. The principle of operation is based on the interaction of the rotating magnetic field of the stator and the constant magnetic field of the

rotor. It depends on the rotating magnetic field that generates electromotive force at synchronous speed.

When the stator winding is energized by giving the 3-phase supply, a rotating magnetic field is created in between the air gaps. This produces the torque when the rotor field poles hold the rotating magnetic field at synchronous speed and the rotor rotates continuously. As these motors are not self-starting, it is necessary to provide a variable frequency power supply.

- **Advantages :**

- ★ Its main advantage is the presence of a decent torque. Detent Torque is defined as the maximum static torque that can be applied to the shaft of an unexcited motor without causing continuous rotation. Under this torque, the rotor comes back to the normal rest position even if excitation ceases. Such positions of the rotor are referred to as the detent positions.
- ★ The motor has full torque at standstill (if the windings are energized).
- ★ Excellent response to starting/stopping/reversing.
- ★ Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependent on the life of the bearing.

- **Disadvantages :**

- 1- Low torque to Inertia ratio.
- 2- Acceleration is slow.
- 3-Very slow dynamic response.
- 4-The step angles are of high range i.e., 30° to 90°

5.3.2 Variable reluctance rotor:

An electromechanical energy conversion device that transforms electrical energy into mechanical energy is a variable reluctance stepper motor. It operates on the reluctance principle, which states that magnetic flux always travels along a path with the lowest possible reluctance. To create the rotor magnetic field, the rotor is either made of permanent magnets or stimulated with a single-phase supply while the stator poles are excited with a three-phase or single-phase supply.

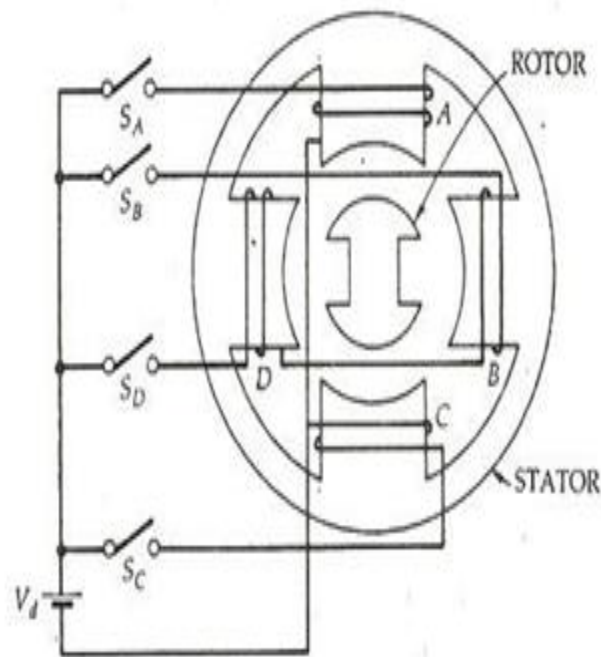


Figure (38)5.4. :Variable Reluctance Stepper Motor

- **Construction of Variable Reluctance Stepper Motor:**

It is the most basic type of stepper motor. The stator of this motor consists of a three-phase wound type. It has six salient poles with concentrated windings around each one of them. The rotor has 4 slots to produce the effects of 4 poles.

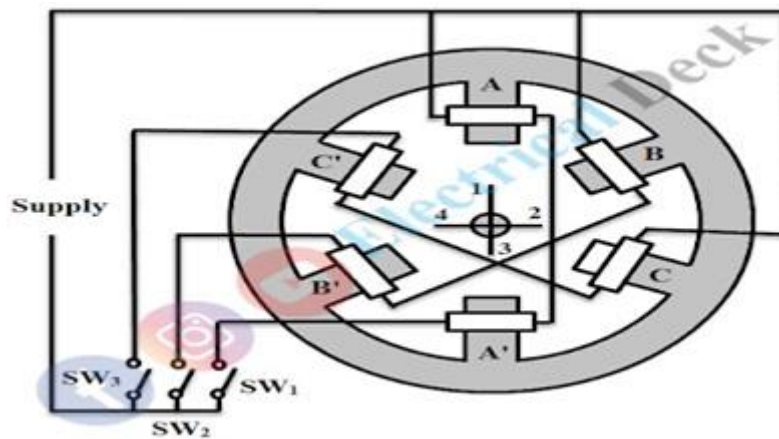


Figure (39) 5.5. :Variable Reluctance Stepper Motor

The two stator windings which are in the opposite direction are connected in series. These windings are then energized by three different switches as shown in the figure.

- **Principle of Operation :**

The varied reluctance locations of the rotor serve as the foundation for the reluctance motor's basic operating theory. Any phase of the stator can be activated by a voltage signal, which creates a magnetic field whose axis runs parallel to the poles.

The rotor now seeks to revolve in a direction where it experiences the least amount of resistance. A position where the axis of the magnetic field created by a stator is equal to the axis passing through any two poles of the rotor is known as this rotation.

- **Advantages of Variable Reluctance Stepper Motor**

- 1-High torque to inertia ratio.
- 2- High rates of acceleration.
- 3-Fast dynamic response.
- 4-Simple and low-cost machines.
- 5- Rotor construction is robust due to the absence of brushes.

5.3.3 Hybrid rotor:

This type of rotor is a hybrid of permanent magnet and variable reluctance versions and has a special construction. The rotor is axially magnetic and features two caps with alternating teeth. With this setup, the motor can benefit from the excellent resolution, speed, and torque of both the permanent magnet and variable reluctance variants. A more sophisticated construction is necessary to achieve this increased performance, which increases the cost. Figure depicts a stylized illustration of this motor's structure. An N-magnetized cap tooth lines up with an S-magnetized stator tooth when coil A is powered. The S-magnetized tooth of the stator aligns with the N-magnetized tooth at the same moment because of the rotor's structure. Although the stepper motor's operating principle is the same, real motors have a more sophisticated structure and more teeth than the one in the illustration. The motor can reach a small step size, down to 0.9° , thanks to its large number of teeth.

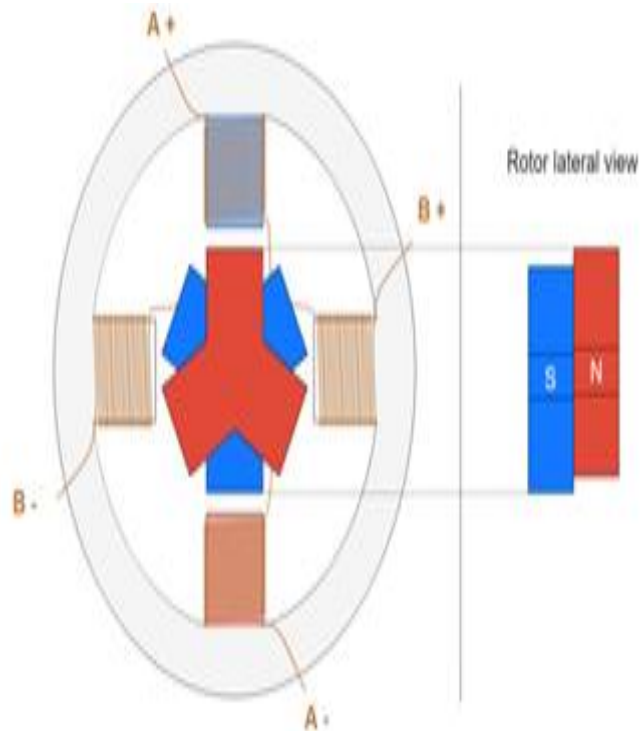


Figure (40) 5.6.: Hybrid Stepper Motor

Stator

The stator is the part of the motor responsible for creating the magnetic field with which the rotor is going to align. The main characteristics of the stator circuit include its number of phases and pole pairs, as well as the wire

configuration. The number of phases is the number of independent coils, while the number of pole pairs indicates how main pairs of teeth are occupied by each phase. Two-phase stepper motors are the most commonly used, while three-phase and five-phase motors are less common (see Figure and Figure).

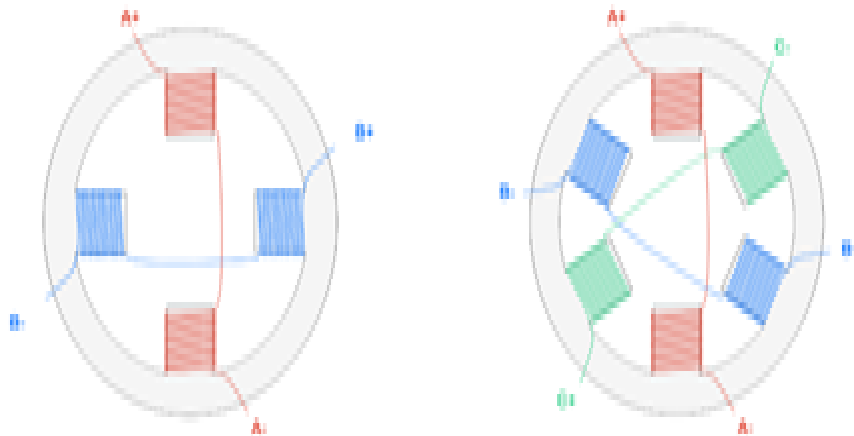


Figure (41) 5.7.: Two-Phase Stator Winding (Left), Three-Phase Stator Winding (Right)

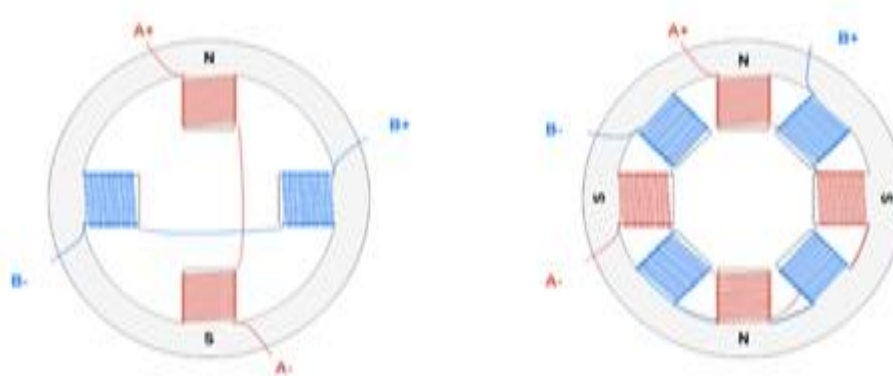


Figure (40) 5.8.: Right: Two-Phase, Dipole Pair Stator; Left: Two-Phase, Single-Pole Pair Stator. The letters display the magnetic field that results from applying positive voltage between A+ and A-.

5.4 Comparison of the types stepper motor:

Advantages / Types of Stepper Motor	Permanent Magnet	Variable Reluctance	Hybrid
Step Angle	7.5° or larger	1.8° or smaller	1.8° or smaller
Output Torque	Moderate	Low	High
Detent Torque	Yes	No	Yes
Pulse Rate / Speed	Low	High	High
Acceleration / Response	Slow	Fast	Fast
Noise	Quiet	Loud	Quiet
Microstep	Yes	No	Yes
Design	Simple	Moderate	Complex

Figure (41) 5.9.:types stepper motor

5.5 Stepper motor drivers:

5.5.1 Introduction:

Stepper system consists of a stepper motor and a stepper driver. Stepper motor driver is an actuator which can transform pulse signal into angular displacement signal, Stepper drivers drive stepper motors to rotate at an angle called step angle in the set direction when receiving a pulse signal. The motor speed is up to the pulse frequency given from the controller, and the displacement is decided on the pulse quantity given from the controller. Performance of a stepper system is not only up to the motor, but also depends on the stepper driver. ([32])

5.5.2 Stepper Motor Driver Types

- On the market, many stepper motor drivers with various functions for various applications are offered. The input interface is one of the most crucial features. The most typical choices are:

- Step/Direction – By sending a pulse on the Step pin, the driver changes its output such that the motor will perform a step, the direction of which is determined by the level on the Direction pin.
- Phase/Enable – For each stator winding phase, Phase determines the current direction and triggers Enable if the phase is energized.
- PWM – Directly controls the gate signals of the low-side and high-side FETs.

Another important feature of a stepper motor driver is if it is only able to control the voltage across the winding, or also the current flowing through it:

- With voltage control, the driver only regulates the voltage across the winding. The torque developed and the speed with which the steps are executed only depend on motor and load characteristics.
- Current control drivers are more advanced, as they regulate the current flowing through the active coil in order to have better control over the torque produced, and thus the dynamic behavior of the whole system. ([33])

5.5.3 The stepper motor we used in the project

A Motor Driver is an essential device that provides the required voltage and current to a stepper motor so that it gets a smooth operation. The selection of a proper power supply, microcontroller, and the motor driver is very important. Motor drivers come in a variety of shapes and sizes depending on the type of motor and control required. In our machine we are going to use TMC2209 .

TMC2209 : Two phase stepper motor driver IC.

Block Diagram / Pinout:

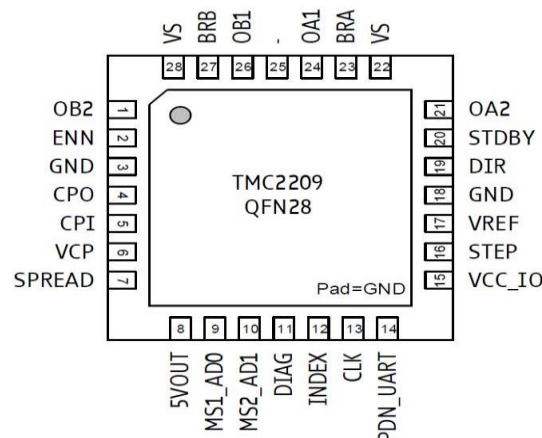


Figure (42) 5.7.3:Stepper motor drivers(TMC2209)

5.5.4 TMC2209 has some amazing special features

- SpreadCycle: a cycle-by-cycle current control which can react extremely fast to changes in motor velocity range for motor load.
- StallGuard4: A sensorless load measurement for stepper motors to verify that it works within the safety margins by adjusting the StallGuard4 sensitivity to fit the applications need , making it ideal for sensorless homing, self-calibration, distance measurement.

Note: Sensorless homing allows to home an axis without the need for a physical limit switch.

- CoolStep: offers dynamic current control based on StallGuard values.
- MicroPlayer
- short detection , Stall detection
- stealthChop2: stealthChop is a quiet mode of operation for stepper motors at standstill and at low velocities. It is based on a voltage mode PWM. With stealthChop2, the driver automatically adapts to the application for best performance ([34])

chapter6

OPEN SOURCE OPEN-PNP SOFWAER:

6.1 introduction:

Open-PnP software is a key component of the Open-PnP project, which aims to provide an open-source solution for pick-and-place (PnP) machines used in electronics manufacturing. The software controls the operation of the PnP machine, enabling precise and automated placement of electronic components onto printed circuit boards (PCBs). ([35])



Figure (43) 6.1.:OPEN PNP

6.2 Features:

Users can create, manage, and execute job files—which specify the components to be placed on the PCB and their locations—using the user-friendly interface it offers.

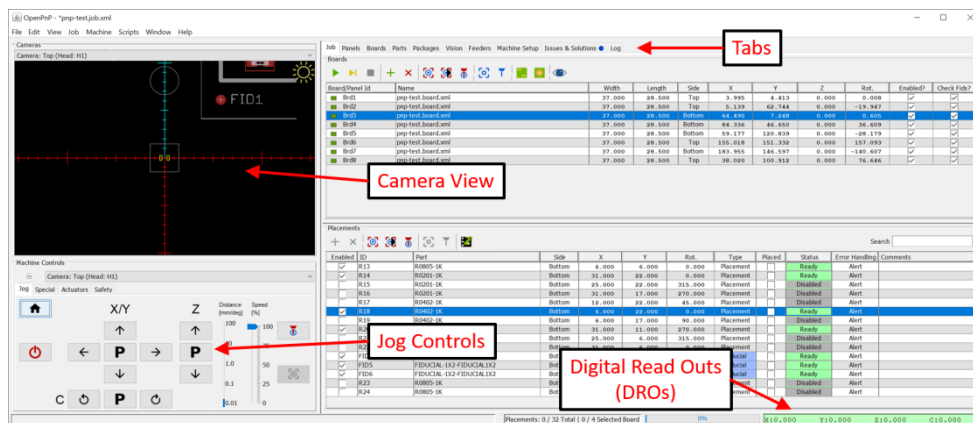
- 1- The Open-PnP software's integration with computer vision technology is one of its key features. Images of the PCB are taken using cameras or vision devices, and image processing techniques are used to identify and locate the components. This makes it possible to arrange components accurately and consistently, even in intricate PCB layouts.
- 2- The program has calibration processes that measure component pickup offsets, align the cameras, and correct for mechanical errors in the system. This calibration guarantees the placement procedure' correctness and enhances overall performance.
- 3- Component library management functions are also available in open-PnP software. Electronic component data, including dimensions, footprints, pick-up and positioning guidelines, and rotation angles, can be created and maintained by users. This component library makes it easier to retrieve the relevant information, which promotes efficient and correct assembly.
- 4- The software offers configuration options that let users alter the PnP machine's behavior and functionality. These options include camera settings, motion control parameters, camera configuration parameters, and error handling options. Users can customize the machine's

performance based on their unique needs by customizing these options.

- 5- Users can import PCB layouts and information on component placement using Open-PnP software, which facilitates the integration with CAD software. The assembly process is streamlined and exact alignment between the design and assembly stages is ensured by this seamless connection.
- 6- The Open-PnP software's open-source nature promotes community involvement and collaboration. By sharing their knowledge and offering new features and improvements that will benefit the entire community, users may help with the development and improvement of the software.

6.3 Open-PnP Settings:

Within the Open-PnP software, there are various settings that can be configured to customize the behavior and performance of the pick-and-place machine. These settings allow users to adapt the software to their specific needs and optimize the machine's operation. Here are some common settings within Open-PnP:



component placement and identification are made possible through calibration.

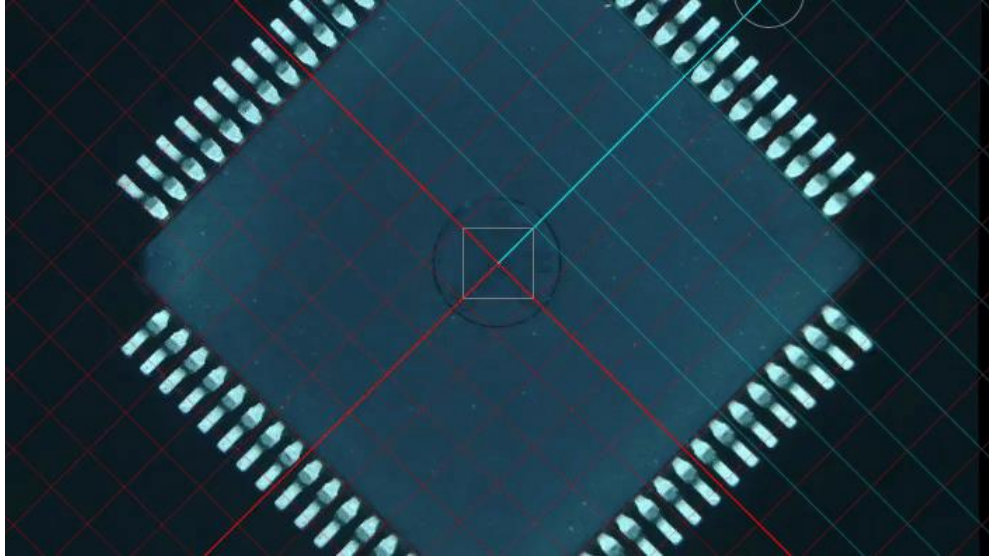


Figure (45) 6.3.1:vision system

- ❖ **Job Settings:** Users can set up several options when creating a job file for a particular PCB assembly. The pick-and-place approach (such as sequential or parallel placement), nozzle choice, pickup offsets, placement offsets, and rotation angles are some examples of these settings. Each assembly's job settings are unique, and they can be altered to meet the needs of the PCB design.

- ❖ **Motion Control Parameters:** Open-PnP offers options for the pick-and-place machine's motion control. Users can set up variables including maximum speeds, motor current limitations, and motor acceleration and deceleration rates. These settings control how the machine moves when picking up and placing components, resulting in efficient and accurate functioning.

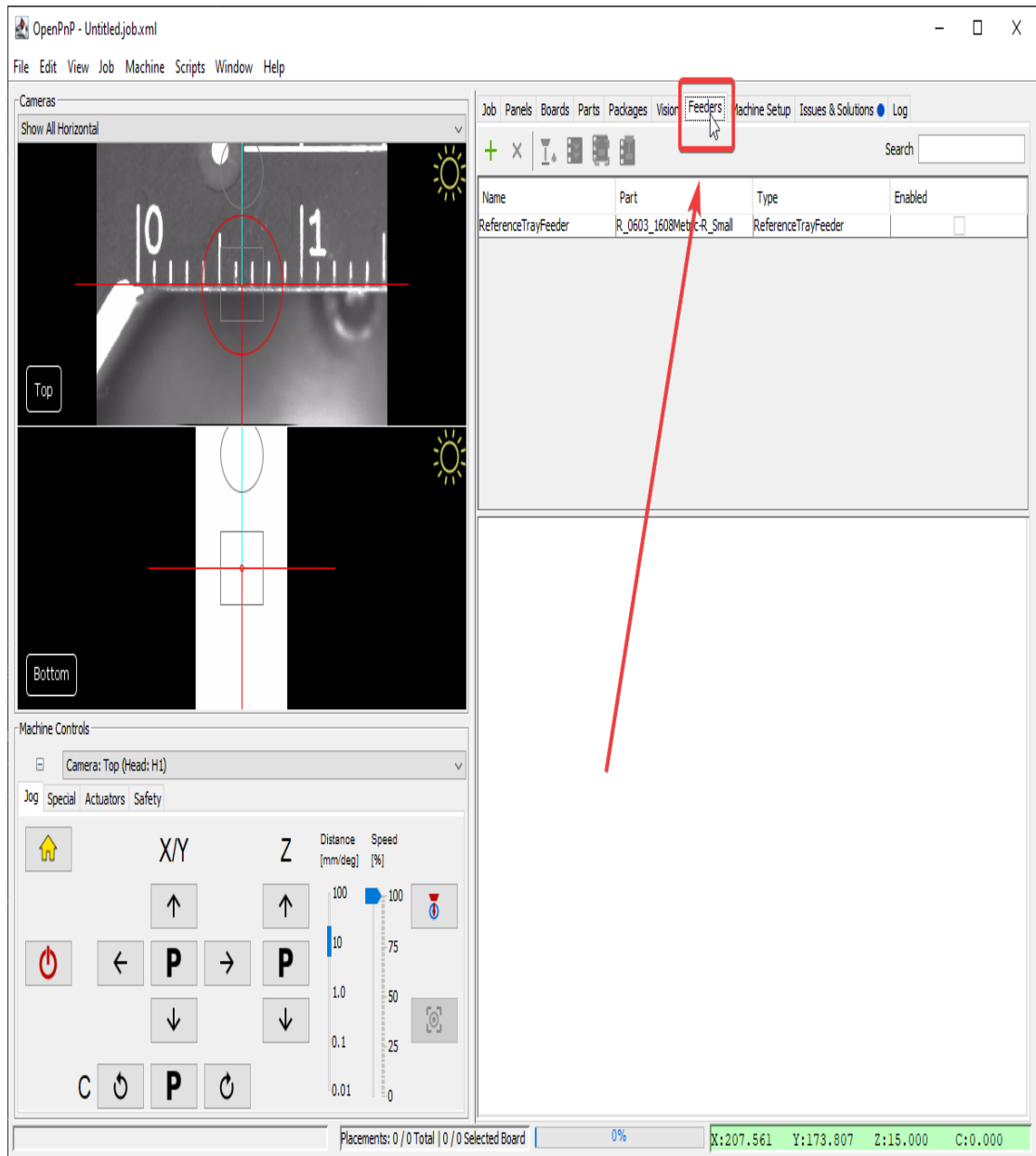


Figure (46) 6.3.2: Motion Control

- ❖ Issues and solutions: Open-PnP allows users to define error handling and retry settings to handle situations where component placement fails or encounters errors. These settings may include the number of retries, delay times between retries, and actions to be taken if the placement is consistently unsuccessful.

Job Parts Packages Feeders Machine Setup Issues & Solutions Log

Find Issues & Solutions **Milestone Calibration** Include Solved? ☐ Dismissed? ☐

Calibrate the machine for precision motion and vision.

After each round of solving issues, please run Find Issues & Solutions again to catch dependent issues.

Subject	Severity	Issue	Solution	State
ImageCamera Top	Funda...	Secondary calibration fiducial position.	Move the camera over the secondary calibration fiducial a...	Open
ReferenceControllerAxis y	Sugge...	Calibrate the low side soft limit of y.	Move axis y to the low side soft limit and capture.	Solved
ReferenceControllerAxis y	Sugge...	Calibrate the high side soft limit of y.	Move axis y to the high side soft limit and capture.	Open
ReferenceControllerAxis Z1	Sugge...	Calibrate the low side soft limit of Z1.	Move axis Z1 to the low side soft limit and capture.	Dismissed
ReferenceControllerAxis Z1	Sugge...	Calibrate the high side soft limit of Z1.	Move axis Z1 to the high side soft limit and capture.	Open
ReferenceHead H1	Sugge...	Enable Visual Homing.	Mount a permanent fiducial to your machine and use it for...	Open
ImageCamera Top	Sugge...	It is recommended to suspend camera preview during ma...	Enable Suspend during tasks.	Open
ImageCamera ImageCamera	Sugge...	It is recommended to suspend camera preview during ma...	Enable Suspend during tasks.	Open
ImageCamera ImageCamera	Sugge...	In single camera preview OpenPnP can automatically swit...	Enable Auto Camera View.	Open
ImageCamera ImageCamera	Sugge...	The preview rendering quality can be improved.	Set to Rendering Quality to High (right click the Camera Vi...	Open
GcodeDriver GcodeDriver	Sugge...	Choose the simplest Motion Control Type for the first basi...	Set to ToolpathFeedRate.	Open
Milestone Calibration	Inform...	Complete milestone Calibration	Calibrate the machine for precision motion and vision.	Open

Subject ReferenceControllerAxis Z1

Issue Calibrate the low side soft limit of Z1.

Solution Move axis Z1 to the low side soft limit and capture.

Move axis Z1 to the low side soft limit.

Jog Z of ReferenceNozzle N1 to do so.

If the axis has a limit switch, use a position close to it but still safe to not trigger the switch by accident.

Then press Accept to capture the lower soft limit.

☐ Accept ☐ Dismiss ☐ Reopen

Figure (47) 6.3.3: Issues & solutions

- ❖ **Axis Limits and Safety Settings:** Open-PnP allows users to define safety limits for each axis to prevent collisions or damage during operation. These limits define the valid range of motion for each axis, ensuring that movements stay within safe boundaries.

Job Parts Packages Feeders Machine Setup Log

Expand Search

ReferenceMachine

Configuration

Properties

Type X

Name x

Controller Settings

Driver NullDriver

Axis Letter X

Switch Linear ↔ Rotational? ☐

Home Coordinate 5.000

Backlash Compensation None

Resolution [Driver Units] 0.000100

Kinematic Settings

Soft Limit Low 0.000 ☒ Enabled?

Safe Zone Low 0.000 ☐ Enabled?

Safe Zone High 0.000 ☐ Enabled?

Soft Limit High 600.000 ☒ Enabled?

Feedrate [/s] 333.333

Acceleration [/s²] 666.667

Jerk [/s³] 0.000

Reset Apply

Figure (50) 6.3.4: Axis Limits and Safety Settings

- ❖ **Axis Configuration:** With Open-PnP, users can specify how each machine axis is set up. Included in here are the mechanical details of the axis, such as step resolution, travel distance, and physical dimensions, as well as the type of motor used, such as a stepper or servo motor.

- ❖ **Coordinate System:** Open-PnP supports different coordinate systems for defining the position and movement of the axes. Common coordinate systems include Cartesian (X, Y, Z,C), polar, or any custom coordinate system suitable for the specific machine configuration. Users can define the coordinate system to match their machine's mechanical setup and working environment. ([36])

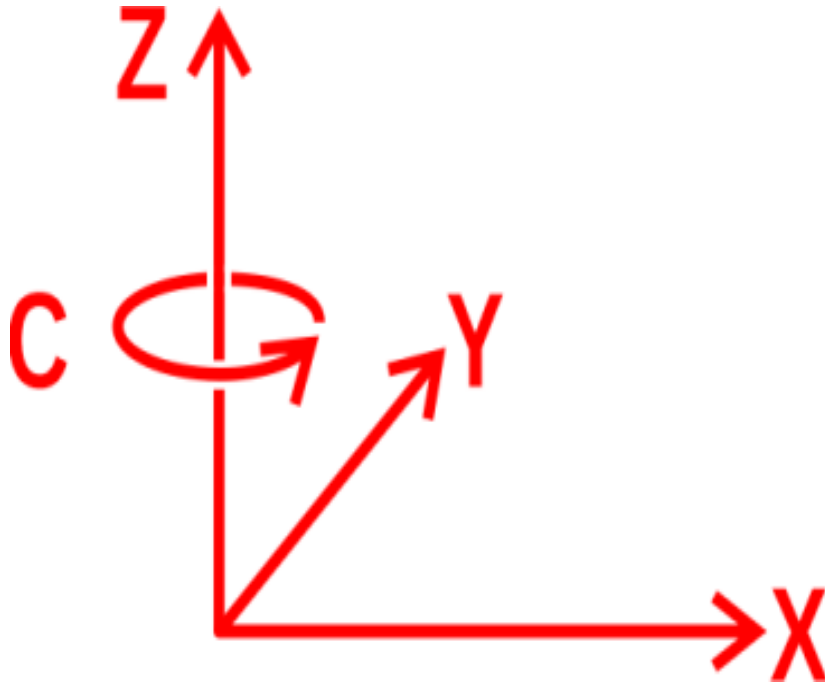


Figure (51) 6.3.5: Axis Settings

Chapter7

Future Recommendations and Conclusion:

7.1 Recommendations

Here we have some future recommendations to which can improve our machine and make it more efficient :

- 1- To make the process more effective and faster we can use more heads.
- 2- Placement head of the z-axis assembly is attached magnetically, therefore it can be changed according to the size of the components.
- 3- We can try more effective automated feeders .

7.2 Conclusion

Our project focuses on developing a portable and efficient Pick and Place for small scale industries with high precision and accuracy by making use of a compact design, reliable controller. We are going to start with modifying the electrical design of the machine and connect it with the OPEN PNP to program and control our machine .

Chapter8

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