# AUTOMATION OF FIBER COMPOSITE MANUFACTURING PROCESS

(In partial fulfillment for the course of Mechatronics, ME5643)

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# Section 1

# Introduction

Composite materials (or composites for short) are engineered materials made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure. Use of composite materials in our daily life is not new and the most primitive composite materials comprised straw and mud in the form of bricks for building construction. Nowadays composites are used for variety of purposes ranging for daily use households such as bath tubs etc. to high end demanding applications such as airplanes and space vehicles etc. Increasing use of composites demand for automation of their manufacturing processes and one such attempt is describing in this report for special class of composite material.

## 1.1 Project Description

A fabric fiber composite material is shown in figure 1. It consists of alternate layers of fiber fabric and bonding resin. Resin matrix acts as a bonding member for fibers. These composites can be of different lengths depending upon the purpose of end product.

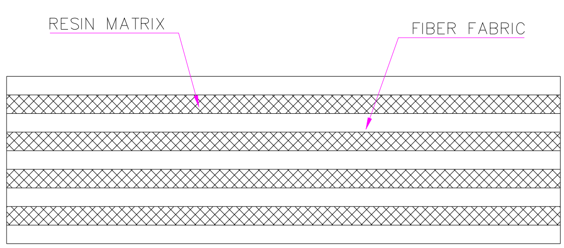


**Figure 1.** Fiber composite material

This project aims at automation of manufacturing process for above composite which includes followings,

1. Cut the fabric in different lengths required.
2. Transport the cut fabric to required place for bonding.

3. Hold it for resin application.
4. Automatically adjust for the increasing thickness with each layer.

The project excludes automation of resin in its current form as it involves too many cumbersome components.

## 1.2 Report organization

The report is organized in following way,

1. Section 2 describes the mechanical design methodology and layout for the automation process, describes important components of layout and discusses their pros and cons.
2. Section 2 describes in details the electrical and electronics parts in the project. It explains detailed circuit diagram for entire project and for the components as necessary.
3. Section 3 details the cost involved in making the current prototype.
4. Section 4 describes the limitations and possible future developments of the project.

Bill of materials and PBASIC code are attached as appendices.

**Section 2**

# Process layout and mechanical design

## 2.1 Process Layout

The entire process layout is shown in figure 2 which also shows different stations of the entire line. As it becomes clear from the diagram, the fabric is in the form of roll which is drawn by main drive rollers via set of idlers that avoid any slack in the fabric. The main drive rollers are rotated by fixed number of revolutions thus decide the length of the fabric to be cut. Right after main rollers, pull in rollers hold the fabric during cutting and also transport the cut fabric to the next stage. In between these two roller sets, cutter is provided which cuts the fabric as drive rollers stop.

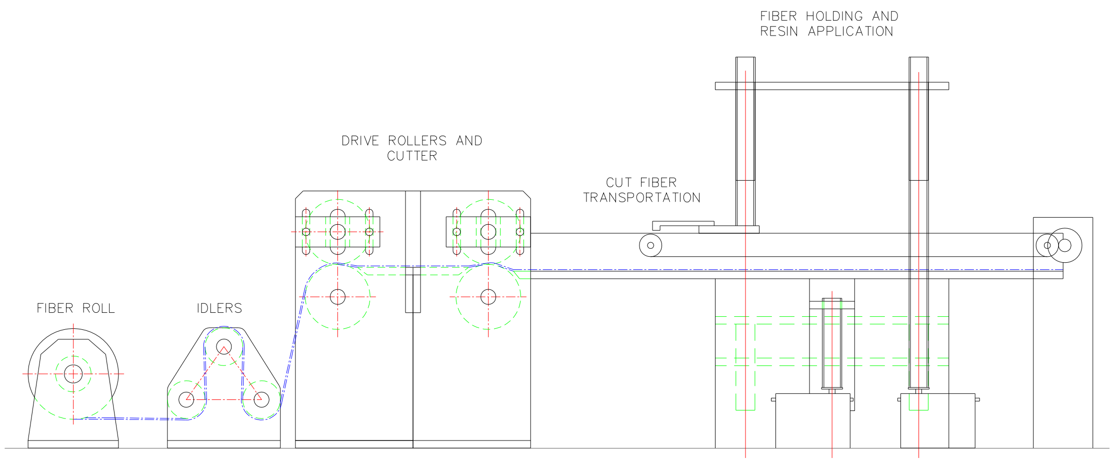


**Figure 2.** Automation layout

The cut fabric strips are transported to next stage which transports them to manufacturing station. The manufacturing station here is nothing but a set of movable tables. This station holds the fabric so that resin can be applied on it and the base table provides mechanism for thickness adjustment. One after the other the stack of fabric and resin goes on building and final composite material is achieved. A prototype photo of entire layout is shown in figure 3. Next part of this section describes major mechanical modules of the line.

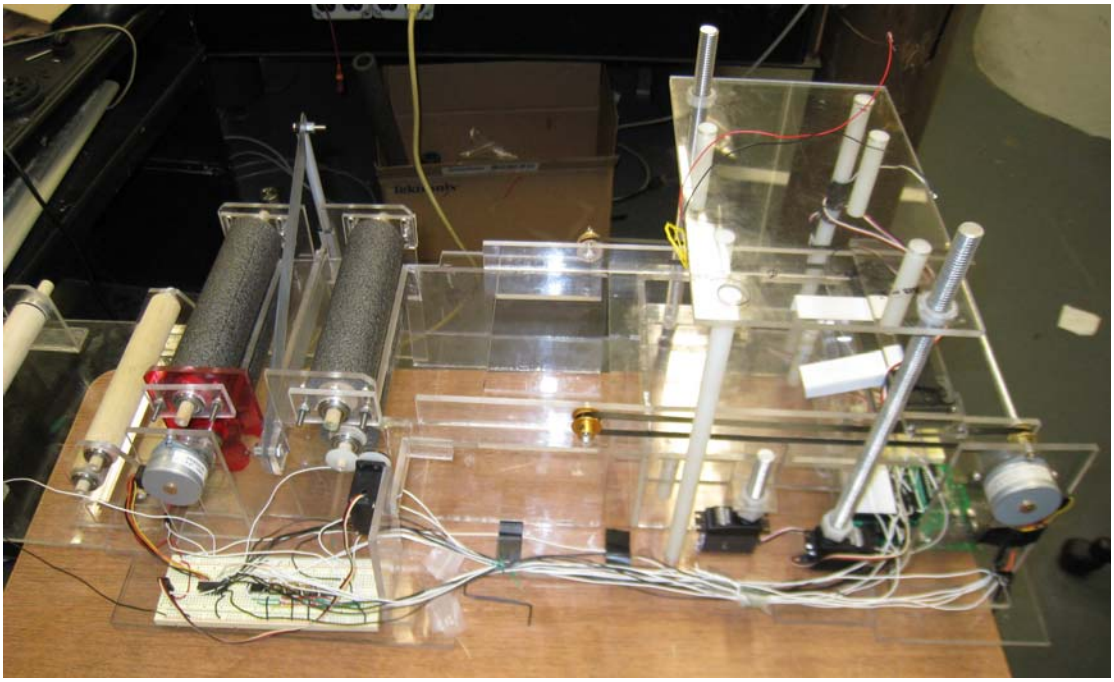

**Figure 3.** Model of manufacturing process

## 2.2 Mechanical Design

The detailed mechanical design is carried out for the model and individual component drawings were prepared. All the frame structures are made up of acrylic for ease in manufacturing. Component wise description and working is explained below.

### 2.2.1 Drive rollers and cutter

Total two drive rollers and two pull in rollers are provided. The rollers are made up of wooden core with foam on them. They are supported in ball bearings in acrylic frame. Lower rollers of drive set and pull in set are driven by motors. A steel cutter is provided between the rollers which is operated by a linear actuator. A pictorial view and photo is shown in figure 4.

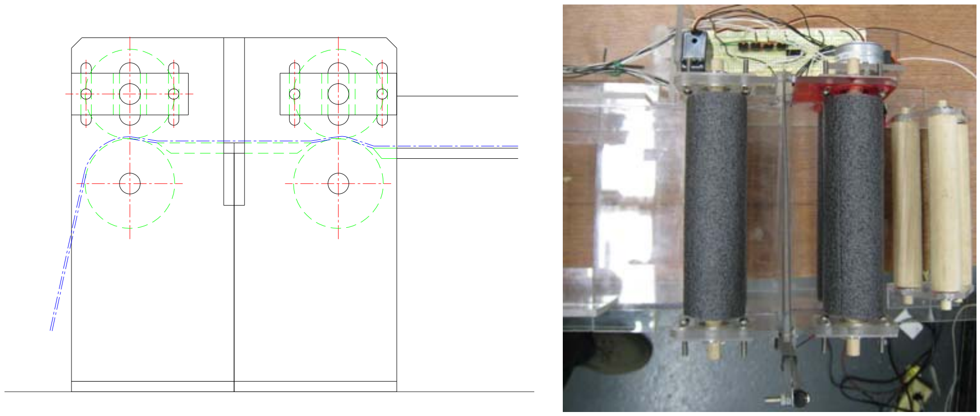

**Figure 4.** Drive rollers and cutter

## 2.2.3 Fiber transportation

A platform operated by motors and timing belt system is used to carry the cut fiber fabric from one place to other. The platform has two standard servo to grip the fabric and stepper motor mechanism accurately transports the fabric to the platform where it drops it. A pictorial view and photo is shown in the figure 5.

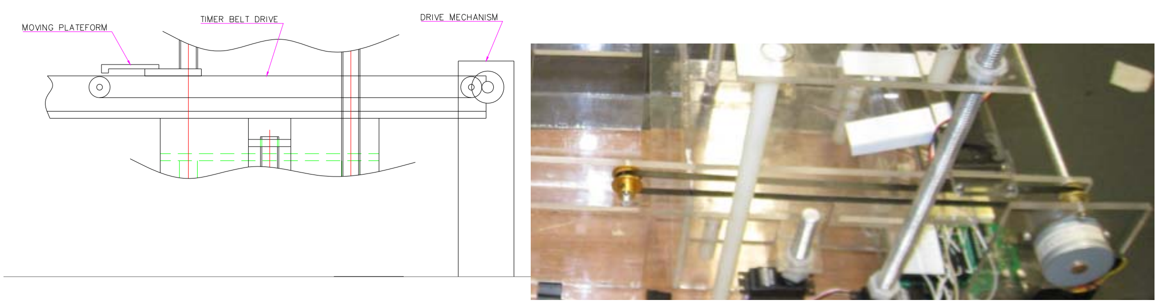


**Figure 5.** Fiber transportation system

## 2.2.3 Holding and resin application platform

The cut fabric is transported to this platform where it is held by means of four legs with the help of servo motors and screw mechanism. A pressure sensor is provided which decided when the legs must stop. After holding and resin application, the lower table moves down again using similar mechanism. This movement is imparted to incorporate the thickness of fabric. Here all the structural parts are made up of acrylic sheets and aluminum screw is used for motion of table using motors. Figure 6 shows pictorial view and photo for this part.

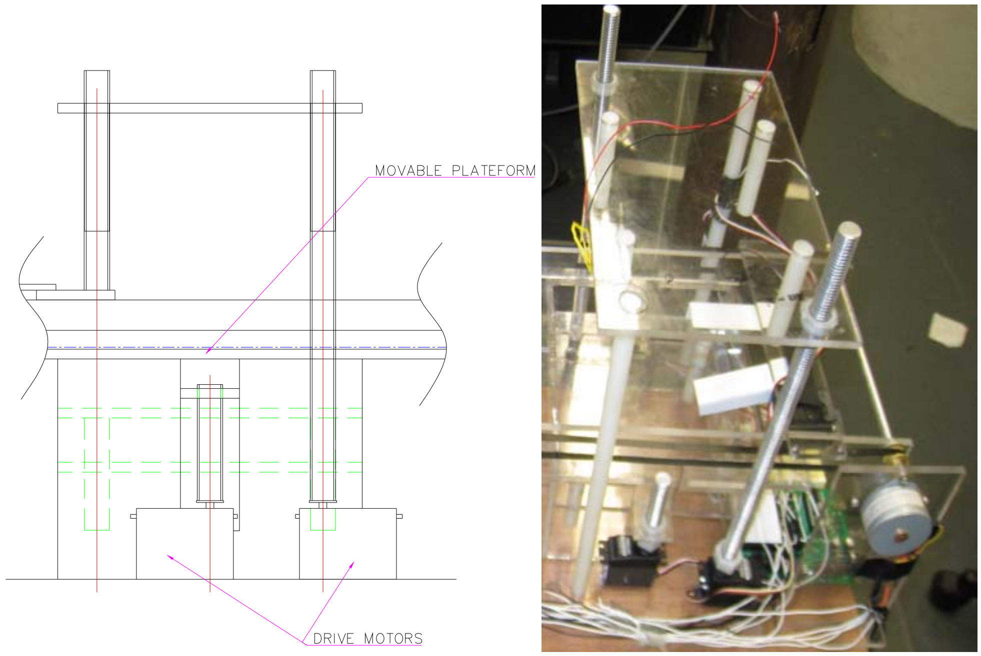


**Figure 6.** Fiber holding and resin application platform

Apart from the above main modules various simple parts like supports and structures are designed based on requirement during fabrication and are made up of acrylic sheets.

## Section 3

# Electrical and Electronic Design

In this section we discuss the major electrical and electronic hardware used in the project. A detailed circuit diagrams are used to explain the position of various components in the system.

## 3.1 Hardware

Followings are the major electrical/electronic hardware used in the project with their specific operation,

1. **Stepper motors**
   Stepper motors are used to drive main rollers and control travel of transportation platform.

2. **Standard servo**
   These are used on the platform to grip the fabric.

3. **Continuous servo**
   These are used to drive pull in rollers, upper table and lower table.

4. **Linear actuator**
   This is used for movement of cutter.

5. **Pressure sensor**
   This is used to decide operation threshold for upper moving table.

6. **Stepper motor drive IC**
   This is used for driving the stepper motors.

7. **Mosfets and buffer**
   Mospfets and buffers are used to form an H-bridge for direction control of linear actuator.

8. **Miscellaneous components**

   Various other components like power supply, jumper wires etc.

## 3.2 Circuit Diagram

There are various circuits connecting to Basic Stamp micro controller. Individual circuit diagrams are shown with their use in the project.

1. **Stepper motor drive circuit**

   This is used to drive two uni-polar four phase stepper motors. An electronic switching device ULN2803 is used for this purpose.

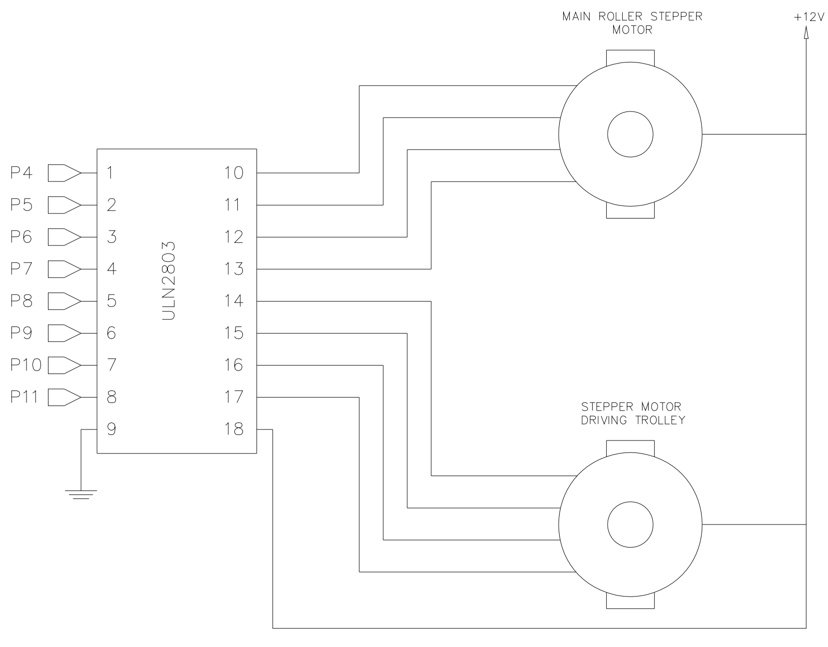


**Figure 7.** Stepper motor drive circuit

2. **Linear actuator drive circuit**

   This is used to drive the linear actuator in both the direction utilizing its motion for cutting. Four n-channel enhancement type mosfets are used for this purpose.

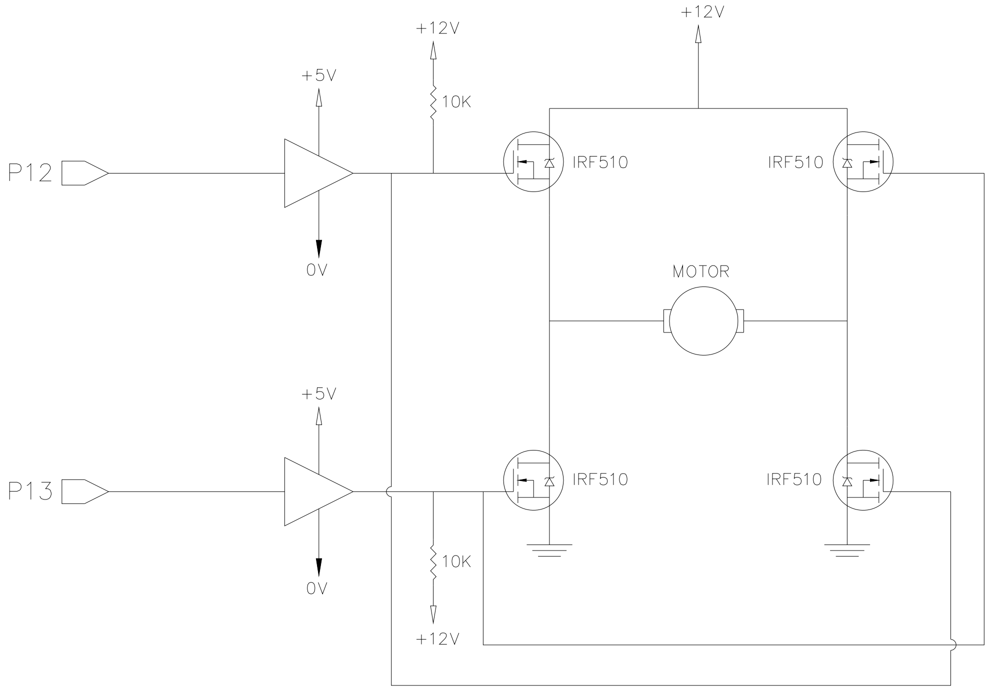


**Figure 8.** Linear actuator drive circuit

**3. Pressure sensor circuit**

This RC circuit uses resistive pressure sensor as resistor and gives out an RCTime value which in turn is used to movement of upper table.

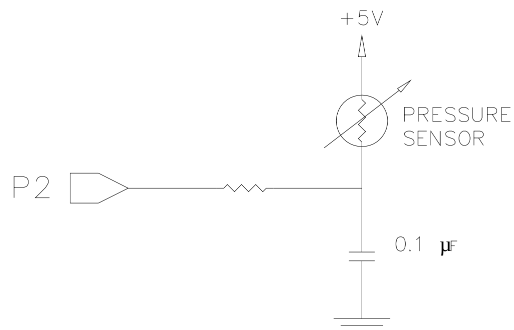


**Figure 9.** Pressure sensor circuit

## 4. Continuous and standard servo drive circuit

This simple circuit is used to drive servos at various places in the system.

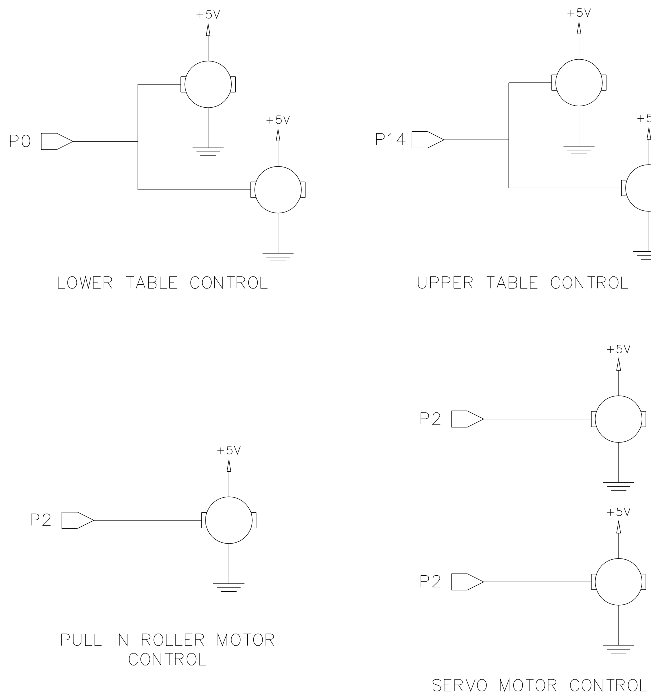


**Figure 10.** Servo drive circuits

## Section 3

# Cost Estimation

The table below lists the cost of all the components used in the project.

**Table 1.** Cost estimation

| Sr. No. | Component Name | Quantity | Cost |
|---|---|---|---|
| 1 | Basic stamp BOE | 1 | 99.95 |
| 2 | Linear actuator | 1 | 70 |
| 3 | Stepper motor | 2 | 21.9 |
| 4 | Continuous servo | 5 | 64.75 |
| 5 | Standard servo | 2 | 25.9 |
| 6 | Mosfets IRF510 | 4 | 16 |
| 7 | Stepper motor driverULN2803 | 1 | 1.5 |
| 8 | Pressure sensor | 1 | 6 |
| 9 | Acrylic sheet, wooden rod and hardware | | 50.49 |
| 10 | Ball Bearings | 16 | 40.8 |
| 11 | Timing belt | 2 | 17.07 |
| 12 | Timing belt pulley | 4 | 35.52 |
| 13 | Gears | 6 | 39.20 |
| 14 | Nylon rods, nuts etc | | 47.22 |
| 15 | Others (Transportation, mailing, taxes etc.) | | 35.68 |
| **Total** | | | **571.98** |

## Section 4

# Limitations

Even though project tries to address most of the automation issues involved, following emerge as its main limitations,

1. The model proposed in its current state doesn’t provide any means to check the fiber orientation which drastically affects composite material property.
2. Resin application is required to be done manually.
3. The holding mechanism proposed is slow due to use of threads but can be easily changed to other linear actuators.

# Future Possibilities

The project associates various promising future possibilities even though above limitations are present which can be thought of obstacles that has to be removed.

1. Incorporate a sensory system to check fiber orientation and discard incorrect pieces
2. Device the mechanism which would allow differently oriented fibers to be processed serially so that mixed type composites can be produced.

# Conclusion

1. The mechanism operates slowly but satisfactorily.
2. It was found that individually the components performed as required but in integrated form synchronization difficulties exist.
3. Cutter has width limitation to handle in the current sate.
4. The model can be improved for its actuation mechanisms and actual line manufacturing can be possibly achieved.

# Acknowledgement

1. Prof. V Kapila
2. Prof. N. Gupta (process and design methodology)
3. Mr. Alessandro Betti (model making assistance)
4. www.paralax.com (circuit and code references)
5. www.trossenrobotics.com (robotics components)

## Appendix A

# PBASIC Code

```
' {$STAMP BS2}
' {$PBASIC 2.5}

'-----[ I/O Definitions ]---------------------------------
OUTPUT 0
OUTPUT 2
OUTPUT 3
OUTPUT 14
OUTPUT 15

'-----[ Constants ]---------------------------------------
StpsPerRev_01 CON 96
' whole steps per rev
StpsPerRev_02 CON 96
' whole steps per rev
LiMoDeTi   CON 10000

'-----[ Variables ]---------------------------------------
Phase_01   VAR OUTB           ' phase control outputs
Phase_02   VAR OUTC
x          VAR Byte
idx        VAR Byte           ' loop counter
tau        VAR Word           ' RCtime
request    VAR Nib
FwdStps    VAR Word
RevrStps   VAR Word
stpIdx     VAR Nib            ' step pointer
stpDelay   VAR Byte           ' delay for speed control

'-----[ Subroutine - Stepper_Motor_01 ]--------------------
 Steps_01 DATA %0011, %0110, %1100, %1001
 DIRB = %1111                        'make P4..P7 outputs
 stpDelay = 15
 FOR idx = 1 TO StpsPerRev_01        'one revolution
  stpIdx = stpIdx + 1 // 4
  READ (Steps_01 + stpIdx), Phase_01 'output new phase data
  PAUSE stpDelay
  PULSOUT 2, 700                     ' rotate clockwise
 NEXT
```

```
'-----[ Subroutine - Linear_Motor ]-----------------------
FOR x = 1 TO 2
 HIGH 12
 PAUSE 13000
 LOW 12
 PAUSE 10
 HIGH 13
 PAUSE 13000
 LOW 13
 NEXT
 PAUSE 200

'-----[ Subroutine - Stepper_Motor_02 ]-------------------
 Steps_02 DATA %0011, %0110, %1100, %1001
 DIRC = %1111
 stpDelay = 1502                  ' output new phase data
 FOR idx = 1 TO 255
    stpIdx = stpIdx + 3 // 4
    READ (Steps_02 + stpIdx), Phase_    PAUSE stpDelay
    NEXT
    PAUSE 100
 FOR idx = 1 TO 200               ' output new phase data
    stpIdx = stpIdx + 1 // 4
    READ (Steps_02 + stpIdx), Phase_02
PAUSE stpDelay
    NEXT
  PAUSE 1000
 FOR idx = 1 TO 55                ' output new phase data
    stpIdx = stpIdx + 1 // 4
    READ (Steps_02 + stpIdx), Phase_02
PAUSE stpDelay
    NEXT
    PAUSE 100

'-----[ Subroutine - Two Servo Motor ]--------------------
FOR x = 1 TO 500
 PULSOUT 3, 500
 PULSOUT 15, 1000
 PAUSE 10
 NEXT
 PAUSE 100

'-----[ Subroutine - Upper Table ]------------------------
FOR x = 1 TO 500
 PULSOUT 14, 500
 PAUSE 10
 NEXT
```

```
 PAUSE 100
 FOR x = 1 TO 500
 PULSOUT 14, 1000
 PAUSE 10
 NEXT
 PAUSE 100

'-----[ Subroutine - Pressure Sensor ]---------------------
DO
 HIGH 1
 PAUSE 3
 RCTIME 0, 1, tau
 'DEBUG ? tau
 PAUSE 100
 IF tau > 500 THEN
    GOTO TableGoUp
 ENDIF
LOOP

TableGoUp:
FOR x = 1 TO 500
 PULSOUT 14, 500
 PAUSE 10
NEXT
 PAUSE 100

'----[ Subroutine - Lower Table ]-------------------------
FOR x = 1 TO 500
 PULSOUT 0, 500
 PAUSE 10
 NEXT
 PAUSE 100
FOR x = 1 TO 500
 PULSOUT 0, 1000
 PAUSE 10
 NEXT
 PAUSE 100
```

## Appendix B

# Bill of material

| Sr. No. | Description | Material | Quantity |
|---|---|---|---|
| 1 | Wooden Rollers for main rollers and idler | Wood | 7 |
| 2 | Wooden roller for fabric roll | Wood | 1 |
| 3 | Foam cover | | 4 |
| 4 | Screws for upper table, ½” Nominal Dia. | Aluminum | 2 |
| 5 | Screws for lower table, ½” Nominal Dia. | Aluminum | 2 |
| 6 | Timer belt | Nylon | 2 |
| 7 | Bearings, Diameter 9.5 mm | | 14 |
| 8 | Bearings, Diameter 12.5 mm | | 2 |
| 9 | Timer belt pulley | Aluminum | 4 |
| 10 | Nuts, ½” Nominal Dia. | Nylon | 4 |
| 11 | Rod, ½” OD | Nylon | 4 fts. |
| 12 | Acrylic sheet, 3’ x 3’ | | 1 |
| 13 | Steel rod, 6mm dia. 220mm long | MS | 1 |
| 14 | Stepper motor | | 2 |
| 15 | Continuous servo | | 5 |
| 16 | Standard servo | | 2 |
| 17 | Linear actuator | | 1 |
| 18 | Mosfets IRF510 | | 4 |
| 19 | Stepper motor drive, ULN2803 | | 1 |
| 20 | BS2 BOE | | 1 |

| | | | |
|---|---|---|---|
| 21 | Jumper wires, glue etc | | |
| 22 | Set Screws | | 14 |
| 23 | Pressure sensor | | 1 |
| 24 | Gears | | 6 |