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Controller based on microcontroller designed to execute the logic control of pneumatic systems*

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This work tries to link the study of pneumatic and electropneumatic systems with the utilisation of specific controller based on microcontroller PIC 16f877 to provide an effective and easy way to control sequences of actuators movements of an electropneumatic system [6].

The principal objective of this work is to use all the advantages of the mentioned microcontroller and show that in some cases it can be a very good solution if it is compared with other kinds of controllers.

1. INTRODUCTION

In pneumatic systems three kinds of elements: actuators or motors, sensors and controller elements. But nowadays, most of the controller elements used to make the logic of the system were substituted by the PLC (Programmable Logic Controller), that works with inputs and outputs. 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 a counter, timers and executes control of all 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 and risk of mistakes reduced and complexity of the system can be increased using the same elements.

It is possible to find solutions with these kinds of Programmable Controllers from big companies (Siemens, Festo, Omrom, Fanuc, Bradley, etc.) that offer complete packages with the controllers plus software to design the logic circuits. But in the other hand it is made solution that can be very expensive depending of the requirements of necessary system. Another solution that offers a total flexibility to create a controller that has the exactly all the characteristics which the system needs, is the use of microcontrollers as a base to controller.

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The controller which is made with the utilisation 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 an 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. APPLICATION

The controller has been created to function with a specific application that is to control the pneumatic system described in work [6]. But inside of this application the controller can be regarded as a very versatile one because it can be programmed to control different configurations and actions of pneumatic system actuators.

A standard circuit called step controls each movement. The controller main task is to substitute those steps. In each step the controller waits for the right signal in the inputs and then it changes the outputs to the suitable value.

All the configuration of those steps stays inside of the microcontroller and is created first on a computer. The sequences of strings are generated there with 4 or 5 bytes; each one 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 things. After that all these sequences of strings are 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 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.

It can generate some limitations, as the fact that this controller can not 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 analysed for each application.

3. CHARACTERISTICS

The controller is based on the MICROCHIP microcontroller PIC16F877 [2] 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. 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 or the analogical input. The EEPROM memory inside is not big, that is why the size of the string is not big either and with this characteristic it is possible to save between 48 to 60 steps (table 1).

Table 1
Resources of the controller

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

3.1. Interaction components

For the real application the controller must have some elements to interact with the final user and to offer a complete monitoring of the system resources that are available to the designer while creating the logic control of the pneumatic system (fig. 1):

- interactive mode of work; function available on the main program for didactic purposes, the user gives the signal to execute the step,
- LCD display, which shows the status of the system, values of inputs, outputs, timer and statistics of the sequence execution,
- beep to give important alerts, stop, start and emergency,
- led to show power on and others to show the state of inputs and outputs.

3.2. Security

To make the final application works property, a correctly configuration to execute the steps in the right way is needed, but more then that it must offer solutions in case of bad functioning or problems in the execution of the sequence. The controller offers the possibility to configure two internal virtual circuits that work in parallel to the principal. These two circuits can be used as emergency or reset buttons and can return the system to a certain state at any time [2]. There are two inputs that work with interruption to get an immediate access to these functions. It is possible to configure the position, the buttons and the value of timeout of the system.

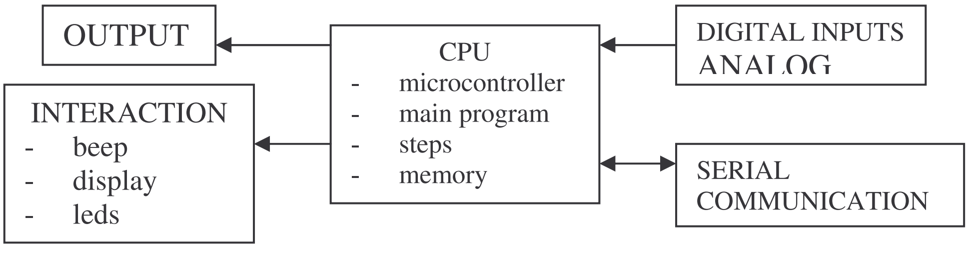

Fig. 1. The components of the system

3.3. User interface program

The sequence of strings can not be programmed directly to the controller. A computer interface is needed to generate easily this sequence. With a good documentation the final user can use a simple program that allows working with values of each byte of the configuration. But it is possible to create a program with visual resources that works as a translator to the user, so his work is internally changed to the values that the controller understands.

A simple protocol with check sum and number of bytes is the minimum requirements to guaranty the integrity of the data transmission.

3.4. The firmware

The main loop of the program works by reading the strings of the steps from the EEPROM memory, that has all the information about the steps, the values that one must wait for in the analogical input, the values of the digital inputs and the timers.

In each step, the status of the system is saved on the memory and it is shown on the display too. Depending of the user configuration, it can use the interruption to work with the emergency circuit or time out to keep the system safety. In fig. 2 a block diagram of microcontroller main program is presented.

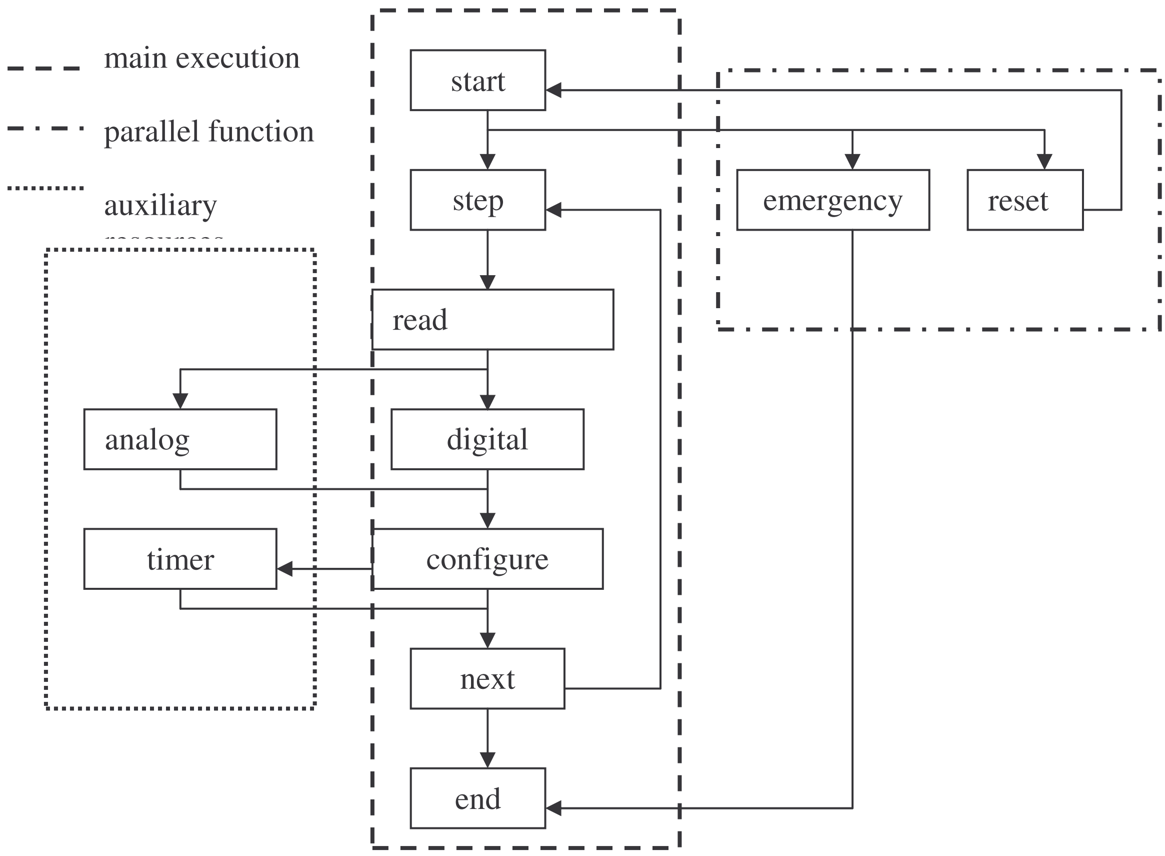

Fig. 2. The block diagram of the microcontroller main program

4. EXAMPLE OF A PNEUMATIC SYSTEM

In the article [6] are presented the pneumatic and electropneumatic circuits used to begin the study of the requires to control a system that work with steps and must offer all the functional elements to be used in a real application. But, as explained above, using a PLC or this specific controller, the control becomes easier and the complexity can be increase also. In table 2 requirements of pneumatic system have been shown.

Table 2
Requirements of the pneumatic system

Digital inputs	7
Digital outputs	5
Analogical inputs	1
Timers	2
Parallel circuits	2 (reset and emergency)

These requirements listed in table 2 are from the previous example plus some elements to explore the controller. The signal from the end position of actuator B is changed to the signal of a pressure sensor. The two timers are used on step one and on step four. One more parallel circuit is included to be the emergency button.

5. CONCLUSIONS

The controller developed during this work shows that it is possible to create a very useful system based on microcontroller. External memories or external timers were not used in case to explore the resources that the microcontroller offers inside. Outside the microcontroller elements to implement the outputs, inputs, analogical input, the display and the serial communication were placed.

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, but it is possible to reach sixty steps in the case of simpler system.

One of the other important microcontroller resources is the analogical to digital converter in order to use one analog input with the pressure sensor for the example. It is possible to use a lot of kinds of sensor that depends only on the experience of the designer to create the right electric circuit outside. The microcontroller offers the possibility to implement more analog inputs.

The objective to create a specific system for the execution of step sequences was reached and also the characteristic that can be adapted to simple or big sequences. 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.

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