Design of a low cost electronic control system for an articulated robot arm

J. J. Rubio Ávila, R. Alcántara-Ramírez, J. Jaimes-Ponce, and I. I. Siller-Alcalá

Abstract— With the continuous growth Mecathronics has had in the past few years, public universities have seen the necessity of developing its own prototypes for the application of Modern and Classical Control laws. The development of such Mechatronical systems involves electronic conditioning circuits of signals as well as power electronic systems for the adequate control of the traction elements of the mechanical system. This article presents the design and the construction of electronic systems for the control of an articulated robot developed for research and teaching in subjects related with instrumentation and control. The main advantage of this design is its lower cost than commercial equipments with similar characteristics, an extra advantage to this, is the fact that the maintenance as well as future modifications can be done in a quick and easy way.

Keywords— Control System, Experimental laboratory, Mechatronics, Process Control, and Robotics.

I. Introduction

In research and teaching, for a better comprehension of the Control Theory [1] in the robotic area, it results very adequate to use real system; on the other hand, a search was made for suitable, commercially available products. The process offered by manufacturers like Feedback, TecQuipment, Quanser Consulting, etc. have prohibitive costs. The previous limitations had impelled to the Laboratory of Control Processes of the UAM-Azcapotzalco to develop a Mechatronical system composed of three big blocks. In Fig. 1, the first block is a graphical user interface developed in Visual Basic that allows the application of the Modern and Classical Control laws, the second block corresponds to an articulated robot arm with 6 degrees of freedom, finally, the third block is constituted by an electronic system of signals conditioning and power stage. The electronic system is the link between the mechanical system and the graphical user interface. During the design [2] and development of the electronic block several considerations were taken into account such as being developed with cheap and reliable circuits and easy acquisition, in order to accomplish a system that will be of an easy maintenance and reproduction.

The electronic block system is composed of three stages as is shown in Fig. 2. The first one is used for the analogue/digital conversion and the communication with the Personal Computer. The second one is used for signal conditioning which are provided by the sensors, and finally the third one the power stage to control the traction elements.

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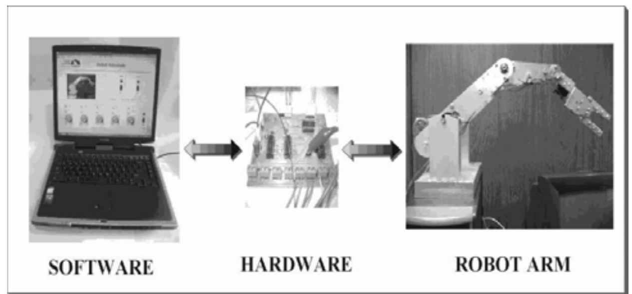

Fig.1 Mechatronical System

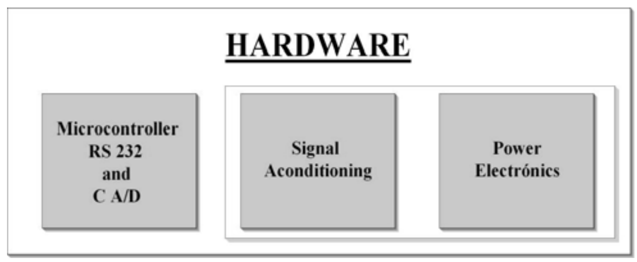

Fig. 2 Electronic Block system

II. The System Description

The system was developed with the versatility of being used in its totally (software-hardware-Robot arm, Fig.1), or by parts (Hardware, Robot arm or only the Robot Arm), in this way, the user will have the possibility to develop each one of the stages. Such is the level of versatility that the robot arm may monitor and control with Matlab´s Simulink, Lab View or any other similar software as well as a data acquisition card, but it is only necessary to use the conditioning signal and the power stage.

Fig. 3 shows the power stage, to be able to use in this last form, an interconnection with electric standards was developed.

The electronic block in Fig. 2 is constituted by the following parts:

Digital System
Conditioning System of Analogue Signals
Power Stage

Digital System

Interface for the serial transmission RS232
Output stage with six digital outputs which are modulated by using PWM [3].
Input stage with six analog inputs. (0 to 5 V).

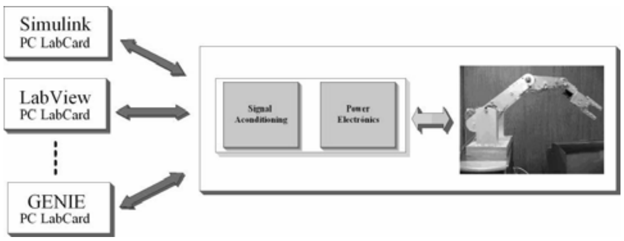

Fig. 3 Versatility in the connections of the developed system

Conditioning System of Analogue Signals

Six conditioners of analogue signals, whose functions are to transform the position of each articulation into a proportional voltage.
Six analogue outputs in the range from 0 to 5 Volts, whose function is to transmit to the microcontroller the articulations position.

Power Stage

Six digital inputs (PWM)
Six inputs to establish the turn direction in each actuator.
Six PMW power outputs for the actuators (Motors).

A. Description of the digital part

This part has as a master module a microcontroller PIC16F876A Figs. 4 and 5 which is charged of processing information that is received and sent to graphical user interface in the PC, it receives as well, the information from the signal conditioner to process the value of the angular position of each robot arm articulation, in other words, the microcontroller is the brain of the interface. In order to carry out the serial communication with the PC, a MAX232 circuit is used to provide the adequate voltage levels in order to interface with the PC. The transmissions are done throughout the serial port of the computer at a speed of 19200 bauds, 8-bit length without parity**.** This master system also provides the six digital signals that control the motors speed; the digital signals are pulse width modulated signals.

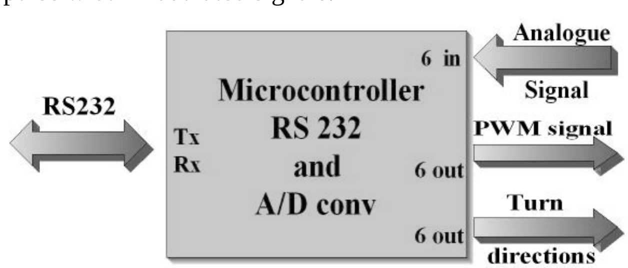

Fig. 4 Block Diagram of the digital system.

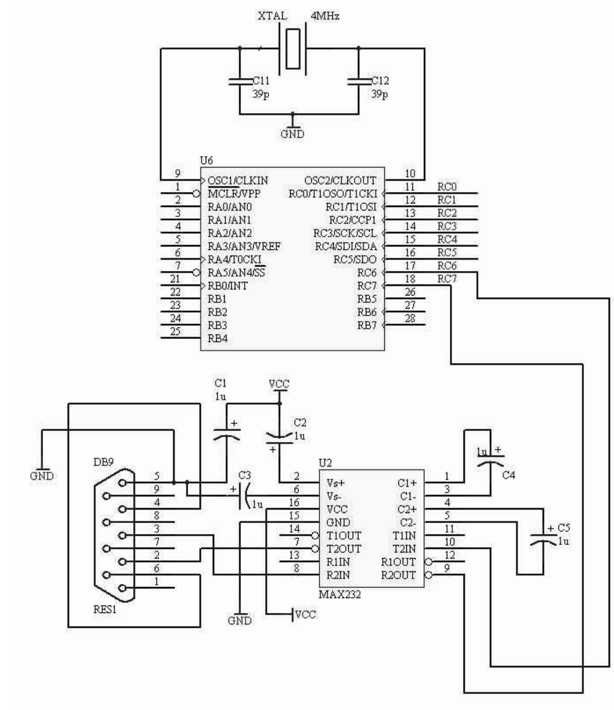

Fig. 5 Microcontroller and serial communication interface.

The distribution of the microcontroller ports is the following:

TABLE I
PORTS DISTRIBUTION OF THE MICROCONTROLLER

Ports	Inputs and Outputs
Port A	Analogue Inputs • The voltages are received coming from the signal conditioning card of angular position sensors.
Port B	Digital Outputs • PMW signal generation to control the motors speed throughout the power card.
Port C	Digital Outputs • Serial transmission • PMW generation to control the turn direction of the articulations.

B. Conditioning System of Analogue signals

To process the analogue inputs signals, Port A of the microcontroller is used. The A/D converter has a 10 bits resolution, which is very acceptable for applications in control processes. Each articulation contains a position sensor based on 10 turn precision potentiometer with infinite resolution.

In order to determine the articulations position, each conditioner stage, first carry out impedance coupling with signals filtration and finally signal amplification [4 and 5].

For the first action an operational amplifier in Follower configuration is used, which allows satisfying with the impedance coupling requirements which are demanded for the devices which will be interconnected (Fig. 6). A capacitor in the input is used for the filtering of noise that may change the real value which is provided by the sensor.

In the second stage, an amplifier with non inverted amplifier configuration is used to provide the adequate levels of voltage to the A/D converter inputs of the microcontroller.

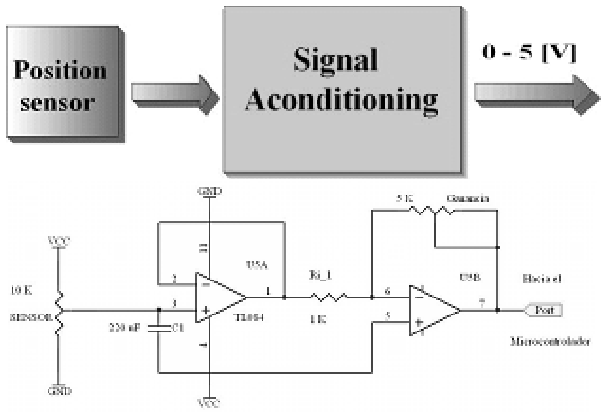

Fig. 6 Signal conditioning coming from the angular position sensor.

C. Power System

The method to control the energy and as a result the speed and motors position, is done with the modulated signals by the Pulse Weight Modulator (PWM), being the area of each pulse the average voltage that is being received by the corresponding actuator (motor), these PWM signals are generated inside the microcontroller and later they are transmitted to the power stage.

As a power stage for the motor speed control, an integrated circuit L293 was used Fig. 7, which consists of two H-bridges and contains all of the necessary devices to provide the sufficient electric characteristics for managing the energy of the actuators.

Each motor uses an H bridge; therefore three integrated circuits can control six motors. The integrated circuit L293 is very simple to use due to its functions, which made it very useful in our design.

In general the IC L293 has the following characteristics:

Output current 600 mA

Range of voltage operation 4.5 to 36 V

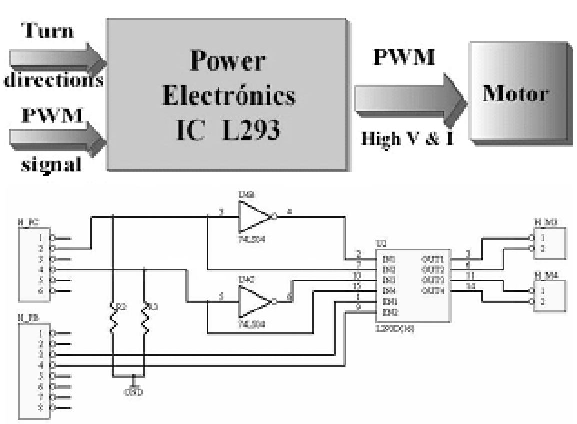

Fig. 7 Speed Control and direction of the motor turn throughout the IC L293.

III. The Graphical User Interface

To develop the graphical user interface, Visual Basic 6.0 was used, accomplishing a very nice environment Fig. 8 and an adequate control of the articulated robot arm.

Fig. 8 The graphical user interface

Like any application under the Windows operative system, this one has a main menu, and one of the most important options is the selection of the controller, Fig. 9 shown the control configuration, the Kp, the PID control, the PD control with gravity compensation, hyperbolic cosine control and sliding modes control.

Also it contains virtual controls Fig. 10, which can establish the desired angle in each articulation.

Fig. 9 Control Configuration

Fig. 10 Virtual controls to establish the desired angle.

IV. Results

After design the stages that constitute the hardware Figs. 11 and 12, the design and construction of the printed circuits were developed Figs. 13, 14 and 15, it can be seen, they are very compact and an easy reproduction.

Once the software, the articulated robot arm and the hardware were developed, experiments were made with the complete system of the above blocks, necessary connections and the pertinent adjustments were done in order to convert the sensor signal of an angular position into voltage.

Modern [6] and Classical [7] control laws were implemented into the software, giving results like the responses shown in Figs. 16 and 17 corresponding to two of the six articulations.

One of the advantages of using Visual Basic is that an excellent presentation may be given to the PC application.

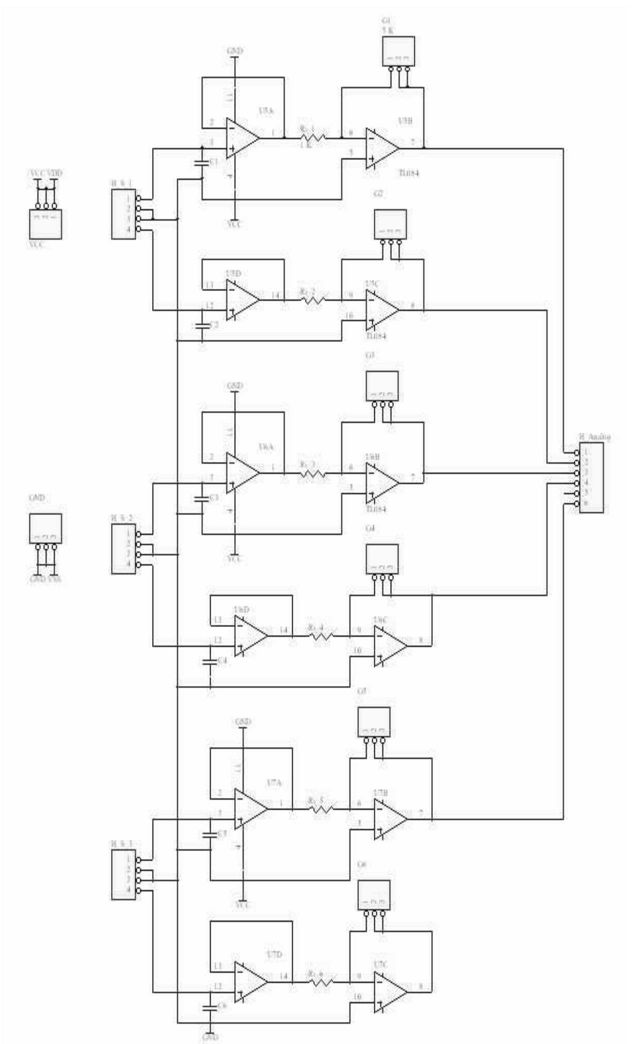

Fig. 11 Conditioning circuits of angular position sensors signals.

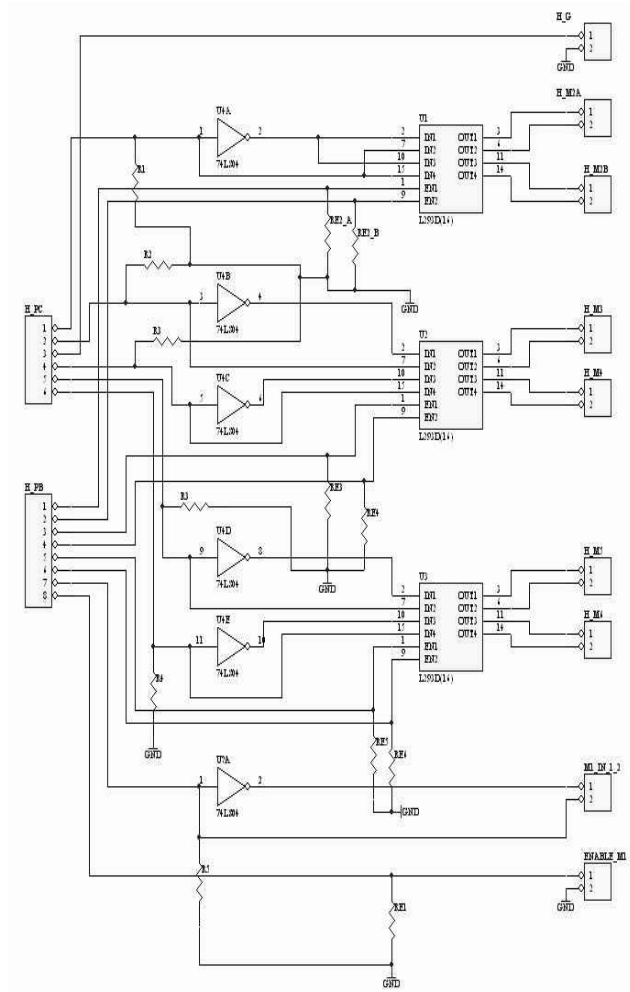

Fig. 12 Power Stage Circuit

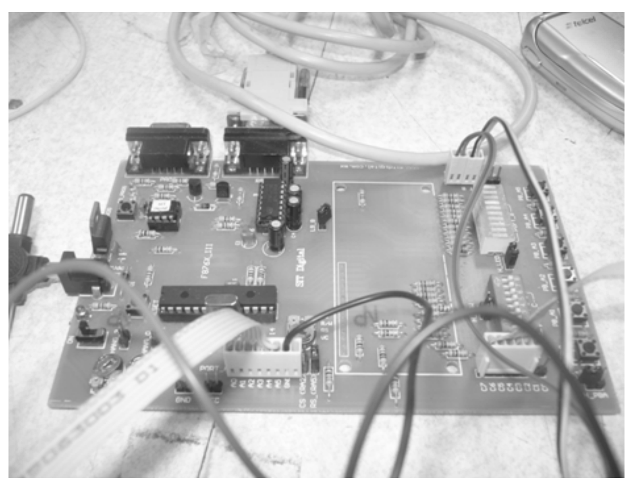

Fig.13 View of the microcontroller card and the serial communication circuit.

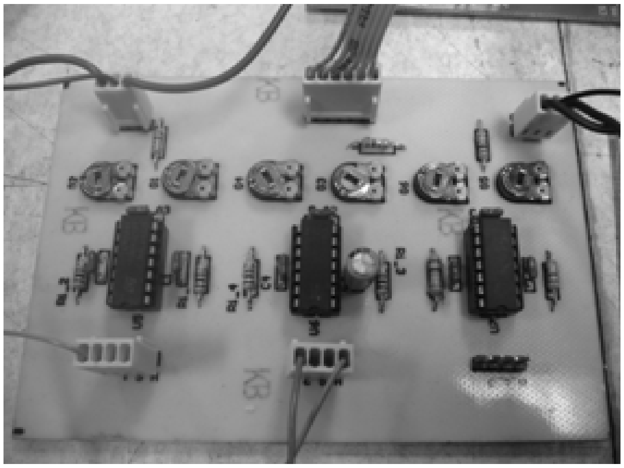

Fig. 14 The signal conditioning card

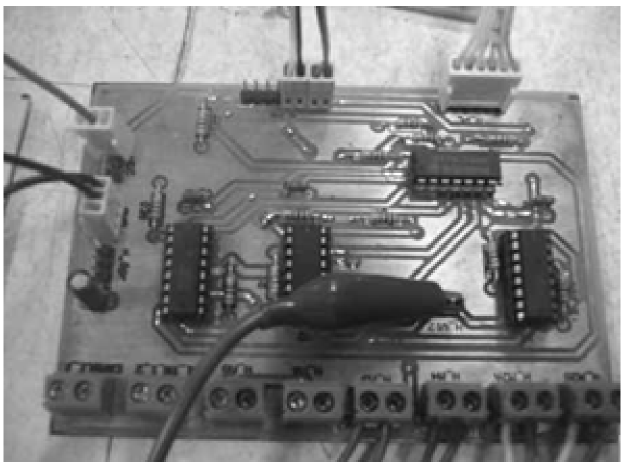

Fig. 15 Power Stage Card

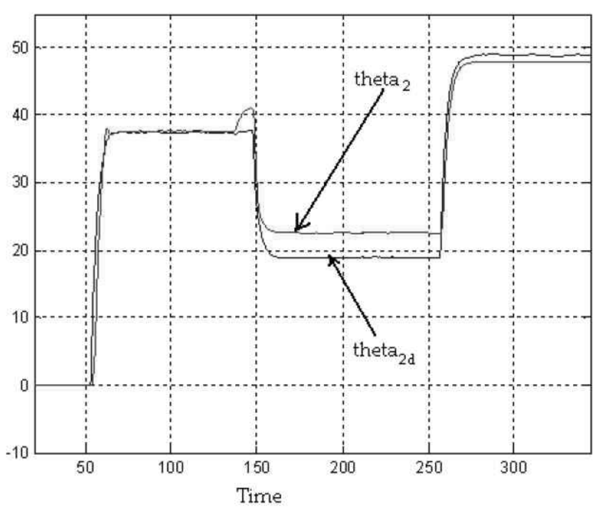

Fig. 16 The Responses of second articulated joint and reference trajectory.

The system performance can be seen in Figs. 16 and 17, the mechanical and electronic parts as well as the Control Laws allow to produce a behaviour in the robot movements that lie inside of acceptable intervals, as shown in Fig. 16 corresponding to the "shoulder articulation" whose job is to carry a bigger weights therefore larger inertial moments are generated its response to extreme variation trajectories (Square trajectories) shown responses very close to desired trajectories, these trials were done either for positive or negative angles as well as for smooth trajectories (sinusoidal signals) and extreme ones and all the control laws were applied.

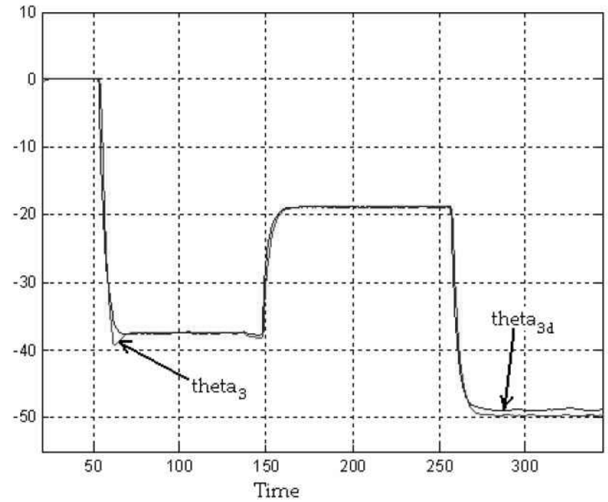

Fig. 17 The Responses of the third articulation and the reference trajectory.

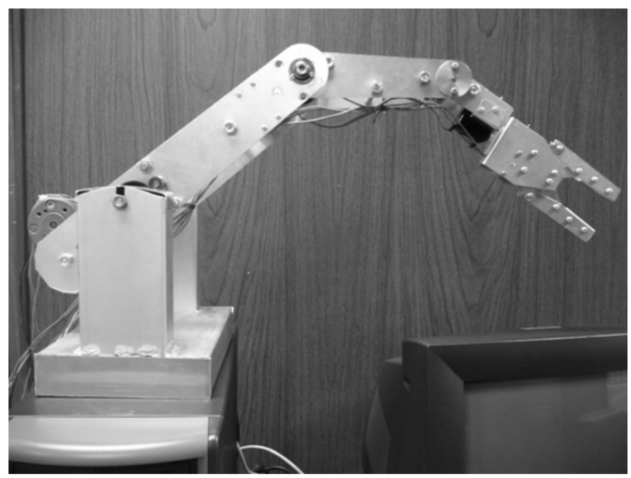

Fig. 18 The Articulated Arm Robot.

V. Conclusion

The development of this type of systems Fig. 18 allows Universities to develop their own equipment with lower costs than commercial equipments with similar characteristics, an extra advantage to this, is the fact that the maintenance as well as future modifications can be done in a quick and easy way by the members of the Institution.

Fig. 17 shows the response of the third articulation corresponding to the "elbow", which supports smaller weight and as a consequence generates smaller inertial moments; this response was achieved through extreme variation trajectories using the Control sliding [8] modes with gravity compensation law, the behaviour of the complete system is very acceptable.

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