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Design of Automated Screen-Printing Machine

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Abstract: India being one of the growing countries still uses manual screen-printing methods which involves using bare hands to spread the ink across and film and aligning the film with the print surface along with loading and unloading of material. This process is very time consuming and results in a decline in production rate. Automating these movements of the process help in enhancing quality of the print and an increase in the production rates and process time which in turn reduces labour cost.
Keywords: Screen-Printing, Computer Aided Design (CAD), Squeegee, Automatic

I. INTRODUCTION

A Screen-Printing machine is used to print a design on a sheet of paper, cloth, or a similar material, using a permeable film, a fixed frame on which its mounted, and the required type of paint to be spread on our film to completely, and without error, form the desired design that's provided on the screen. Screen printing is usually done by hand, especially in India, and due to this, there is a large chance that the screen will tear, or the too much, or too little pressure is applied. This might cause some damage to the system, and thus by automating the process, we eliminate the risk of human error, and doing it in a cost-effective way, so that small scale industries can be supported. The present project aims to design and fabricate an automated screen-printing machine.

II. AIM AND OBJECTIVES

The aim of this work are as follows:

1) Design and manufacture an Automatic Screen-Printing Machine to automate the process.
2) To increase the productivity and efficient use of labour.
3) To decrease exposure of workers to harmful chemicals.
4) Improved cost savings for the manufacturing company.

The objectives of this work are as follows:

a) Make an automatic screen-printing machine at an acceptable cost.
b) Use of affordable materials to increase the production availability & ease.
c) Better ergonomics, reduce cost of production, and increase in printing speed.
d) Comfortable relation between the operator, and the Screen-Printing machine.

III. LITERATURE REVIEW

The reference papers and literature surveys show us that the quality of the screen print depends on the surface on which the design is being printed. The print quality is determined by various factors such as, quality of material, flatness of bed, the type of ink used, the mesh size and the printing support configuration. We need to design a print bed that is perfectly flat, and thus get the best quality print possible. This is also helped by the fact that we are using an automatic mechanism, which makes calculation of distances easier than it would be otherwise, if it was a manual system. We have the capability to find a squeegee capable of applying enough pressure so that no tearing of screen occurs. Realizing about various methods of production of the film, we could find the best method of producing a stencil/design effectively, and capable of handling the amount of force exerted on it during the printing process. Learned various methods of reproduction of the screens, that gives us the optimal and cost-effective design. We found out the challenges faced while transporting the film, and how the industry has made progress in automobile paint and screen-printing technology, which enables us to expand our horizon and take influence from designs used in those processes.

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IV. METHODOLOGY

A. Introduction

To make the Manufacturing and fabrication easy, strong, and light, Aluminium bars are used and an exoskeleton is formed to support other components. The printing frame is also made of aluminium bars for ease of loading and unloading. For to and fro motion of Squeegee and Loading table, stepper motors are used in conjunction with GT2 pulley and belt to prevent slippage and correct number of turns to increase accuracy. Linear Guide rails are used to give accurate linear motion to squeegee and loading tables. The linear bearings are used to decrease friction between guide rails and table. A microcontroller (Arduino) is used here to give control signals to the stepper motor to control the rotation of motors. Since the supply given to motors is less than supply voltage, Motor driver circuit is required to power the Arduino and motors. A relevant block diagram in shown in the fig.1.

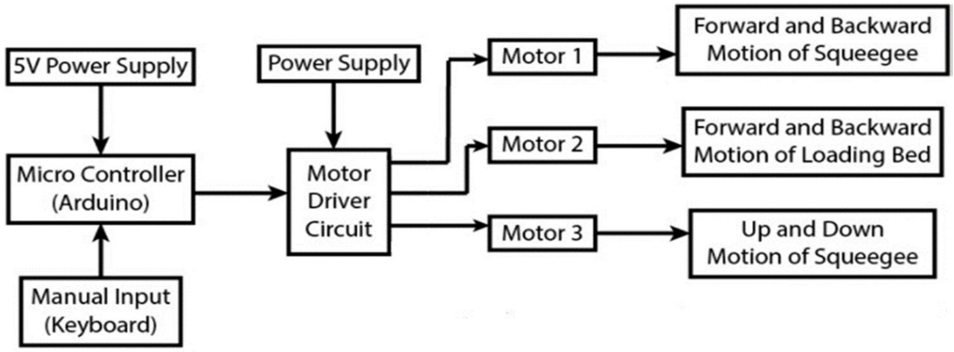

Figure.1 Functional Block Diagram

B. Mechanical and Electronic Components

1) *Microcontroller Arduino Uno:* The Arduino Uno is an open-source microcontroller developed by Arduino.cc shown in fig.2. The board is equipped with sets of digital and analog I/O pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins, 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.

Fig.2 Arduino Uno Microcontroller

2) *L298N Motor Driver Controller:* The chosen motor driver is shown in the fig.3. A motor driver circuit is an interface that helps with the communication of the motors and the control circuits. Since motors require a high amount of current, but the controller circuit works on a much lower current, the function of this device is to convert those low power signals to high current signal to drive the motor.

a) VCC pin supplies power to the motor. Voltage anywhere between 5 to 35V can be applied. Remember, if the 5V-EN jumper is in place, you need to supply 2 extra volts than the motor's actual voltage requirement, to run the motor at its maximum speed.

b) 5V pin supplies power to the switching logic circuitry inside the L298N IC. If the 5V-EN jumper is in place, this pin acts as output and can be used to power up the Arduino. If the 5V-EN jumper is removed, we need to connect it to the 5V pin on Arduino.

c) ENA pins are utilized to control the speed of Motor A. Supplying this pin with HIGH logic makes the Motor A rotate, supplying it with LOW logic causes the motor to stop. Removing the jumper and connecting this pin to the PWM input let us control the speed of the Motor A. It is similar process for Motor B.

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d) IN1 & IN2 pins are used to control the direction of Motor A and IN3 & IN4 pins are used to control the direction of the Motor B.
e) OUT 1 & OUT 2 pins are connected to Motor A and OUT 3 & OUT 4 pins are connected to Motor B.

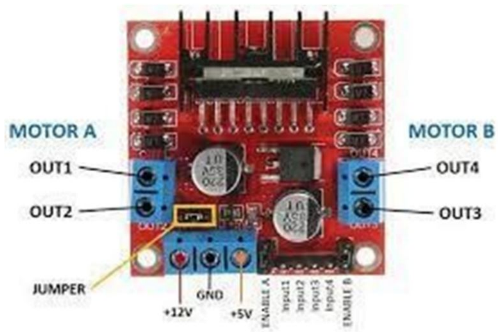

Fig.3 L298N Motor Driver Controller

3) *Stepper Motor:* Stepper Motors are DC motors that have angular steps defined for movement. We have used NEMA 17 Stepper Motor in our project, shown in fig.4. Black, Yellow, Green wires are part of the first winding where Black is center tap and Yellow & Green are coil ends. While Red, White, and Blue is part of the second winding in which White is center tap and Red & Blue are coil end wires. In use, the center taps of the windings (Black and White) are typically wired to the positive supply, and the two ends of each winding are alternately grounded through a drive circuit.

Fig. 4 NEMA 17 Stepper Motor

4) *Lead Screw Stepper Motor:* A lead screw stepper motor, shown on in fig.5, converts the rotational motion into linear motion by having a part slide over it when the motor rotates. The motor has six wires, which are Black, Yellow, Green wires are part of the first winding where Black is center tap and Yellow & Green are coil ends. While Red, White, and Blue is part of the second winding in which White is center tap and Red & Blue are coil end wires. In use, the center taps of the windings (Black and White) are typically wired to the positive supply, and the two ends of each winding are alternately grounded through a drive circuit.

Fig.5 NEMA 23 Lead Screw Motor [14]

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5) *Linear Guide Rails:* Guide Rails, shown in fig.6, are vertical rods with smooth finish which as the name suggest move a part in a particular axis in whatever motion the user lies. These rails are used where motion is restricted to only one axis and are very accurate in guiding this movement. The rails will be made of stainless steel of diameters 16x25x30mm with characteristics of high rigidity, high speed operation, low friction, low noise, and high precision.

Fig.6 Linear Guide Rails

6) *Linear Motion Bearing:* Linear motion bearings, shown in fig.7, are used to provide a frictionless motion in one axis. They are used with guide rails to support weight over them and move the part in one direction according to its application. The bearings used in the project has ball bearings and is made of stainless steel.

Fig. 7 Linear Motion Bearings

7) *GT2 Belt Drive and Timing Pulley for Linear Actuation:* The GT2 belt, shown in fig.8, is a loop of material that is flexible and is used to link two or more rotating shafts mechanically. They are mostly in parallel for an efficient transfer of motion. These belts looped over pullets that drive these belts. The GT2 pulley, shown in fig.9, can be called a medium between the motor shaft and the belt to create a strong link and prevent the slip of the belt. The belt has internal grooves whereas the pulley has external ones and once assembled these grooves lock in for direct transfer. GT2 is one type of specification for these belts and pulleys which are intended for a low load application. These are designed specifically for linear motion, and both use rounded tooth profiles. So, when one reverses the pulley there is no room for the belt to move in the groove.

Fig.8 GT2 Belt

Fig.9 Timing Pulley

8) *Limit Switch:* A limit switch is an electromechanical device operated by a physical force applied to it by an object. They are used to detect the presence or absence of an object. Limit switches are electromechanical devices consisting of an actuator mechanically linked to an electrical switch. When an object contacts the actuator, the switch will operate causing an electrical connection to make or break. In our project, the limit switches are connected at the two ends so that when the platform traverses at either of the ends, the limit switch will prevent it from overrunning. This saves us from the complexity of coding extensively to specify the number of turns to be turned by stepper motor. It also provides accuracy and is cost effective. We have used the *Lever Limit Switch* in our project.
9) *Power Supply:* A device that supplies electric power to an electrical load. The primary function is to supply the correct voltage and current for the specific use case. The main function of these is to convert the wall-voltage AC power to lower voltage DC power. This power supply, shown in fig.10, converts 240V AC into 12V DC 2A, which is the required specification for the electronics.

Fig.10 Power Supply

10) *Component Specifications Table*

Table below shows the various values of material to be used in the project work.

Table 1

Sr. No.	Components	Specification	
1.	NEMA 17 Bipolar Stepper Motor	Operating Voltage	12V DC
		Operating Temperature	-10°C to 40°C
		Rated Current	1.2 A at 4V
		Step Angle	1.8 deg
		Holding Torque	4.5 kg-cm
2.	Guide Rails	Material	Stainless Steel
		Length	1140mm
		Diameter	12mm
		Weight	150gm
3	GT2 Belt	Material	Fiber Glass
		Shape	Toothed
		Width	6mm
		Length	5m
4	GT2 Pulley	Material	Aluminum
		Inner Diameter	13mm 5mm
		Outer Diameter	5mm 13mm
		Width	6mm

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5	Linear Bearings	Material	Chromium Steel
		Diameter	12mm
6	Lever Limit Switch	Maximum Current	5A
		Maximum Voltage	250V
		Dimensions	20x10x7mm
7	Squeegee	Material	Wood Rubber
		Dimensions	100x50mm
8	Flat Bed	Dimensions	250x350mm
9	Mesh	Dimensions	200x200mm
10	Arduino Uno (Microchip ATmega328P)	Operating Voltage	5V
		Analog I/O Pins	6
		Clock Speed	16MHz
		Digital I/O Pins	14
		Flash Memory	32kb
		Input Voltage	7V - 20V
11	Motor DriverCircuit L298N	Operating Voltage	5V – 35V
		Battery Protection Mode	Yes
12	Power Supply	Output Voltage	12V
		Output Current	2A

11) *Computer Aided Design Model:* The major aspects of the design of the machine are shown below which consists of various component assemblies and mechanisms responsible for performing the functions of the screen printer such as moving the base tray, moving the Squeegee in both X and Y axis directions. We have SolidWorks to build our CAD model. Fig.11, fig.12 and fig.13 show different angles of the CAD model design.

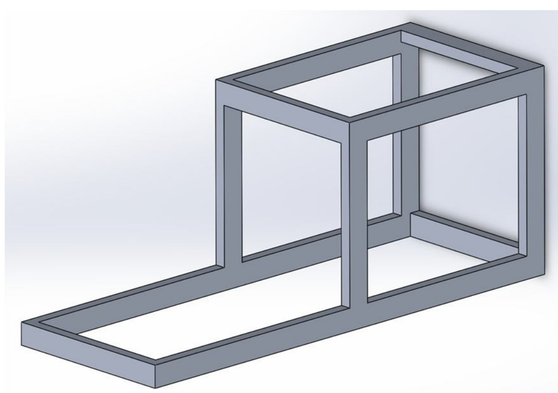

Fig.11 Aluminum Frame CAD Model

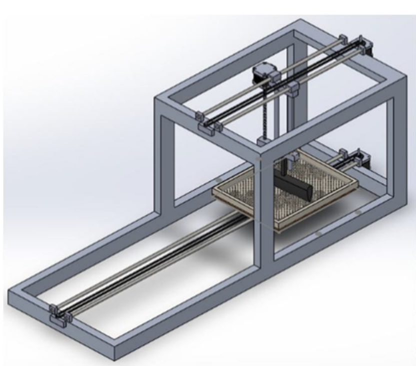

Fig.12 CAD Model Top View

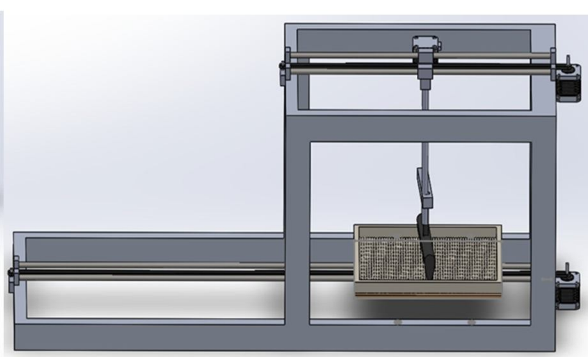

Fig.13 CAD Model Side View

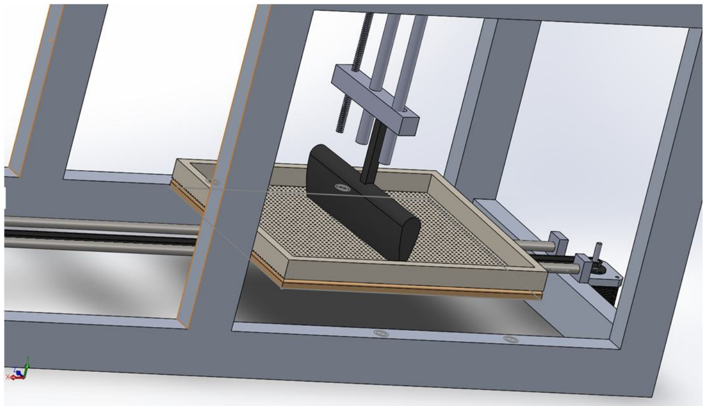

Fig.14 CAD Model (Squeegee Assembly)

12) *Method for Linear Actuation:* The linear actuation mechanism, shown in fig.14, for flat bed and squeegee is achieved with the help of GT2 pulley and timing belt. The pulley is mounted on the shaft of the stepper motor and the stepper motor is bolted with nuts on the aluminum frame. Two Stainless Steel rods are fixed across the length, where motion is desired. These rods are fixed with linear bearings, which reduce the friction in motion. The bearings are then bolted to a flatbed which rests on bearings. The timing belt is then attached to a flatbed. Thus, belts when placed on toothed pulleys can actuate linearly depending on the steps of the stepper motor thereby providing accurate and smooth actuation.

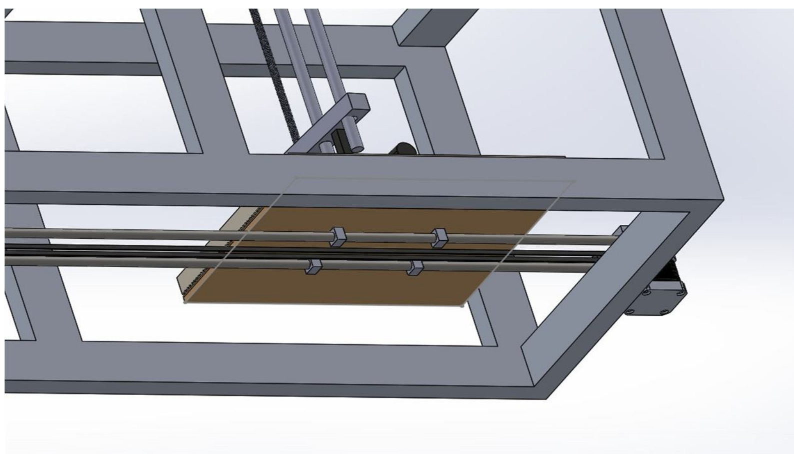

Fig.14 Linear Actuation Mechanism

13) *Design Parameters*

a) *Drive Motor Torque Calculations for Flatbed*

Weight of flat bed with material to be worked on = 1.25 kg
Maximum four linear bearings will be used on Stainless steel guide rails
Normal force on single bearing (N)= 1.25/4 = 0.3125 kg
Coefficient of friction between bearing and steel for dry condition (μ) = 0.55
Friction force on single bearing = μ × N = 0.55 × 0.3125 = 0.171 kg
Total frictional force = 0.171 x 4 = 0.685 kg
Radius of pulley = 6.5 cm
Torque acting on motor shaft = 0.685 x 6.5 = 4.468 kg-cm
Since this is the max torque that will be in action on motor shaft
Therefore, we select Stepper motor NEMA 17 of 4.5 Kg-cm torque

b) Drive Motor Torque Calculations for Squeegee and Collector Assembly

Weight of Squeegee assembly = 2.5 kg(max)
Four linear bearings will be used on Stainless steel guide rails
Normal force on single bearing (N)= 2.5/4 = 0.625 kg
Coefficient of friction between bearing and steel for dry condition (μ) = 0.55
Friction force on single bearing = μ × N = 0.55 × 0.625 = 0.0.343 kg
Total frictional force = 0.343 * 4 = 1.375kg
Radius of pulley = 6.5 cm
Torque acting on motor shaft = 1.375 * 6.5 = 8.937 kg-cm
Since this is the max torque that will be in action on motor shaft
Therefore, we select Stepper motor NEMA 23 of 7.2 Kg-cm torque
Same motor coupled with a lead screw can be used for vertical motion of Squeegee assembly

c) Belt Length Calculation for Flatbed

Belt length = Distance between pulley + 2 x (π) x (Outer Radius of pulley)
= 1120 + 13 = 1133mm

d) Belt Length Calculation for Squeegee Assembly

Belt length = Distance between pulley + 2 x (π) x (Outer Radius of pulley)
= 570 + 13 = 583mm

14) Simulation and Code

a) Simulation: The simulation of the electric circuit was run on TinkerCad software. TinkerCad is a free, online 3D modeling program that runs in a web browser. The simulations that we ran were for checking circuit connections and providing ample amounts of voltage and current. The simulation included implementing IC498 on breadboard along with three stepper motors which are included in our project. Each motor is named in respect of their function and use. Each motor requires a driver circuit (IC) which drives it from the pulses received by Arduino uno. The wires of Stepper motors are connected to Arduino and Power supply. There is also a feature to upload your codes and test them. When code is uploaded, the debugger checks for errors and compiles the code. The code can then be tested by running the simulation. Various components like Breadboard, Arduino, IC, Resistor, Capacitor, Encoder etc. can be browsed and placed on the workbench as shown in fig.15.

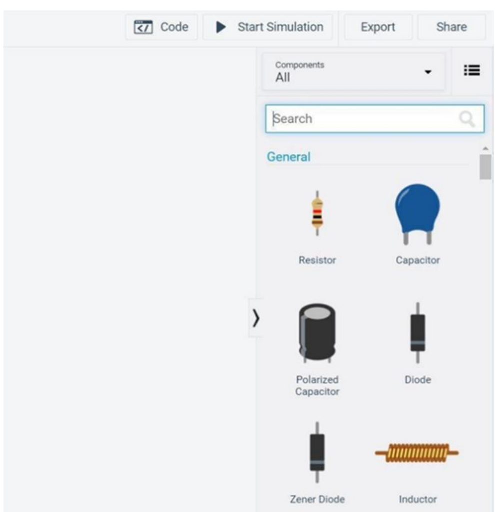

Fig.15 Electrical Components for Simulation

Simulation shown in fig.16 is for 3 motors controlled by driver circuit receiving pulses from Arduino uno running on 12V Power supply.

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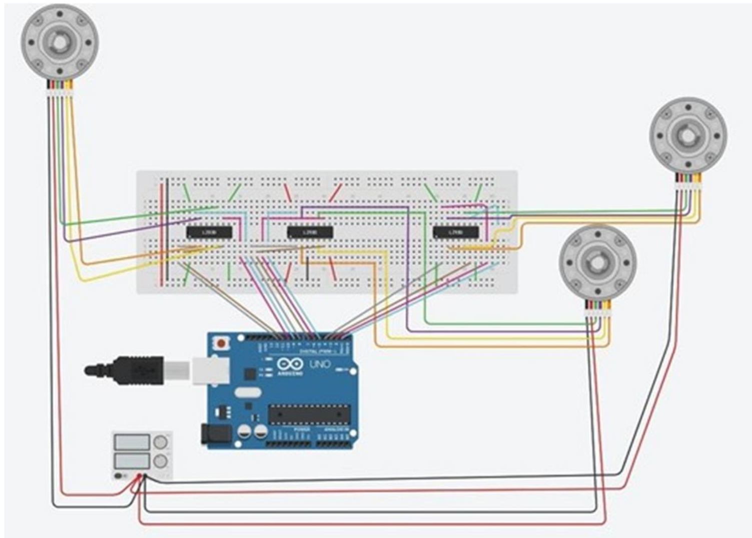

Fig.16 Simulation of Motors on TinkerCad

b) C ++ Code Syntax used to Control the Stepper Motors

- *For Flatbed*

```
// defines pins numbers const int stepPin = 1;
const int dirPin = 2;
const int enPin = 3;
const int homeSwitchPin = 4;
void setup ()
{
Serial.begin (9600);
// Sets the two pins as Outputs
pinMode(stepPin,OUTPUT);
pinMode(dirPin,OUTPUT);
pinMode(homeSwitchPin , INPUT);
 pinMode(enPin,OUTPUT);
digitalWrite(enPin,LOW);
// Set Dir to Home switch
digitalWrite(dirPin,LOW); // Enables the motor to move in a particular direction
}
void loop ()
{
int homeSw = digitalRead( homeSwitchPin);
if( homeSw == HIGH && (digitalRead(dirPin) == LOW) )
{
motorStep(1);
}
else if( homeSw == LOW && (digitalRead(dirPin) == LOW) )
{
digitalWrite(dirPin,HIGH);
delay(2000);
}
if( (digitalRead(dirPin) == HIGH) )
{
```

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```
 motorStep(2000);
 digitalWrite(dirPin,LOW);
delay(2000);
}
}
void motorStep( int MAX)
{
for(int x = 0; x < MAX; x++)
{ digitalWrite(stepPin,HIGH);
delayMicroseconds(500);
digitalWrite(stepPin,LOW);
delayMicroseconds(500);
}
}
```

- *For Squeegee Linear Actuation*

```
// defines pins numbers const int stepPin = 5;
const int dirPin = 6;
 const int enPin = 7;
const int homeSwitchPin = 8;
void setup() {
Serial.begin(9600);
// Sets the two pins as Outputs
pinMode(stepPin,OUTPUT);
pinMode(dirPin,OUTPUT);
pinMode(homeSwitchPin , INPUT);
pinMode(enPin,OUTPUT);
digitalWrite(enPin,LOW);
// Set Dir to Home switch
digitalWrite(dirPin,LOW); // Enables the motor to move in a particular direction
}
void loop ()
{
int homeSw = digitalRead( homeSwitchPin);
if( homeSw == HIGH && (digitalRead(dirPin) == LOW) )
{
motorStep(1);
}
else if( homeSw == LOW && (digitalRead(dirPin) == LOW) )
{
digitalWrite(dirPin,HIGH);
delay(2000);
}
if( (digitalRead(dirPin) == HIGH) )
{ motorStep(750);
digitalWrite(dirPin,LOW);
 delay(2000);
}
}
void motorStep( int MAX)
```



```
{
for (int x = 0; x < MAX; x++)
{
digitalWrite(stepPin,HIGH);
 delayMicroseconds(500);
digitalWrite(stepPin,LOW);
 delayMicroseconds(500);
}
}
```

V. CONCLUSION AND FUTURE SCOPE

1) *Conclusion:* An automatic screen-printing machine is profitable in the long term, and our design is much cheaper than designs available in most markets in the present day. The major advantage of automatic screen printing over manual printing is, that due to a reduction of human involvement, the chances of tearing of screen or reduction in capacity of printing is minimal. It also ensures that the quality of print remains consistent, so that the final product is much easier to mass manufacture, and the chance of human error is reduced by a very big factor.

2) *Limitations*
a) Maintenance Requirement
b) Affected by Print Surface Elevation
c) Does not offer Scaled Cost Reduction

3) *Future Scope:* The need for making an Automatic Screen Printer is necessary to check how far this technology can be taken when it comes to printing in multiples may it be paper or textiles. The Future scope for screen printing includes usage of spray mechanisms, or 3D printed components for ease of manufacturing or mass-manufactured and machined components so that the manufacturing of Automated Screen-Printing Machine in a much more effective way. The use of laser technology to etch designs into a flat plane can also use the same technology and method of printing that we use, by replacing the squeegee on top with a nozzle that sprays paint, or a laser that etches a pattern into the required component. We aim to minimize the wastage as well as the cost for the whole setup which can make it easy for more industries to save money on their machines and adapt to this method. The future is also aimed at taking up less working space and to make this technology available at the same cost for both single and bulk printing.

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