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Design of Automated Machine to Collect and Stack Boxes

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Abstract: *This document presents the process carried out for automation design of a machine whose function is to collect boxes of 4 in 4 for later stacking, making use of simulation software (LOGO), Programmable Logic Controller (PLC) and three cylinders A, B and C mounted on a test bench. System must organize four boxes in a row and when they are ready, they must be run to give space for the process to be carried out again. Finally, results obtained in the process time are shown when performing the work in a different number of consecutive times compared with the manual work.*

Keywords - *Automation, boxes, machine, programmable logic controller (PLC), simulation, stacking.*

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I. INTRODUCTION

Over the past few years, mechanization of production processes, manufacturing, and other sectors of the economy and modern industry have sought a goal, to free man from excessive physical effort and to increase effectiveness, speed, and profitability of each of these sectors.

All these needs have given rise to significant improvements using electronic, electrical, pneumatic and hydraulic devices [1]. Which have achieved excellent results in terms of information processing and storage capacity, speed and agility in repetitive processes and durability of the materials used in automated systems. [2].

Pneumatic actuators have been widely used in global industry for over a hundred years thanks to their ability to convert energy of a pressurized gas into mechanical energy and produce motion [3]. They are also well known for their low cost and easy of maintenance.

They are frequently used in automation of riveting, drilling, stacking, stamping processes, among others [4].

Currently, there are several companies that offer automation and pneumatics products that allow manufacture of electropneumatic machines for industrial use, adapting technical characteristics and operability that client requires [5], some of these are SIEMENS, FESTO, PARKER PNEUMATIC [6], BOIX with its cardboard box forming machine Q2400 [7], NE ENGINEERING with its series automatic stacker DEX4 for corrugated cardboard sheets [8].

With the aforementioned pneumatic actuators, innumerable automated systems can be realized which seek to imitate actions of living beings, through a set of chained functions to achieve a result. In this way, systems work with an input, a processing and an output. Automation is a system where production tasks, usually carried out by human operators, are transferred to a set of technological elements whose purpose is to generate added value to the work materials with which they operate [9].
For this reason, an automated box stacking system is presented below.

II. METHODOLOGY

Controllers

An automatic controller compares the actual value of the output of a plant with the reference input (set point), determines the deviation and produces a control signal that will reduce the deviation to zero or a small value. The way in which the automatic controller produces the control signal is called the control action [10].

Controllers are additional elements to original system to improve their operating characteristics, with the aim of satisfying the design specifications both in transitory regime and in steady state.

The first way to modify the characteristic response of the systems is gain adjustment (which will later be defined as proportional control). However, although generally the increase in gain improves the operation in steady state, there is a poor response in transitory regime and viceversa. For this reason, it is necessary to add elements to the simple gain variation, which gives rise to the different types of controllers [11].

Design specifications are often used to describe what the system should do and how to do it. These specifications are unique to each individual application and often include specifications such as relative stability, steady state accuracy, transient response and frequency response characteristics [12].

Programmable Logic Controller

Programmable Logic Controller (PLC), is a computer used in automatic engineering or industrial automation, to automate electromechanical processes, such as the control of factory machinery in assembly lines or mechanical attractions [13].

PLCs are used in multiple industries and machines. Unlike general-purpose computers, PLC is designed for various types of input and output signals, among the advantages of using PLCs are: extended temperature ranges, immunity to electrical noise and resistance to vibration and impact. The programs for the control of operation of the machine are usually stored in backups in non-volatile memories. PLC is an example of a "hard" real-time system, where the output results must be produced in response to the input conditions within a limited time, otherwise it will not produce the desired result [14].

Materials used for this process are the following:

- PLCs LOGO Siemens S7200 V6. 12/24 RC.
- Electropneumaticcilynders (3)
- 5/2-way bistable pneumatic valves (3)
- Electropneumatic bench.

Process of gathering and stacking boxes is carried out as shown in figure 1.

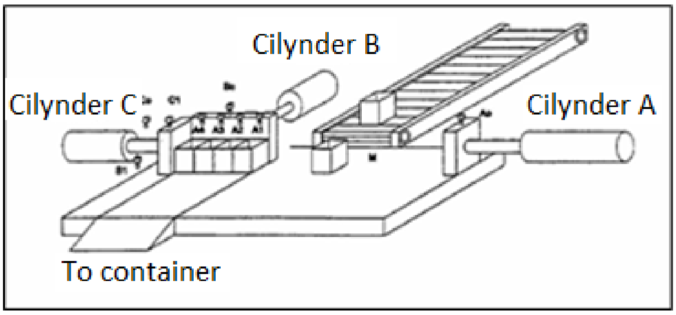


Figure 1. Machine outline

Cylinder A is tasked with pressing and adjusting boxes toward cylinder C, which will hold them while the quota (4 boxes) is full. After 4 boxes are arranged in a row, cylinder C is collected and cylinder B will stack them to the front.
Finally, system returns to its initial position to start a new cycle, so cylinder A and B will be collected and cylinder C will be extended.
Equation (1) of motion is as follows

$$B- \; C+ \; A+ \; A- \; C- \; B+ \qquad (1)$$

Automated system was carried out in fluidsim program, to simulate process by three cylinders as shown in figure 2.

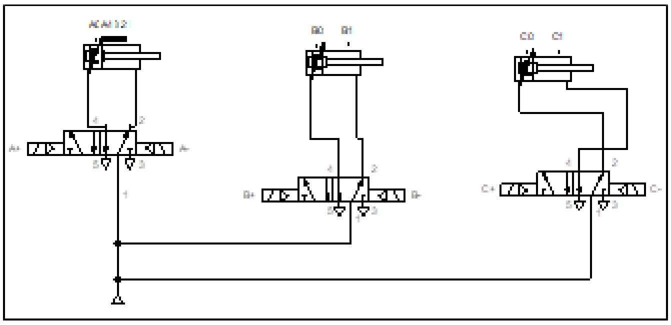


Figure 2. Electropneumatic diagram

Next, in figure 3, power diagram implemented in the simulation is shown.

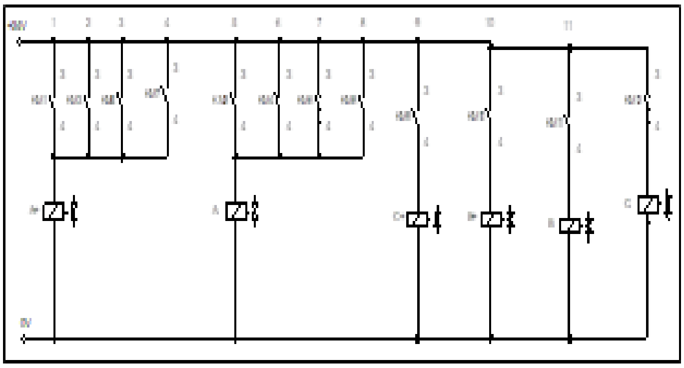


Figure 3. Power diagram

Figure 4 shows box stacking design control diagram

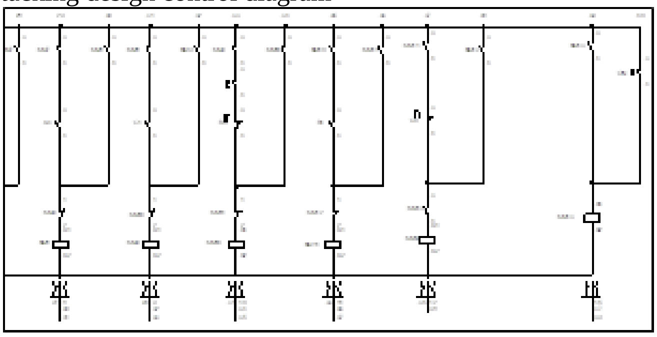


Figure 4. Control diagram

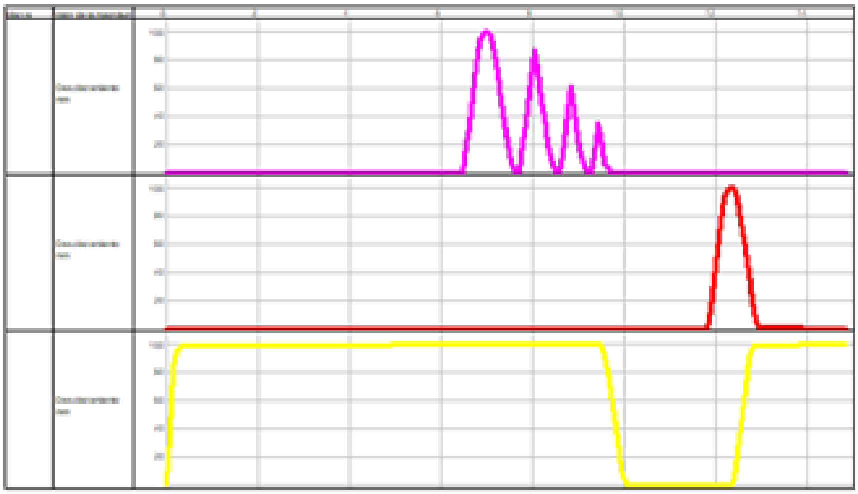


Figure 5. Space phase diagram

Figure 5 shoes sequence executed in the simulation, only that at the initial moment it has a button to connect to power, it has a button to start sequence and when the four boxes are already together, it is automatically collected cylinder C. Following this, Cylinder B will be activated to stack the boxes, and finally system will be restarted for a new cycle.
Program is carried to ladder language and to carry it out, flow diagram is shown in figure 6:

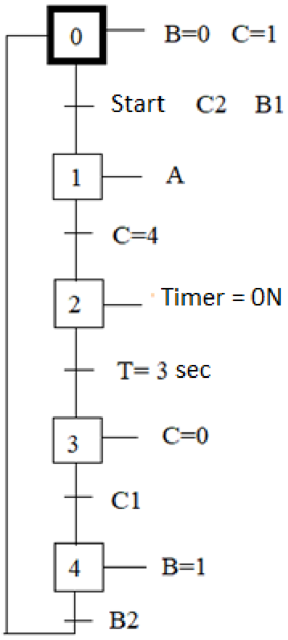
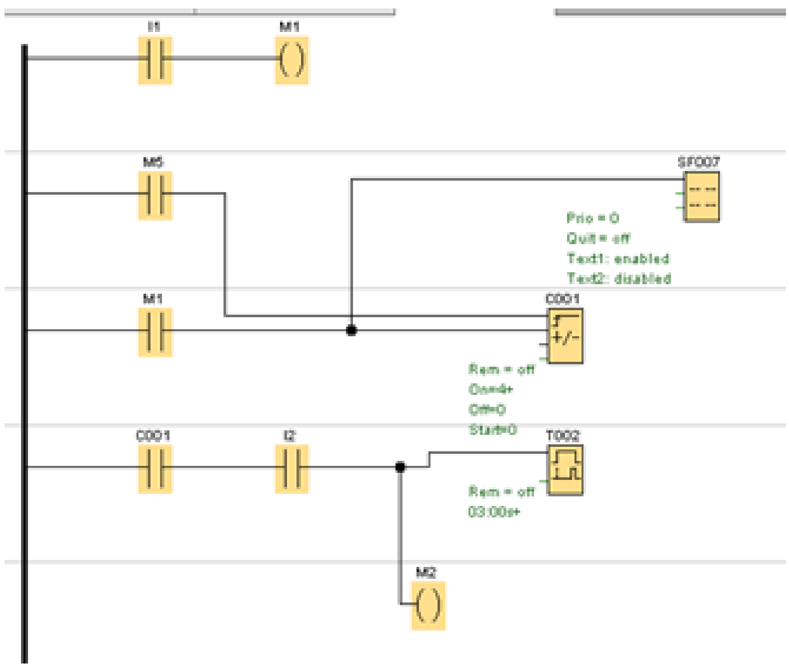


Figure 6. Flow diagram

Programming in LOGO for PLC is shown in figure 7.



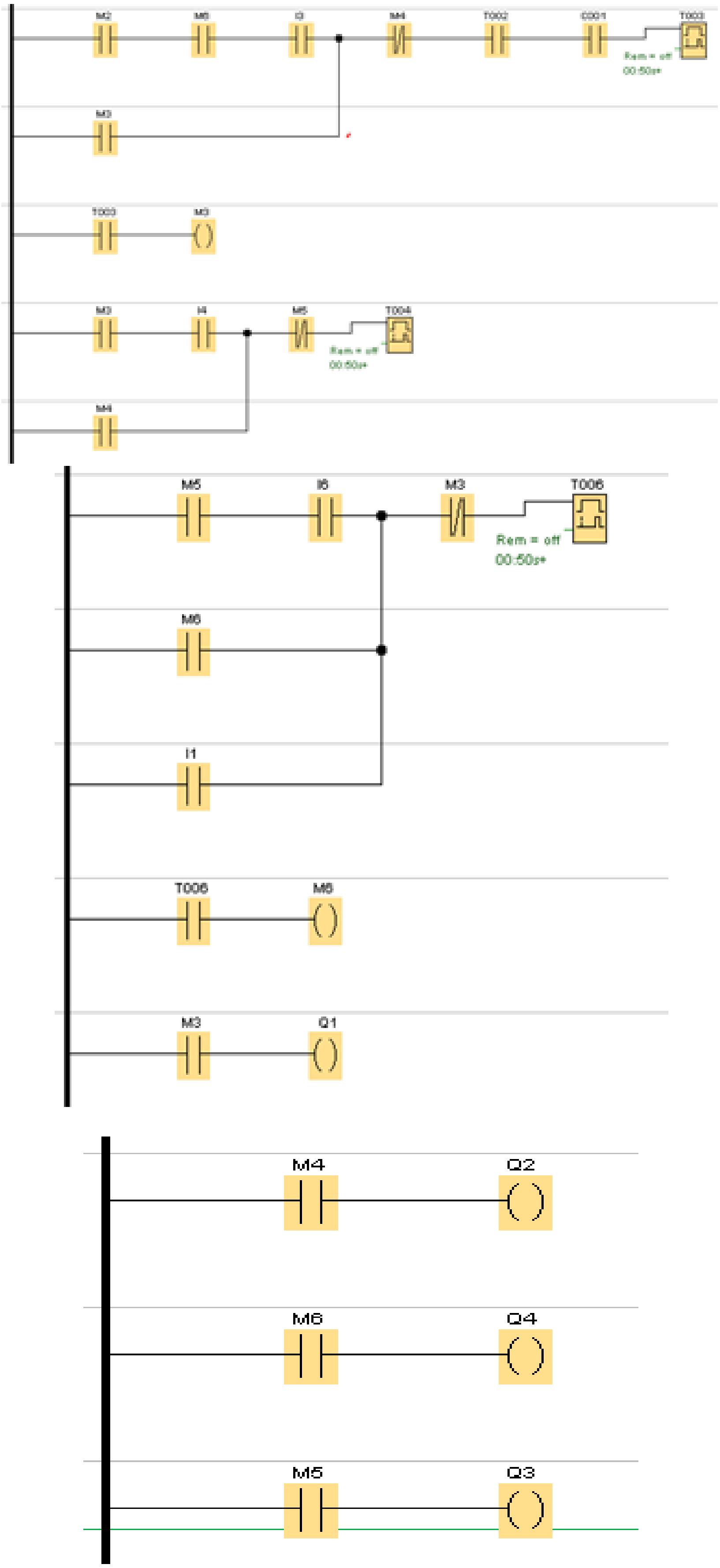


Figure 7.PLC LOGO programa

Operation is as follows; First, cilynder A and B are collected. Cilynder C will be extended.
A button must be pressed four times with which each time it is pressed, a monostable cylinder is activated.
Next, wait three seconds, cylinder C is picked up, cylinder B is extended, and finally, all the cylinders return to their initial position, for a new cycle.

Symbols are shown in table 1

Table 1.LOGO Symbols

Component	Symbol
Start (button Cilynder A)	I1
Emergency stop	I2
Cilynder B contracted	I6
Cilyndro B extended	I5
Cilynder C contracted	I4
Cilynder C extended	I3
Valve B contracted	Q2
Valve B extended	Q3
Valve C contracted	Q4
Valve C extended	Q1

III. RESULTS AND DISCUSSIONS

Next, response obtained from bech can be observed according to programming implemented in the programmable logic controller. Figure 8 shows system in initial state.

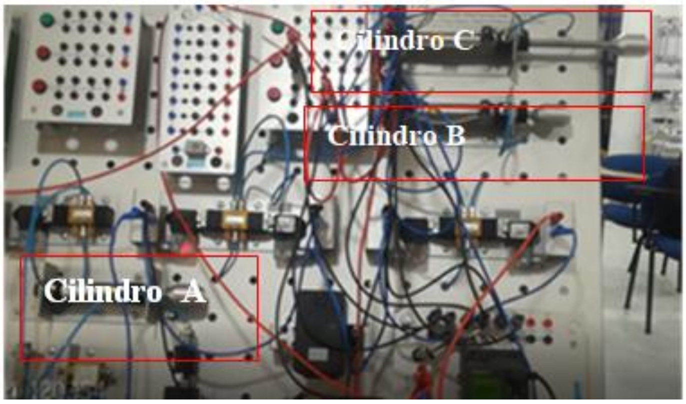


Figure 8. Cycle start

Figure 9 shows that, by pressing button, cylinder A extends. Being monostable, it automatically returns to its initial position, so the button must be pressed 4 consecutive times for it to be activated again and then continue with the process.

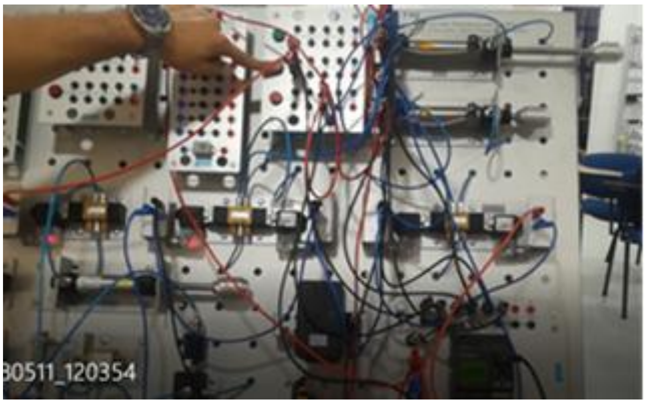


Figure 9. Cilynder A responding to pulse

Cylinder A activation count is shown in figure 10.

Figure 10. Cylinder A activation count

Three seconds later cilynder C contracts and next cilyndro B extends, as shown i figure 11.

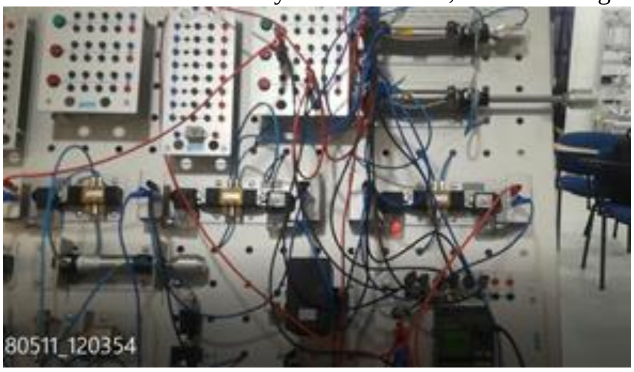


Figure 11. Cilynder C contracts, cilyndro B extends

Cylinders B and C require pressure from the valve connected to the cylinders at both ends to direct, as directed, to contract or expand into a mechanical force. Finally, system returns to its initial state as shown in figure 12.

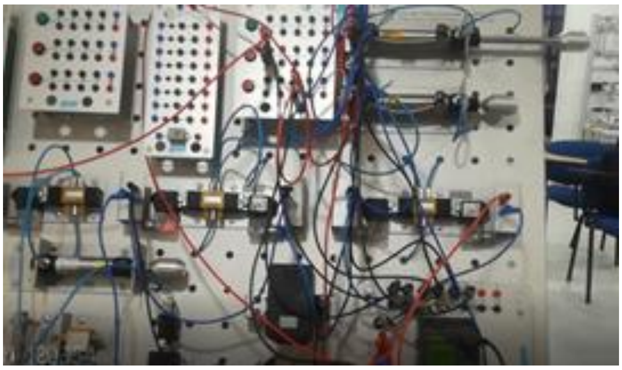


Figure 12. Cilynders in initial state

Implementation in the test bench was carried out and recorded in table 2 with the intention of comparing times with the process carried out manually with the process carried out in an automated manner, performing it differently a number of repetitive times, but with the same amount of boxes per stack per cycle. Results are the following.

Table 2. Repetition time of boxes stacking cycles

Number of cycles repetition	Automated time (sec)	Manual time (sec)
5	35	61.5
10	70	125
15	105	187.5
20	140	250
25	175	322.2
30	210	459.5
35	245	535.7
40	280	758

45	315	913.9
50	350	1003

Table 2 shows comparison between manual process time with automated process, it´s drastically reduced, since operator, as the cycles increase, reduces their effectiveness. In automated process, the cycle time is the same for any number of stacking repetitions.

IV. CONCLUSION

Automated systems achieve cost reduction in industry since availability of personnel is not necessary permanently, but may only need short-term supervision.

Automated box stacking system designed will allow this activity to be carried out in a shorter time and can be extended to long working hours without stopping. Features that benefit the industry.

This system helps to reduction of personnel risks by eliminating contact with materials or items to be treated and long-term damage that repetitive tasks can cause.

It´s possible to improve and modify conditions of the system which is demonstrated from simulation and tests of the cylinders that allow to calculate and carry out a greater precision of tests without having to have the system physically implemented.

Reduction of risks that affect the contents or the appearance in the boxes when stacking by a null operator, since the adjustment of cylinder force can be done repeatedly in the event that contents of these are variable or are change, for example, merchandise.

Implementing a flowchart will make development and implementation of programmable code in the selected PLC much easier and more practical. In addition to this, easy modification and understanding will be achieved on future occasions.

To carry out various tests on the bench, space must be given for the components to rest, since after a period of use, they stop receiving orders as air accumulates in the pneumatic elements.

You must be clear about each of the connections that the components of the assembly have, know what the inputs and outputs are, their name and location, so that when implementing it there are no problems and programming in the PLC is not wrong.

Grafcet method for designing coding in PLC is one of the best practices for maintaining order and practical understanding of systems.

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