UNIVERSITY OF NAIROBI

DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING

CONTROL LAB MANUAL

AUTOMATION OF A CONVEYOR BELT SYSTEM

July, 2018

OBJECTIVE AND INTRODUCTORY REMARKS

The objective of this lab is to design and implement a PLC program that can control a conveyor belt system. The lab incorporates various aspects of PLC programming as well as electropnuematic actuators, which were introduced in the first semester.

This is a mini-project and all the five lab sessions are to be used for the design and implementation of the PLC program. You are encouraged to explore and make use of the S7-200 Siemens simulator to carry out further design and experimentation even when outside the lab.

ASSESSMENT

Success in the lab will be gauged by the degree to which the developed program achieves the specifications given for the conveyor belt system.

Marks will be given for the following:

i. Whether 12 sequences of the machining cycle (as described in the specification in Chapter 3) have been achieved
ii. Preparation => evidence of **theory and manual** read, designs prepared outside the lab, **simulations carried out**
iii. Participation: involvement during actual lab work
iv. Explaining the preparation, work done and how objectives are met
v. Most impressive part of your design/implementation
vi. Challenges faced and how they were overcome
vii. Answering questions posed in the lab by the lecturer/technician
viii. Lab report

NB: no. i will carry the bulk of the marks, followed by no. ii – vii (taken together) and followed by the lab report. More marks will be awarded to students who are seen to be more active in regard to no. ii – vii.

CONTENTS

CHAPTER 1:INTRODUCTION

The conveyor belts, called conveyors, are widely used by the industry in fields which are varied such:

• **Metal and mechanic field**
• **Chemical-industrial field**
• **Agro-industrial field**
• **Packaging field**

In the above fields, the conveyors represent a segment inside wider productive line; this takes to the need to integrate these systems to the other parts so to automate the production cycles. In this context, the control of conveyors with **PLC** (**P**rogrammable **L**ogic **C**ontroller) is very important, as their programming via PC enables a high flexibility in the parameters variation.

The automation process with conveyor mod. TSM-700/EV (fig. 1.1) has been specifically designed for the development of PLC programming exercises involving the use of mechanical, electrical, electronic, pneumatic technologies.
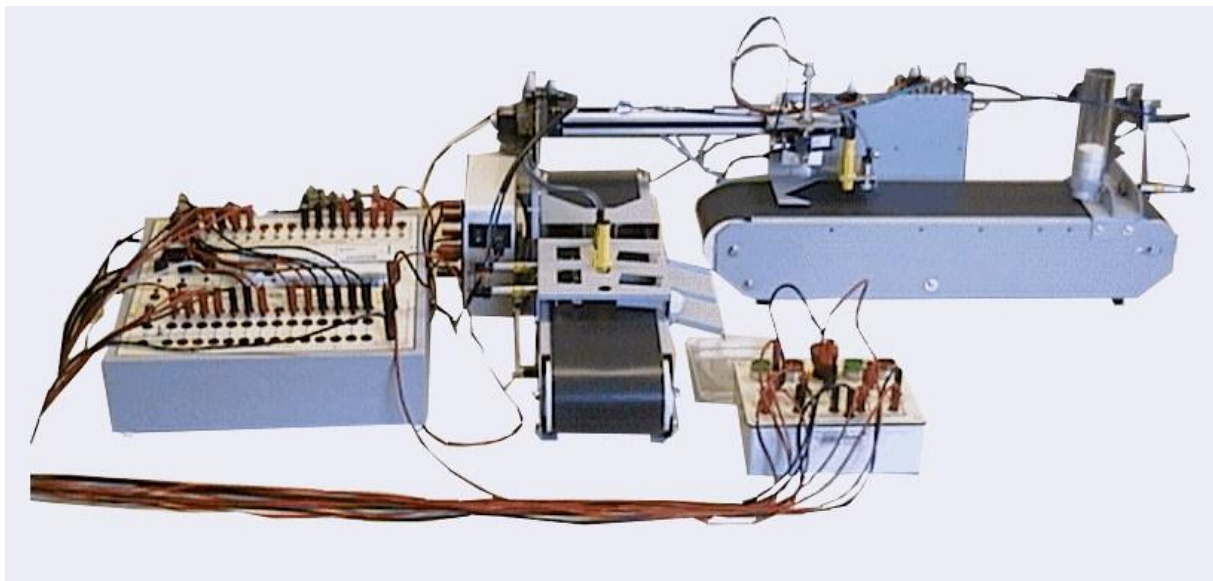

fig. 1.1 Automation process with conveyor mod. TSM-700/EV.

CHAPTER 2:GENERAL DESCRIPTION OF THE SYSTEM mod. TSM-700/EV

2.1 STRUCTURE AND FUNCTIONS OF THE SYSTEM

The automation process with conveyor mod. TSM-700/EV shows a **modular** architecture, as it is composed of 2 independent conveying units, each of which, developing a different machining phase, integrates inside the production cycle. So, the system on its whole is composed of:

- **CONVEYOR UNIT 1**

- **CONVEYOR UNIT 2**

- **CONTROL UNIT**

2.2 CONVEYOR UNIT 1

The conveyor unit 1 (see fig. 2.1a and fig. 2.1b) is composed of:

- Conveyor belt controlled with single-phase a.c. motor
- Plexiglass cylindrical magazine for the vertical pieces.
- Pneumatic piece pushing cylinder consisting a single-effect cylinder.
- Support for capacitive and inductive sensors (fig. 2.2)
- Capacitive sensor (24 Vdc-output)
- Inductive sensor (24 Vdc-output)
- **"Pick and Place"** mobile unit composed of a vacuum unit and a simple-effect lifting cylinder (fig. 2.3)
- Double-effect rodless cylinder for carrying the **"Pick and Place"** unit (fig. 2.4)**.**
- Set of monostable solenoid valves for control of the pneumatic actuators.
- 3 magnetic limit switches type "**REED"** set on the conveyor cylinder for detection of the position of the **"Pick and Place"** unit.
- Electrical control board (fig. 2.5) provided with:
- Electrical terminals ($\varnothing$ 4 mm) for connection to PLC via the supplied cables;
- silk screen bakelite panel, with the symbols of the used electropneumatic components and the related electrical connections.
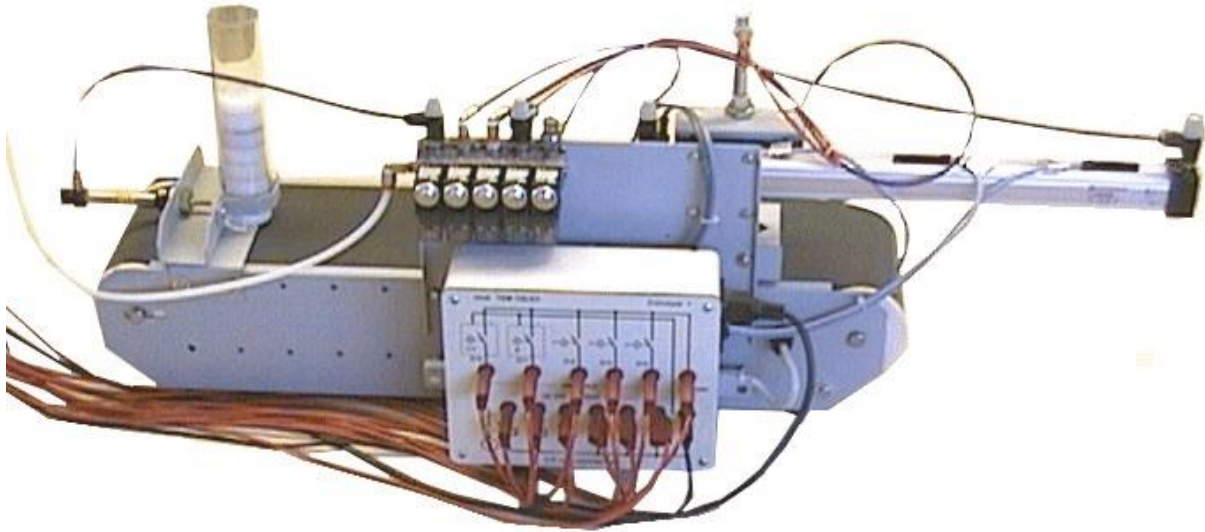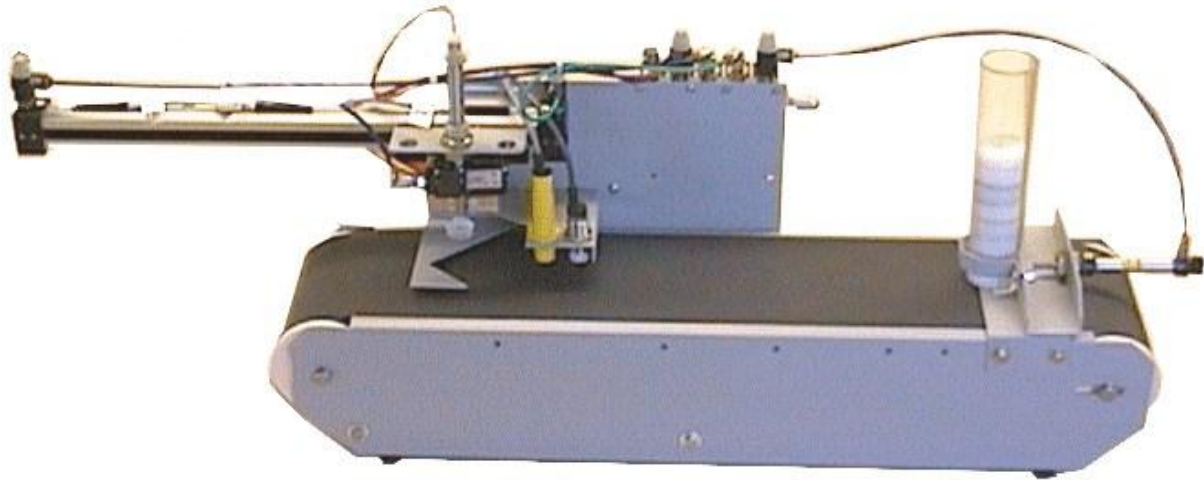
fig. 2.1.a Conveyor unit 1 (front side)

fig. 2.1.b Conveyor unit 1 (back side)

The vertical magazine can contain 8 cylindrical machining pieces divided in this way:

• 4 plastic pieces type "A" covered with an aluminum film.
• 4 plastic pieces type "B"

The inductive sensors can only detect the type "A" pieces whereas the capacitive sensors can detect both type "A" and type "B" pieces.

The following truth table shows the possible situations:

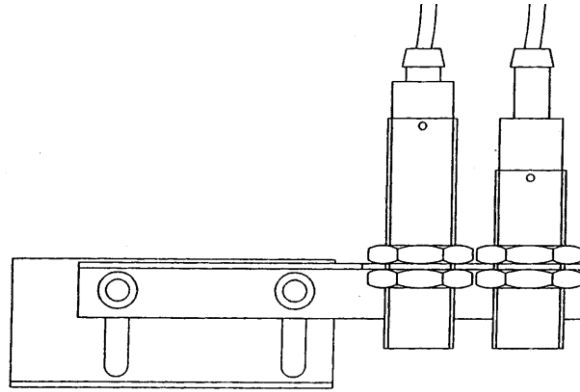| Type of piece present	Logic State of Inductive Sensor	Logic State of Capacitive Sensor
"A"	1	1
"B"	0	1

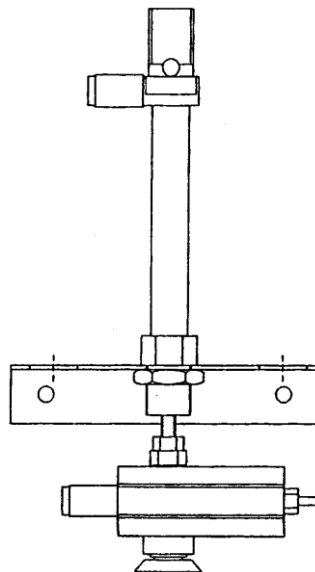*fig. 2.2 Sensor-holding metal support*
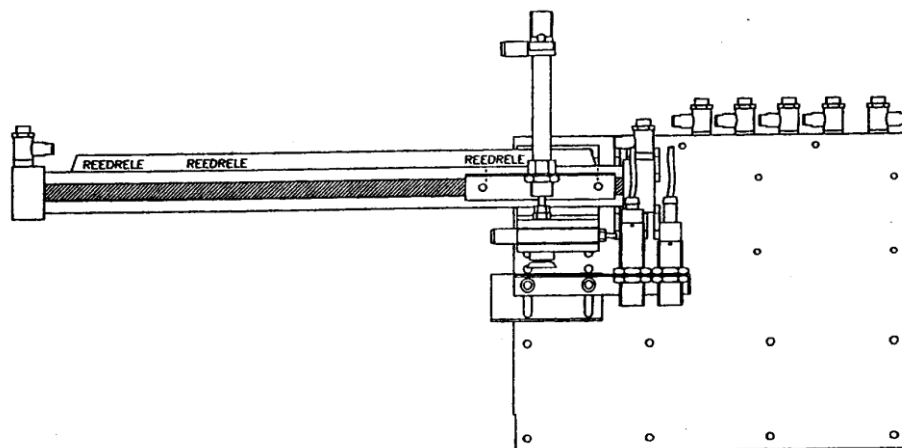

fig. 2.3. Pick and Place unit.

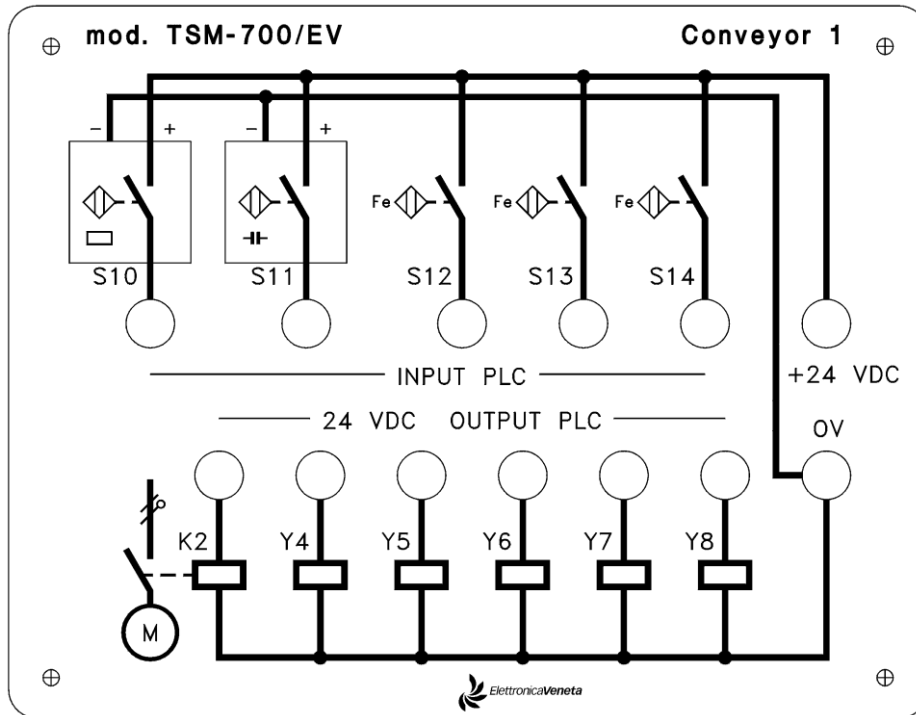*fig. 2.4. Double-effect conveyor rodless* cylinder

fig. 2.5 Electrical control board.

2.3 MACHINING SEQUENCES WITH BASE CONVEYOR UNIT 1

Hereafter follow the base machining sequences that can be carried out with the conveyor unit 1. **These sequences are only a guideline; therefore, different variations "ad libitum" can be developed according to the kind of approach chosen by the lab group.**

1. The conveyor belt starts moving by powering the single-phase motor.
2. The machining pieces are ejected by the cylinder and conveyed by the belt. Note that conveyor unit 1 has 2 sensors.
3. The sensors detect the presence of the pieces. It is sufficient to use the capacitive sensor for detecting a piece regardless of its type (i.e. metallic or non-metallic); however, the inductive sensor can be used for counting and quality control operations.
4. Once the piece passes the sensors and is under the "Pick and Place" unit, the conveyor belt stops moving and the "Pick and Place" unit provided with vacuum unit lifts the piece.
5. The conveyor cylinder moves the mobile **"Pick and Place"** unit to a position determined by the limit switches type **"REED" S12, S13, S14.** At this point the piece is released onto the conveyor unit 2.

2.4 CONVEYOR UNIT 2

The conveyor unit 1 (see fig. 2.6.a and 2.6.b) is composed of:

- Conveyor belt controlled with single-phase a.c. motor
- Support for capacitive and inductive sensor with chute with two ways for pieces "A" and "B" (fig. 2.7).
- Set of solenoid valves for control of the pneumatic actuators.
- Capacitive probe
- Inductive sensor
- Pneumatic pushing cylinder for pieces type "A"
- Pneumatic pushing cylinder for pieces type "B"
- Electrical control board (fig. 2.8) provided with:
  - Ø 4-mm connectors for PLC connection
  - silk screen bakelite panel, with the symbols of the used electropneumatic components and the related electrical connections.
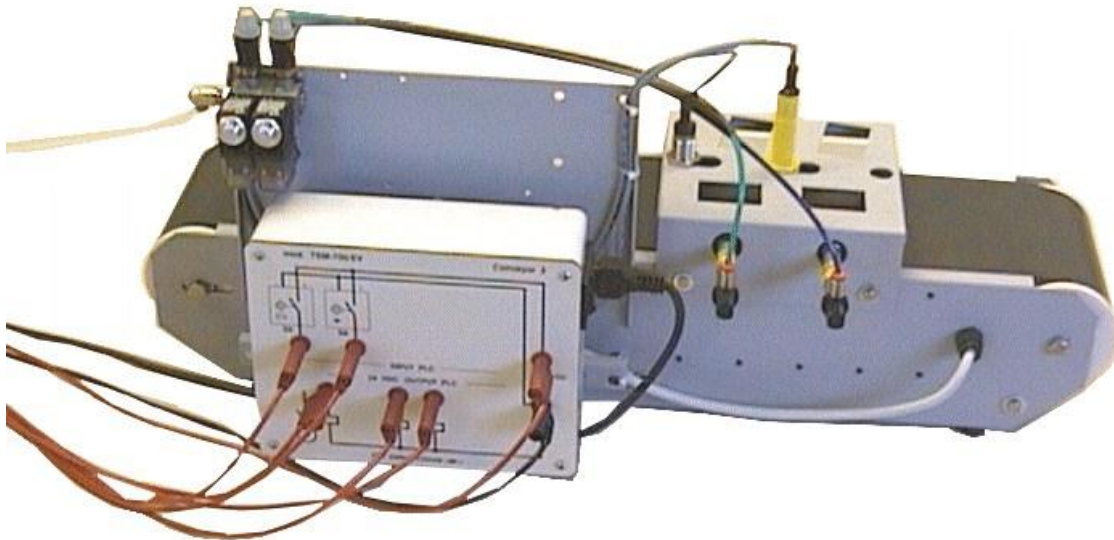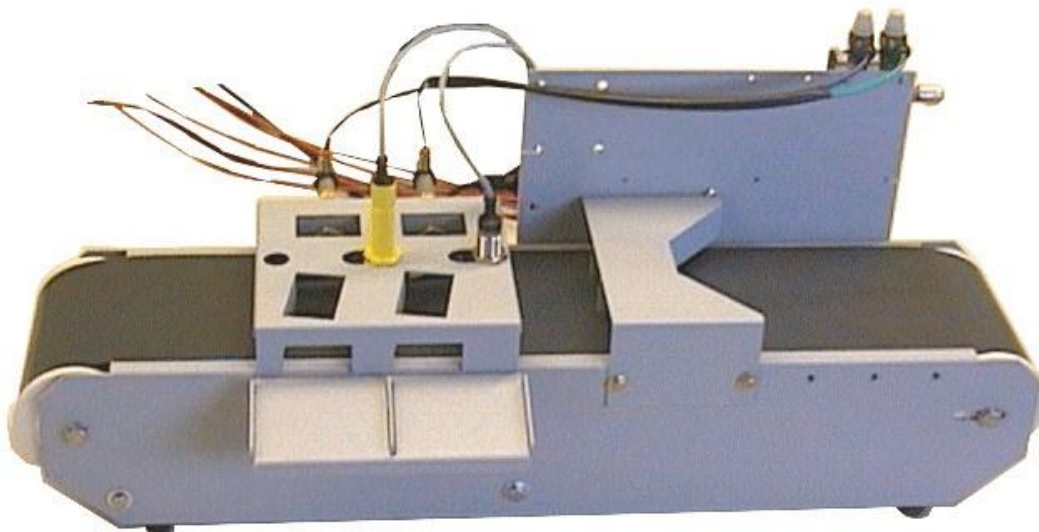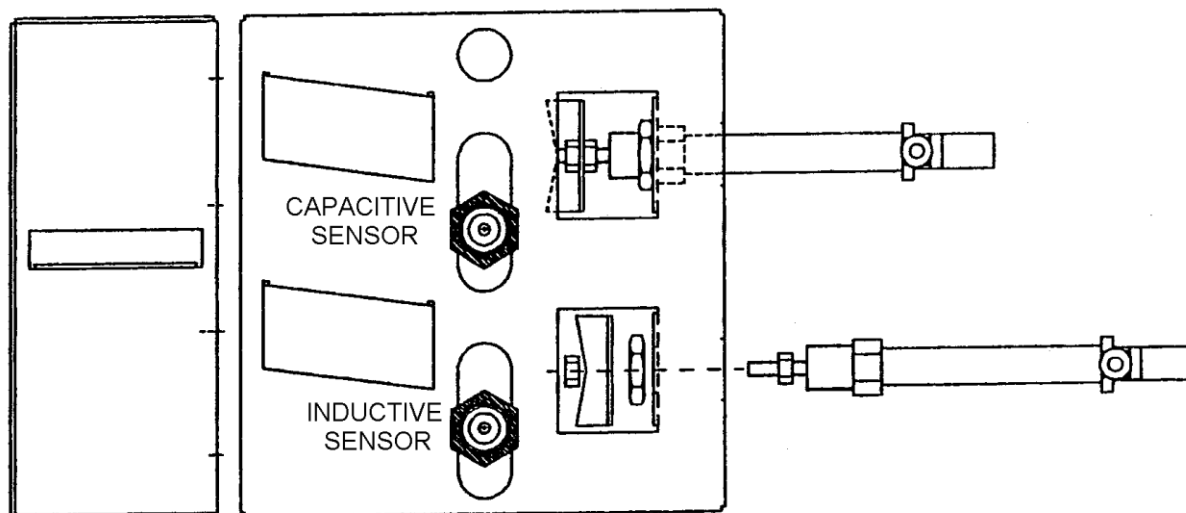
fig. 2.6.a Conveyor unit 2

fig. 2.6.b Conveyor unit 2

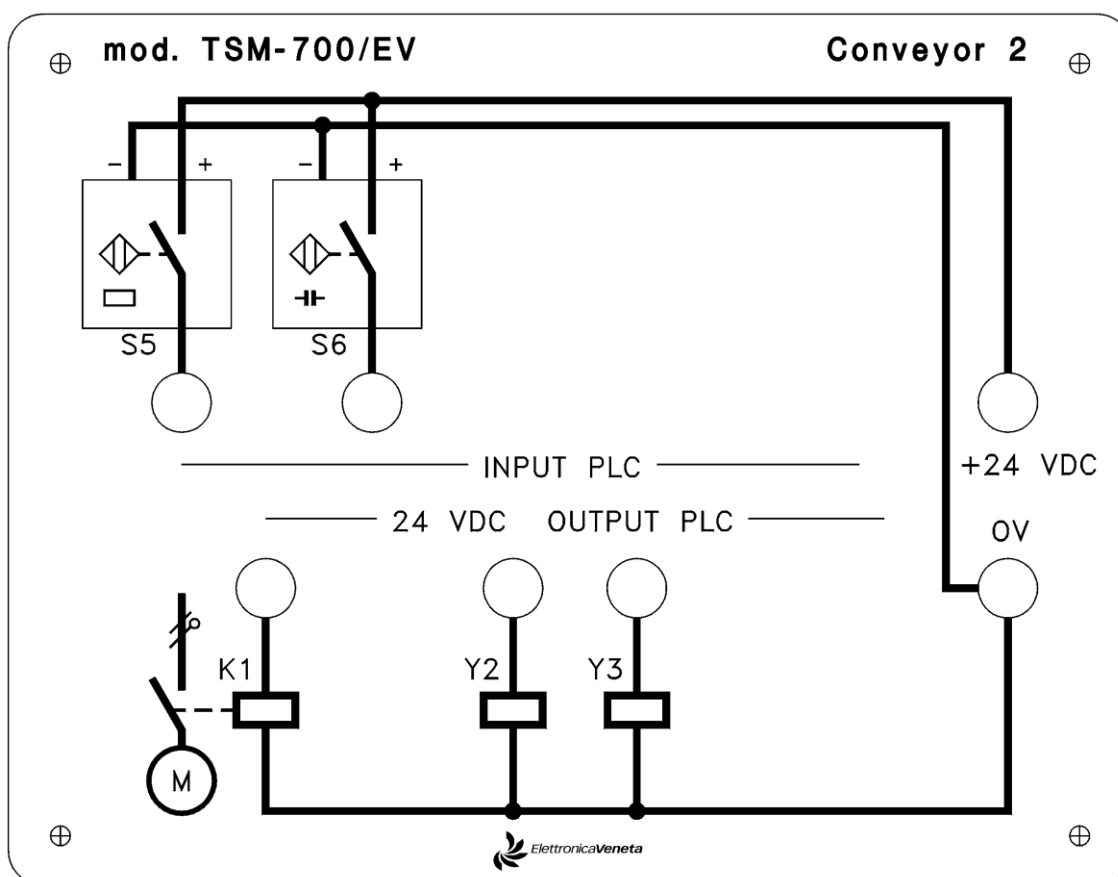*fig. 2.7 Support for capacitive and inductive sensors.*

fig. 2.8 Electrical control board

2.5 MACHINING SEQUENCES OF THE BASE CONVEYOR UNIT 2

Hereafter follow the basic machining sequences which can be carried out with the conveyor unit 2. **These sequences are only a guideline on which a number of variations "ad libitum" can be developed according to the kind of approach chosen by the class group**.

1. The conveyor belt starts moving powered by the single-phase motor. NB: this happens once the pieces have been placed onto the conveyor from conveyor unit 1. NB2: when the belt of conveyor unit 2 is moving, there is no need for the belt of conveyor unit 1 to be moving, and vice versa.
2. The machining pieces are transported under the two sensors.
-   The pieces type "A" are detected by the inductive sensor and pushed by one of the pistons trough the first chute
-   The pieces type "B" are detected by the capacitive sensor and pushed by the other piston in the through the second chute The machining cycle is finished in this way.

2.6 CONTROL UNIT
The control unit (see fig.2.9) enables controlling the process via pushbuttons with signaling lamp and emergency button; it constitutes the user/machine interface and connects directly to the process control PLC.
It is composed of:

•   2 pushbuttons with N.O. (Normally Open) green signaling lamp
•   2 pushbuttons with N.C (Normally Closed) red signaling lamp
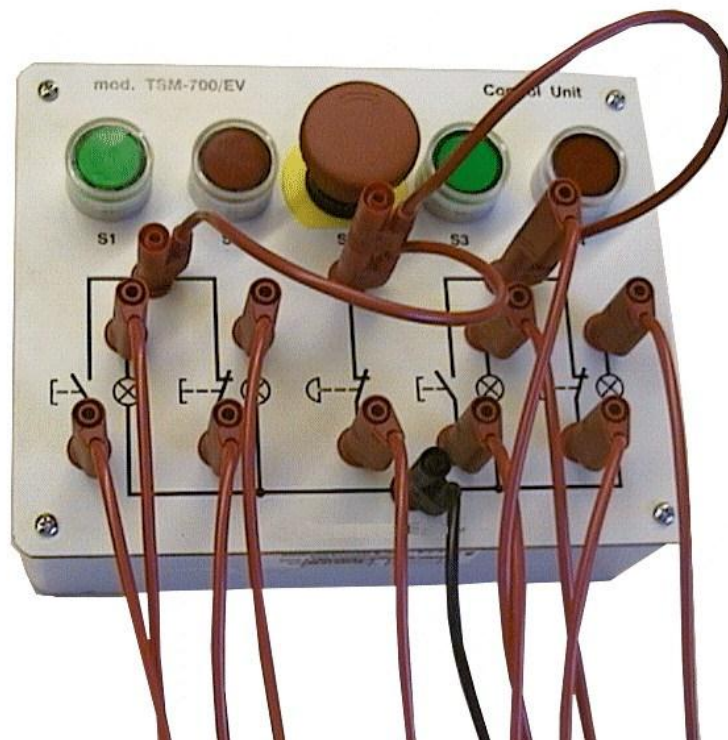•   1 emergency N.C. (Normally Closed) red pushbutton
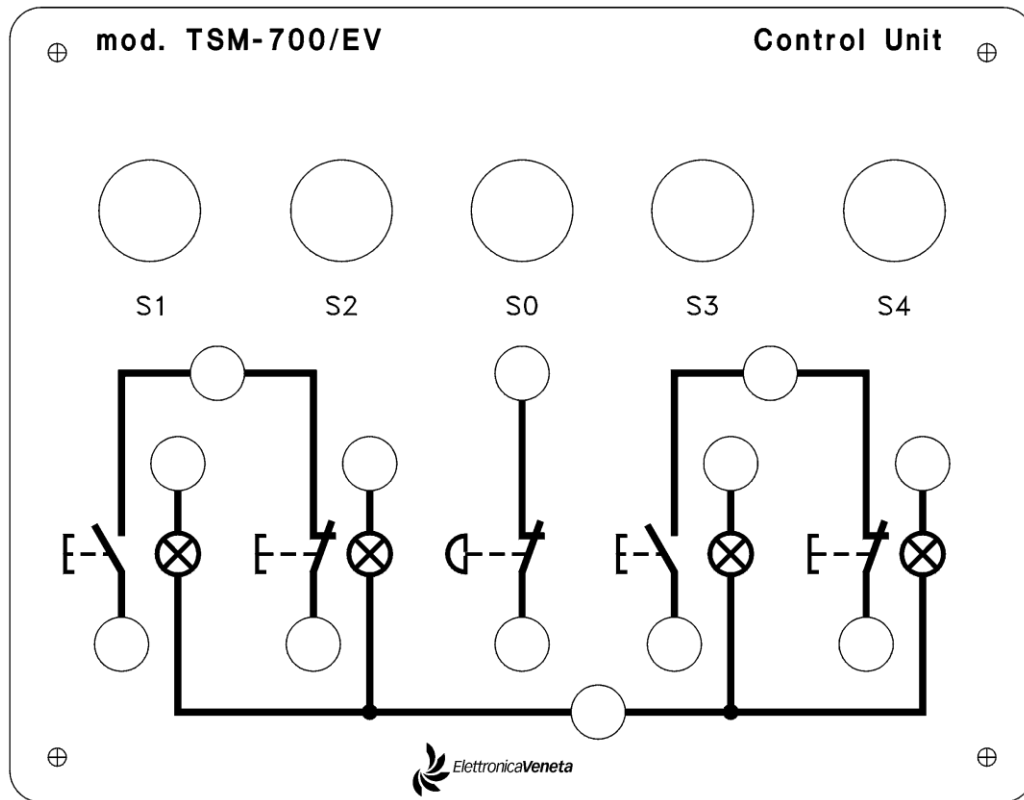

Fig. 2.9 Control unit

Fig. 2.10 Silk screen panel of the control unit.

CHAPTER 3: CONTROL WITH PLC

3.1 PROCESS CONTROL WITH PLC

The automation process with conveyor mod. TSM-700/EV easily connects to the trainers PLC mod. PLC-5A/EV, mod. PLC-8/EV and mod. PLC-7/EV.
The connections are physically actuated via digital inputs/outputs of the PLC.
The following table shows the correspondence between the I/O digital signals of the PLC and the I/O process signals.

PLC	PROCESS mod.TSM-700/EV
Digital Inputs	• Capacitive sensors • Inductive sensors • REED sensors • Control unit pushbuttons
Digital Outputs	Solenoid valves • • Relays • Control unit lamps

fig. 3.1 Table of the PLC/Process correspondence mod.TSM-700/EV.

3.2 CONNECTIONS TO THE PLC TRAINER

Hereafter follow the recommended connections between the automation process mod. TSM-700/EV and the PLC used for the development of a program to achieve the desired sequences for conveyor units 1 and 2.

INPUTS

PROCESS SYMBOL	PLC INPUTS	DESCRIPTION
S0	I 0.0	EMERGENCY pushbutton for the control unit
S1	I 0.1	START green pushbutton for the control unit
S2	I 0.2	STOP red pushbutton for the control unit
S3	I 0.3	START green pushbutton for the control unit
S4	I 0.4	STOP red pushbutton for the control unit
S5	I 1.5	Inductive sensor for the conveyor unit 2
S6	I 1.6	Capacitive sensor for the conveyor unit 2
S10	I 1.0	Inductive sensor for the conveyor unit 1
S11	I 1.1	Capacitive sensor for the conveyor unit 1
S12	I 1.2	REED limit switch for the conveyor unit 1
S13	I 1.3	REED switch for the conveyor unit 1
S13	I 1.4	REED switch for the conveyor unit 1

OUTPUTS

PROCESS SYMBOL	PLC OUTPUTS	DESCRIPTION
K1	Q 1.0	A.c. 1-phase motor relay for the conveyor unit 2
K2	Q 0.5	A.c. 1-phase motor relay for the conveyor unit 1
Y2	Q 1.2	Pushing cylinder solenoid valve for pieces type "A"
Y3	Q 1.3	Pushing cylinder solenoid valve for pieces type "B"
Y4	Q 1.4	Solenoid valve for magazine pieces pushing cylinder conveyor unit 1
Y5	Q 1.5	Solenoid valve for transport cylinder delivery conveyor 1 unit
Y6	Q 1.6	Solenoid valve for transport cylinder return conveyor 1 unit
Y7	Q 1.7	Solenoid valve for vacuum unit lifting cylinder conveyor unit 1
Y8	Q 0.0	Solenoid valve for vacuum unit
H1	Q 0.1	Lamp green pushbutton for the control unit
H2	Q 0.2	Lamp red pushbutton for the control unit
H3	Q 0.3	Lamp green pushbutton for the control unit
H4	Q 0.4	Lamp red pushbutton for the control unit

3.3 LAB EXERCISE

Write a PLC program to achieve the following functions and sequences. The sequences are based on the general machining sequences for the conveyor units described in Sections 2.3 and 2.5.

You will especially need to use timers as well as various internal memory bits (apart from I and Q) to act as flags for the various states that need to be stored. Keep in mind that various parts of the conveyor system can be in various states and they transition from one state to another based on certain inputs being detected.

Functions of the control unit pushbuttons

S0: EMERGENCY PUSHBUTTON
S1: START PUSHBUTTON
S2: STOP PUSHBUTTON
S3: INITIALIZATION PUSHBUTTON
S4: STOP PUSHBUTTON

Initialization and Start

1. When the PLC program is started, the 4 lamps H1, H2, H3, and H4 flash simultaneously.
2. In this state, to initialize the system, push S3. The green lamps H1, H3 turn on permanently whereas H2 and H4 go off.
3. To start the automatic machining cycle push S1.

End pieces control

4. When the pieces in the tool magazine are finished the system blocks and goes back to starting condition described in no. 1.

Stop situation control

5. Pushing S2 during the machining cycle, the system controls the **"STOP"** situation. The "Pick and Place" unit goes back to its starting position, determined by the REED S12 sensor and releases the piece (the red lights H2, H4 flash on and off *alternately*). At this point the system must be initialized to start another machining cycle (no. 2).

Emergency situation control

6. Pushing the emergency pushbutton S0 the system stops where it is (red lights H2, H4 flash on and off *simultaneously*). If the "Pick and Place" unit is not in starting position (S12) keeping S1 pushed takes it back to its starting position and then the lights H2, H4 stop flashing. The emergency button can then be released. At this point the system must be initialized to start another machining cycle (no. 2).

Description of the machining cycle
The program carries out an automatic machining cycle divided into the following sequences and phases:

Sequence 1
Starting the automatic machining cycle the motor (relay K2) is started and moves the belt of the conveyor 1.

Sequence 2
After 2 seconds from motor start up, the ejection cylinder (solenoid valve Y3) of the conveyor 1 pushes the first piece on the belt conveying it to the inductive S10 and capacitive sensors S11 for detection.

Sequence 3
The capacitive sensor S11 detects the piece presence and after 2 seconds stops the motor and the ejection cylinder (solenoid valve Y3) is retracted; if after 10 seconds no piece is detected by the sensor S11, the system blocks and goes back to starting situation.

Sequence 4
2 seconds after the motor K2 stops (and so the belt) the "Pick and Place" unit goes down (solenoid valve Y7) to touch the piece.

Sequence 5
After 4 seconds the vacuum unit (solenoid valveY8) is activated to take the piece and simultaneously lift it.

Sequence 6
After 4 seconds from lifting the "Pick and Place" unit moved by the double-effect cylinder (solenoid valve Y5) carries the piece up to the conveyor 2.

Sequence 7
The intermediate REED sensor S13 detects the "Pick and Place" unit and the motor is activated which starts the conveyor 2 belt (relay K1).

Sequence 8
The limit switch REED sensor S14 detects the presence of the "Pick and Place" unit and so the piece is allowed to drop onto the belt by disabling the vacuum unit (solenoid valve Y8).

Sequence 9
The "Pick and Place" unit is made go back to starting position determined by the REED S12 sensor position.

Sequence 10
The pieces type "A" detected by the inductive sensor are pushed by the related cylinder (solenoid valve Y2) to the related way "A" of the chute.
Sequence 11
The pieces type "B" detected by the capacitive sensor are pushed by the related cylinder (solenoid valve Y3) to the way "B" of the chute.

Sequence 12
The machining cycle related to a single machining piece stops, the motor (relay K1) blocks. The cycle restarts from **Sequence 1** with a new piece.