# Low Cost Equipment for Laboratories


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***Abstract*** — *Nowadays, automatic control is a very important subject in engineering education. Normally this subject is very difficult to understand due to the topics it treats. The lecturer also has a lot of difficulties trying to do it easiest in the blackboard. To resolve this problem the student should work with real systems in order to understand all the subject peculiarities. In order to work with real system a very good equipped laboratories are necessary. Normally industrial systems are used and it involves a very high investment that is used in a very low percentage of their possibilities. Industrial equipment is robust and has a lot of features that exceed academic requirements a lot. Moreover if the equipment fails, what is very usual due to students are learning, reparations are also very expensive.*

*This paper presents a solution for this problem. Specific laboratory equipment can be make by students which can be adapted to academic necessities in all points of view. In this case a low cost data acquisition system has been done. It is very easy and cheap to construct and to repair. Its operation is very similar to real industrial equipment. This system involves all the necessary equipment to achieve practical sessions of automatic control in the laboratory with a very low cost.*



***Index Terms*** — *data acquisition system, laboratory equipment, low cost, system control.*


## INTRODUCTION

Concepts used to explain dynamic control of physical systems are connected with a lot of mathematics expressions. All of these mathematical expressions are an approximated representation of physical behaviour of the system (its exact representation will be more complicated and it does not add more significant information).

All these mathematical expressions and the real behaviour of the systems are very difficult to relate and the student has a lot of difficulties to connect the automatic control theory with the dynamics of the real system. Also, the lecture has some difficulties to explain this relation with words. The result is students who learn how to use these mathematical expressions in the paper but they have no idea of how to use it with real systems. They are engineers with a good theoretical learning but with a not quite good experience with real systems.

In order to resolve this problem, a more practical learning should be done together with the lectures. First concepts are explained in the blackboard and afterwards they should be put in practice in the laboratory. This way of learning can be done if there are real systems to operate in the laboratory. Taking into account the budget of the university it is very complicated to have very good equipped laboratories. Normally industrial systems are very expensive due to they have been designed to work in a very difficult industrial conditions. Moreover they have a lot of features most of them are not used in the laboratory.

By the other hand, the maintenance of this equipment results very expensive too. Since, only qualified staff who is out of the university has knowledge about the industrial system, if the system breaks down, it has to be sent to the repairing service and an expensive bill is paid. Normally students hardly known how to operate the industrial system and then damages are caused and always a some system is in the repairing service, leaving the laboratory with less equipment.

So, very expensive equipment is acquired in less number of units that are really necessary, and only a few features of these systems are used. Moreover, this equipment suffers a lot of damages because students operate it, and very expensive bill are paid in order to repair it. This could be a little bit controversial if there is not much money to buy them.

## LABORATORIES EQUIPMENT

One way to save money in laboratory equipment could be to invent systems with similar features to the real industrial one but they should be adapted to the practical sessions requirements. With low cost elements is possible to make systems that can be used in the laboratory like the industrial one will be used. Since these elements have been designed in the department, laboratory staff can make them as much as necessary and if they broke down, this staff can repair in a few days.

This solution has two advantages in the future engineer. First, the students directed by one lecturer do the design and build the prototype. This work could be developed as a diploma thesis for example. Second, the knowledge of the design allows laboratory staff to built as much as necessary systems in order to have one of them for each student in each practical session.

## DEVELOPED EQUIPMENT

In order to achieve an automatic control of a system, it is necessary to have a data acquisition system connected to a computer. The industrial data acquisition systems have several inputs and output digital and analogical channels and also several timers. These electronic cards are also designed to work in a very noisy industrial environment during full days. As a consequence this cards are very expensive.

Another element that is necessary in any control loop is the driver that operates the system. This industrial element is normally a regulated supply, which receives a signal from the data acquisition subsystem and operates the system. Systems are normally motors if speed and position is wished to control, if temperature is going to be controlled resistances and Peltier cellules are used.

So, a regulated supply and a data acquisition system are necessary in each place in the laboratory. In the Automatic Control and Systems Engineering Department of the Polytechnic University of Valencia, an electronic card with these two elements has been designed. Figure 1 shows it.

The operating of this data acquisition system is based on low cost microcontroller from Microchip. Mainly, this microcontroller has an A/D converter with several inputs connected to it, some digital inputs and outputs, two PWM output signals y several timers. The communication with the computer is done thought a parallel port also included in the microcontroller. This parallel port is very easy to connect to a standard ISA slot [1]-[2]-[3]-[4]. With all of these elements included in the microcontroller, a few externals elements are needed to complete the data acquisition system. The two PWM outputs are connected to a two H-bridge power devices in order to supply achieve output currents up to 6A. This two power devices replace the regulated supply. On communication matter, just a few TTL devices are used in order to manage data thought the port. This allows full control of the data acquisition system from the computer. It is possible to access from the computer to all the microcontroller register that control the digital and analogical inputs, as the digital and PWM outputs. Moreover, it is also possible to program one microcontroller timer in order to determine the working sample time. Data flow between the computer and the data acquisition system can be done via interruption handler or polling. All this features can be easily used thanks to software driver that has been programmed also. The general acquisition system diagram is show in figure 2.

Features of this low cost data acquisition card are the following:

- 5 analogical input channels. 10-bit resolution. 0-5 V.
- 8 digital inputs TTL compatible
- 8 digital output TTL compatible
- 2 PWM output 55V – 3A. Peak current up to 6A
- 1 timer. 10 _s to 17 minutes programming time.

These features are enough to achieve automatic control practical sessions. The control of this data acquisition system is very similar to any industrial one. The manufacturer gives the data acquisition system whit its software driver to control it. In this case the behaviours is the same but it has a very interesting advantage: the design has been done in the department and with low cost we can make as much as necessary with a very low cost and also repair it, if it breaks down. Moreover, all the elements are in the card, so the assembly is very easy and fast as is shown in figure 3. In this case the low cost data acquisition system is used to control speed and position of a DC motor.

## PRACTICAL SESIONS

With this low cost data acquisition system several practical training related with automatic control can be achieve.

**DC motor model identification**

This practice consists on obtaining the DC motor model in an experimental way. The result of this practice is the starting point for the next one. The elements used in this practice are the low cost data acquisition card, a DC motor and a PC with C compiler. These are shown in figure 3. The student has to identify the velocity model and the position model versus the working percentage of the actuator. The experiments are done in an open loop way. In order to achieve the identification, the student has to write a C program using the driver to manage the data acquisition system. First, the program has to set the data acquisition system timer to the sample time. Second, it has to put the DC motor at a working point. Third, when the DC motor speed is stable then it should apply a step change in order to increase or decrease the velocity. Moreover, the program has to store all the data generated during the experiment in a file. So, when the student writes the program, they execute it and the use the results to obtain the model parameters. They use Matlab to show the results. These results are shown in figure 4. The left figure shows velocity identification data and the right one shows the position.

**DC motor digital control**

Starting from the model obtained in the last practical session the control of the velocity and the position of the DC motor can be done. In this case three different controllers are proposed. First, a proportional controller in order to obtain a output with less time response and less overshoot, Second a proportional plus integral action controller to achieve the same behaviour than the first one. Third, an algebraic with final time controller with the same specifications than the two previous has to be designed. The objective is to test the three types of controllers in order to compare the responses and to see the advantages and disadvantages of each one. Moreover the student has to compare the real responses with the simulation done with Matlab. The way and the materials to resolve this practice are similar to the first one.

**RC network digital control**

In this case an easier practice is proposed. The student has to control the voltage in a capacitor supplied through a resistor. The way to resolve the practice and the material are the same than the first one. In this case a capacitor is used instead of a DC motor. The results obtained in this practice are very similar to the simulated one because the system is very simple (just a capacitor and a resistor). The real responses obtained with the low cost data acquisition system are shown in figure 5. The behaviour of this data acquisition system is excellent.

## CONCLUSIONS

A low cost data acquisition system has been developed. Results shows that it behaviour is very similar to some industrial data acquisition system. From engineering education point of view this is a very interesting work since it allow obtaining a well-equipped laboratories with a very low cost. These laboratories are used by students to understand all topics of automatic control working with real systems similar to industrial one. Moreover as the student is the designer of the system together with a lecturer, they can achieve a very good engineering training.

## FUTURE WORK

Since the ISA standard is going to dead in a few years, future works are towards connect the low cost data acquisition system to the PCI standard bus.

## REFERENCES


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## FIGURES AND TABLES

FIGURE 1
LOW COST DATA ADQUISITION SYSTEM DEVELOPED

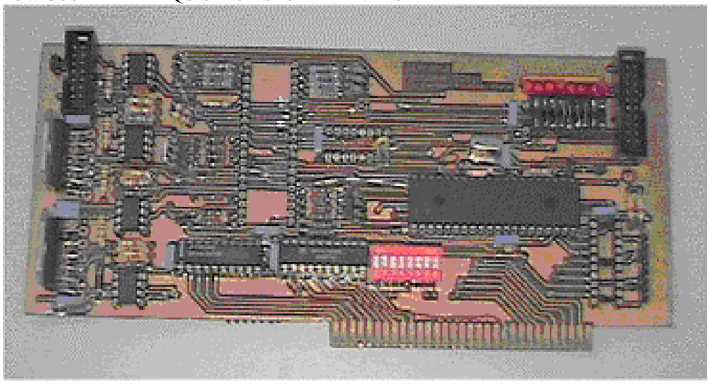

FIGURE 2
LOW COST DATA ADQUISITION SYSTEM DIAGRAM

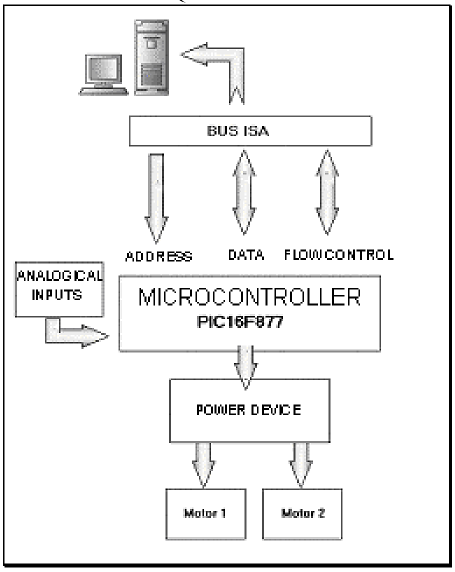


FIGURE. 3
LOW COST DATA ADQUISITION SYSTEM USED TO CONTROL SPEED AND POSITION OF A DC MOTOR

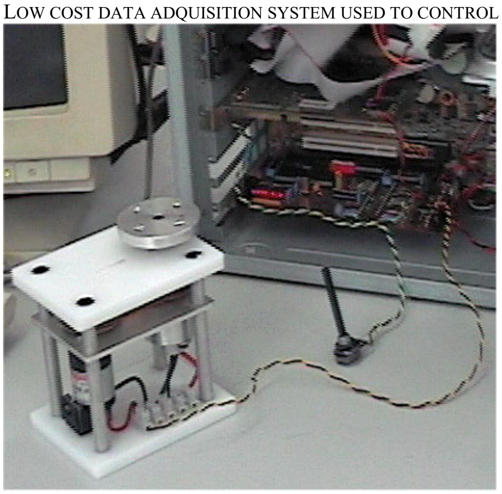

FIGURE. 4
Data obtained using the low cost data acquisition system to calculate the velocity and position models of a DC motor. The left figure shows velocity experiment and the right one position experiment

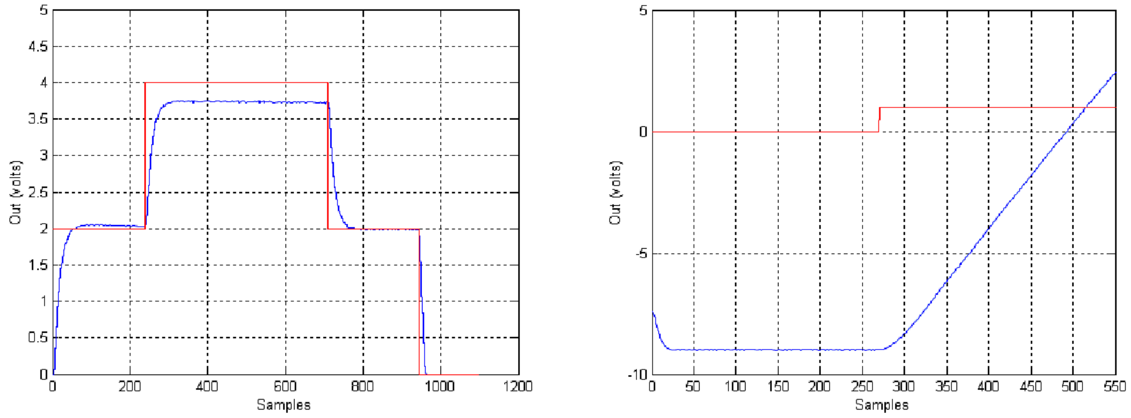


FIGURE. 4
Data obtained from the voltage control of a capacitor in a RC network using four different controllers. Top left proportional, top right proportional + integral, down left proportional + integran cancelling the slower zero, down right proportional + integral + derivative. (Blue line is control and the green one is the voltage in the capacitor)