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# Programmable controller designed for electro-pneumatic systems*

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**Abstract:** This project deals with the study of electro-pneumatic systems and the programmable controller that provides an effective and easy way to control the sequence of the pneumatic actuators movement and the states of pneumatic system. The project of a specific controller for pneumatic applications join the study of automation design and the control processing of pneumatic systems with the electronic design based on microcontrollers to implement the resources of the controller.

**Keywords**: Programmable Controller, Microcontroller, Electro-pneumatic, Automation

## 1. INTRODUCTION

The automation systems that use electro-pneumatic technology are formed by mainly three kinds of elements: actuators or motors, sensors or buttons and control elements like valves. Nowadays, most of the control elements used to execute the logic of the system were substituted by the PLC (Programmable Logic Controller). Sensors and switches are plugged as inputs and the direct control valves for the actuators are plugged as outputs. An internal program executes all the logic necessary to the sequence of the movements, simulates other components like counter, timer and control the status of the system.

With the use of the PLC, the project wins agility, because it is possible to create and simulate the system as many times as needed. Therefore time can be saved, risk of mistakes reduced and complexity can be increased using the same elements.

An conventional PLC, that is possible to find on the market from many companies, offers many resources to control nor only pneumatic systems, but all kinds of system that uses electrical components. The PLC can be very versatile and robust to be applied in many kinds of application in the industry or even security system and automation of buildings.

Because of those characteristics, in some applications the PLC offers to much resources that are not even used to control the system, electro-pneumatic system is this kind of

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application. The use of PLC, especially for small size systems, can be very expensive for the automation project.

An alternative in this case is to create a specific controller that can offer the exactly size and resources that the project needs. This is made using microcontrollers as the base of this controller.

The controller, which is made with the utilization of microcontroller, can be very specific and adapted to only one kind of machine or it can work as a generic controller that can be programmed as a usual PLC and work with logic that can be changed. All these characteristics depend on what is needed and how much experience the designer has in developing an electronic circuit and a program for microcontroller. But the principal advantage of this kind of application for the microcontroller is that designer has the total knowledge of his controller, which makes it possible to control the size of the controller, change the complexity and the application of it. It means that the project gets more independence from other companies, but at the same time the responsibility of the control of the system stays at the designer hands.

## 2. ELECTRO-PNEUMATIC SYSTEM

On an automation system one can find three families of components, which are sensors, valves and actuators. An adequate technique is needed to project the logic circuit to integrate all the necessary components and execute the sequence of movements properly.

For a simple direct sequence of movement an intuitive method can be used [1], but for indirect or more complex sequence the intuition can generate a very complicated circuit and signal mistakes. It is necessary than to use another method that can save time of the project, make a clean circuit, can eliminate occasional signal overlapping and redundant circuits.

The present method is called step-by-step or algorithmic [3], it is valid for pneumatic and electro-pneumatic and it was used as a base in this work. The method consists of designing the systems based on standard circuits made for each change on the state of the actuators, these changes are called steps.

The first part is to design those kinds of standard circuits for each step, the next task is to link the standard circuits and the last part is to connect the control elements that receive signals from sensors, switches and the previous movements, and give the air or electricity to the supply lines of each step.

## 3. THE METHOD APPLIED INSIDE THE CONTROLLER

The result of the method presented before is a sequence of movements of the actuator that is well defined by steps. It means that each change on the position of the actuators is a new state of the system and the transition between states is called step.

The standard circuit described before helps the designer to define the states of the systems and to define the condition to each change between the states. In the end of the design the system is defined by a sequence that never changes and states that have the inputs and the outputs well defined. The inputs are the condition for the transition and the outputs are the result of the transition because they change on each step.

All the configuration of those steps stays inside of the microcontroller and is executed the same way it was designed. The sequences of strings are programmed inside the controller with 4 or 5 bytes; each string has the configuration of one step of the process. There are two bytes for the inputs, one byte for the outputs and two more for the other configurations and auxiliary functions of the step. After programming, this sequence of strings is saved inside of a non-volatile memory of the microcontroller, so they can be read and executed.

The controller task is not to work in the same way as a conventional PLC, but the purpose of it is to be an example of a versatile controller that is design for an specific area. A conventional PLC process the control of the system using a cycle where it makes an image of the inputs, execute all the conditions defined by the configuration programmed inside, and then update the state of the outputs. The controller of this work in a different way, where it read the configuration of the step, wait the condition of inputs to be satisfied, then update the state or the outputs and after that jump to the next step and start the process again.

It can generate some limitations, as the fact that this controller cannot execute, inside the program, movements that must be repeated for some time, but this problem can be solved with some external logic components. This limitation is a characteristic of the system that must be analyzed for each application.

## 4. CHARACTERISTCS OF THE CONTROLLER

The controller is based on the MICROCHIP microcontroller PIC16F877 [5] with 40 pins, and it has all the resources needed for this project. It has enough pins for all the components, serial communication implemented in circuit, EEPROM memory to save all the configuration of the system and the sequence of steps. For the execution of the main program it offers complete resources as timers and interruptions.

The list of resources of the controller was created to explore all the capacity of the microcontroller to make it as complete as possible (Figure 1).

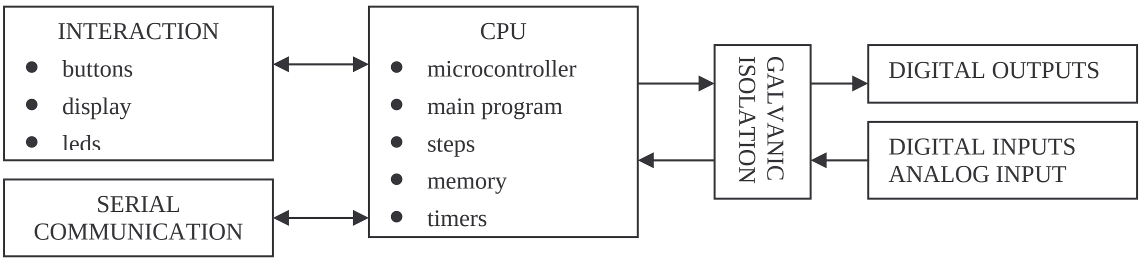


Figure 1. Components of the controller

During the step, the program chooses how to use the resources reading the configuration string of the step. This string has two bytes for digital inputs, one used as a mask and the other one used as a value expected. One byte is used to configure the outputs value. One or two bytes more are used for the internal timers, the analog input or time-out. The EEPROM memory inside is 256 bytes length, that is why the size of the string is not big and with this characteristic it is possible to save between 48 to 60 steps (table 1).

The controller has also a display and some buttons that are used with an interactive menu to program the sequence of steps and other configurations

Table 1
Resources of the controller

| | |
|---|---|
| Digital inputs | 8 |
| Digital outputs | 8 |
| Analog inputs | 1 |
| Internal timers | 2 |
| Parallel circuits | 2 |
| Lines of steps | 48-60 |

## 6. CONCLUSIONS

The controller developed for this work shows that it is possible to create a very useful programmable controller based on a microcontroller. External memories or external timers were not used in case to explore the resources that the microcontroller offers inside. Outside the microcontroller, there are only components to implement the outputs, inputs, analog input, the display for the interface and the serial communication. Using only the internal memory, it is possible to control a pneumatic system that has a sequence with forty-eight steps if you use all the resources for all steps.

The programming of the controller do not use PLC languages, but a configuration that is simple and intuitive. With electro-pneumatic system, the programming follows the same technique that was used before to design the system, but here the designer works directly with the states or steps of the system.

With a very simple machine language the designer can define all the configuration of the step using four or five bytes. It depends only on his experience to use all the resources of the controller.

The controller task is not to work in the same way as a commercial PLC but the purpose of it is to be an example of a versatile controller that is design for an specific area. Because of that, it is not possible to say which one works better; the system made with microcontroller is an alternative that works in a simple way.

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