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Implementation of Matlab communication and Allen Bradley PLC for control of the AMATROL JUPITER XL Robot

Implementación de comunicación Matlab y PLC Allen Bradley para control del Robot AMATROL JUPITER XL

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Abstract

The article introduces a method to enable a robot, the "AMATROL JUPITER XL," without relying on its conventional controllers. Instead, a Human-Machine Interface (HMI) is employed using Allen Bradley's "ControlLogix 5550" software. This setup combines the engineering program MATLAB (via the Simulink extension) to develop control block diagrams containing calculations for robot design and comprehension. A data read-write interface is implemented on an "Allen Bradley 1756-L1" PLC, along with the integration of an Open Platform Communication (OPC) platform using the "RSLinx Classic" software. This configuration empowers the user to manipulate trajectories and objectives using calculations that depict the kinematics and dynamics of the mentioned robot. Consequently, this setup offers a control option that enables direct application of theoretical mathematical principles to the design and control aspects of robotics, leading to enhanced understanding of these principles.

HMI, Control, Robotic

Resumen

En este artículo se presenta una forma de habilitar un robot “AMATROL JUPITER XL” sin la utilización de sus controladores convencionales. En su lugar se utiliza una Interfaz Hombre - Máquina (HMI) usando el software de la empresa Allen Bradley “Control Logix 5550” con una configuración que combina el programa de ingeniería MATLAB (mediante la extensión de simulink, en el que se desarrollan el diagrama de control por bloques de comando los cuales contienen los cálculos para el diseño y comprensión de un robot) y una interfaz de lecto-escritura de datos, aplicada en un PLC “Allen Bradley 1756-L1”, con la implementación de una Plataforma de comunicación Abierta (OPC) haciendo uso de los software “RSLinx Classic” la cual permite al usuario poder manipular las trayectorias, y los objetivos, empleando cálculos que representan la cinemática y dinámica del mencionado robot. Todo esto provee una opción de control que permite al usuario una aplicación directa de los principios teóricos matemáticos del diseño y el control en la robótica, permitiendo una mayor comprensión de los mismos.

HMI, Control, Robótica

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Introduction

Robotics is one of the most exciting branches of engineering, but also one of the most complex subjects for a student. Institutions acquire equipment and due to the complexity of the design the software and controller provided by the company itself; this implies the need to be trained in the electronics and software provided to manipulate the robot. The tasks for the robot applied to control, trajectory tracking and positioning, require the use of specialized hardware and different for each robot manufacturer in the industry that are generally incompatible with each other, representing high costs in hardware acquisition and training in case of not having this equipment for a specific robot. At the Institute we have an obsolete but very functional robot which is no longer supported by the company and we do not have software and certain hardware to manipulate it. In this article we present the way in which we achieved the communication with the robot using Matlab Simulink programming through the Allen Bradley PLC 1756-L1 to have a "home-made" alternative to achieve the control of the industrial robot ADEPTO of 4 degrees of freedom AMATROL JUPITER XL.

The system that has been designed allows us to dispense with the acquisition of software and hardware from the manufacturer and achieve the rehabilitation of the robot that have been discontinued, also allows the unification of multiple work units and create a general communication network, allowing the integration of different automated machines.

Electrical System

It is worth mentioning that, although this alternative presents the solution in the application of not using the usual controls, the A721 servo amplifier driver is still used to control the power of the motors used in the "AMATROL JUPITER XL" robot (Figure 1).

Figure 1 Amatrol Jupiter XL Robot

Table 1 shows the identification of each of the cables that communicate from the robot to the controller, as well as the controller and the encoders which are routed and connected to the PLC; the 24 connector pins are identified and described in Figure 2.

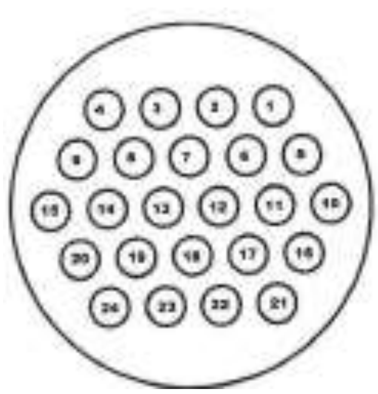

Figure 2 24-pin connector layout

Pin	Data	Pin	Data	Pin	Data
1	Engine 2 (+)	7	Motor 4 (+)	13	Tach 1 (+)
2	Engine 2 (-)	8	Engine 4 (-)	14	Tach 1 (-)
3	Engine 3 (+)	9	Tach 2 (+)	15	Tach 4 (+)
4	Engine 3 (-)	10	Tach 2 (-)	16	Tach 4 (-)
5	Engine 1 (+)	11	Tach 3 (+)	17-20	-
6	Engine 1 (-)	12	Tach 3 (-)	21-24	-

Table 1 Pin Identification

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An additional connection is necessary for the pneumatic drive area of the robot with the relation presented in table 2, which is a 16-pin connection as shown in figure 3 and will allow us to control the actuators from the PLC through the solenoid valves it contains, however, for the mentioned connection it is not necessary to take as a standard the pin relation presented in this article, since, being a created connection, it is left to the decision and definition of whoever uses it.

Pin	Data	Pin	Data	Pin	Data
1	RTN 1	7	RTN 4	13	-
2	Drive 1	8	Drive 4	14	-
3	RTN 2	9	Relay (-)	15	Relay (+)
4	Drive 2	10	-	16	Sensors (-)
5	RTN 3	11	Switch (+)	-	-
6	Drive 3	12	Switch (-)	-	-

Table 2 Identification of pins of the additional connection

Communication to PLC

For the communication of the robot to the PLC (figure 3) a 16-pin cable is used, whose connection is located in the controller and the 4 cables of 24 pins with output from the robot that correspond to the 4 encoders, making use of them, the connection to the PLC is made, the diagram of the controller cable pins is presented in figure 4, and the identification of them is presented in table 3.

Figure 3 Cabinet with the connections between the robot and the PLC

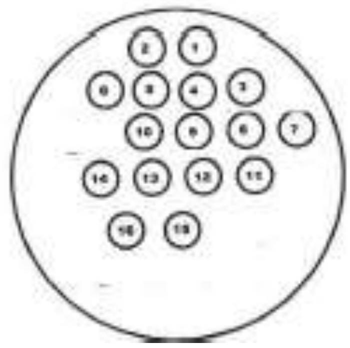

Figure 4 16-pin connector layout

Pin	Data	Pin	Data	Pin	Data
1	GND 12v	7	Valve 2	13	Tool 2
2	Tool	8	-	14	Valve 3
3	Tool 1	9	Valve 4	15	-
4	-	10	Valve 5	16	-
5	Tool 3	11	Valve 6	-	-
6	Valve 1	12	GND 24v	-	-

Table 3 Identification of the cable that communicates the controller with the PLC.

The "Allen Bradley PLC Control Logix 1756-A7 A series 7-slot Chassis" requires the integration of the modules described below:

"ControlLogix Controller and Memory Board 1756-L55" module, is used as a controller and non-volatile memory for storing virtual tags which are used for the operation of electrical components controlled from a computer machine.

The "ControlLogix High-Speed Counter Module (1756-HSC/A)" is used to count the pulses in the encoders, which occupy both input A and B of the counter, making the connection as shown in Figure 5. The relationship between these two channels determines whether it is positive or negative.

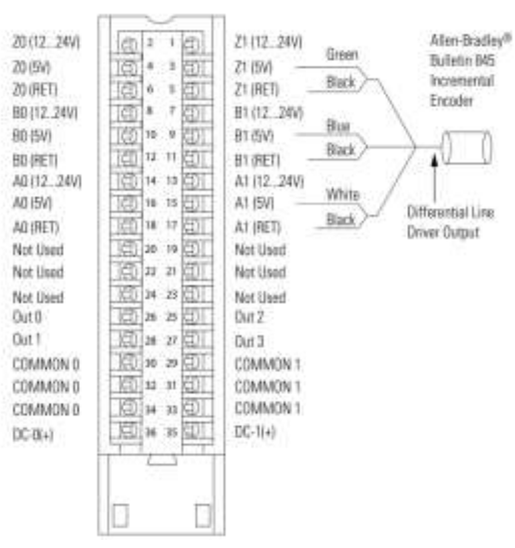

Figure 5 Encoder to PLC connection diagram

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The "ControlLogix I/O Module Analog Output (1756-OF8)" module is used to control the four motors of the "Amatrol Jupiter XL" robot, since this module manages the necessary voltages (positive or negative).

These ControlLogix output modules receive a signal from the A721 controller and process it internally through hardware and an ASIC (Application Specific Integrated Circuit) before sending the signal to the output device through the RTB as shown in Figure 6.

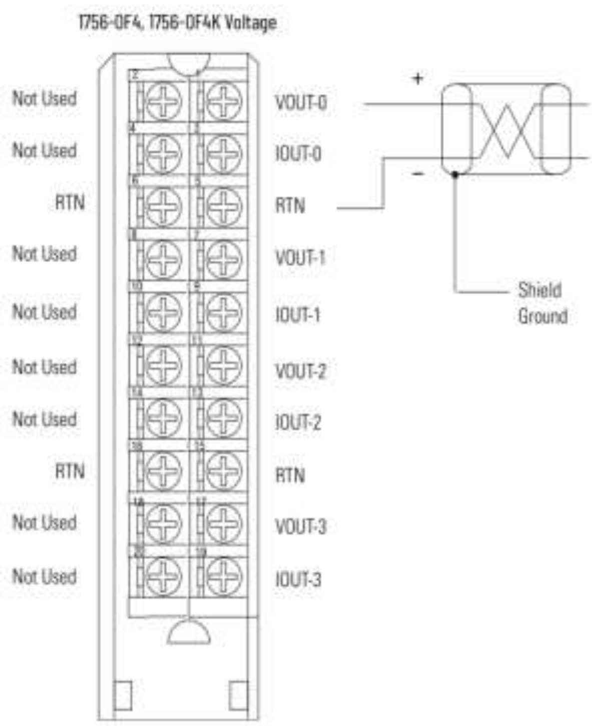

Figure 6 Wiring diagram for motor control.

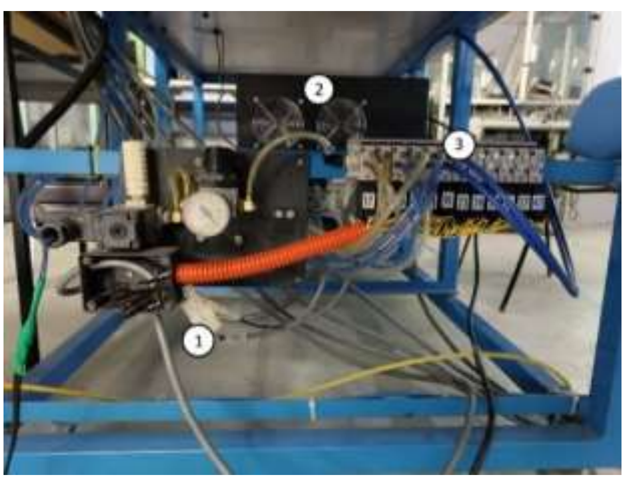

Figure 7 1) Connection 2) Servo controller. 3) Solenoid valves.

The "ControlLogix I/0 Module Digital Output (1756-OB8)" module is used to drive the solenoid valves (Figure 7) and the signals to the motor controller module using the diagram in Figure 8.

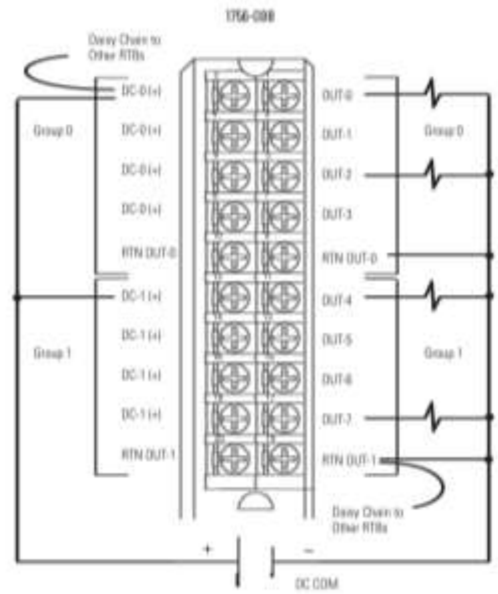

Figure 8 Connection diagram for valve control.

The Encoders use a cable with a 24-pin connector as shown in Figure 1, towards the PLC the classification identified in the cables is presented in Table 4.

Pin		Date	Pin	Date	Pin	Date
1		A	7	5v	13	-
2		$\overline{A}$	8	0v	14	-
3		B	9	-	15	-
4		$\overline{B}$	10	-	16	-
5		Z	11	-	17	-
6		$\overline{Z}$	12	-	18-24	-

Table 4 Identification of encoder cables

PLC-RSLogix Communication

Through the serial communication port a relationship is established between the PLC and the computer, using the RSLogix 5000 program the configurations for each of the modules that are used are established, and later, with the creation of a main program the labels for each of the outputs and inputs of the system are created and loaded to the PLC, this allows the user to have an almost instantaneous visualization of the data obtained from the encoders and sensors, likewise it allows the drive of the motors and therefore the manipulation of the trajectories (figure 9).

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The tags created in the main program that is loaded to the PLC are essential for communication from the MATLAB program because it allows the values to be modified in real time, with a slight delay of no more than 1s from the time it is modified until the robot responds.

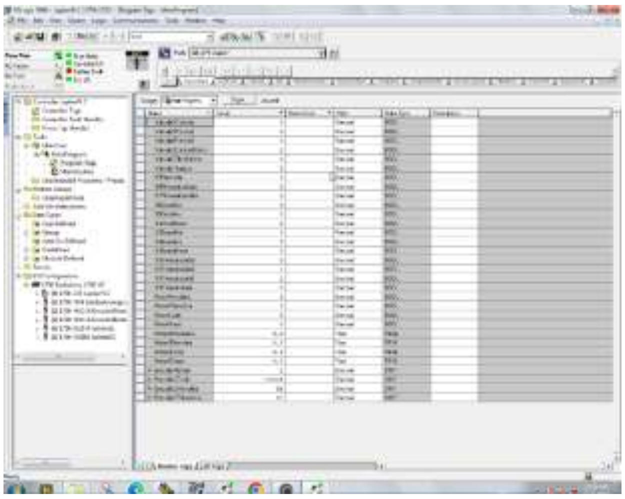

Figure 9 RSLogix 5000 software running with the tags; here we can see the information obtained from the tool's sensors reflected by the Boolean value 1

ControlLogix link to MATLAB

Using the programs "RsLinx Classic Gateway" and "DeviceNet - RSNetWork for DeviceNet" an OPC is built to allow the transfer of information between the PLC programs and the program to be used for the simulation and design of the robot trajectories, which in this particular case are RSLogix 5000 and MATLAB respectively, so that the values of the tags created can be modified, thus obtaining movement and manipulation of the physical system of the robot.

Control program in MATLAB

In order to obtain a precise movement of the robot using the MATLAB tool (SIMULINK), a virtual PID control system must be designed which allows the modification and correction of the positions and speeds required.

In the same way, the program displays data of analysis of the robotic system such as Position, Velocity, Angular velocity, Acceleration, etc.

The virtual system for the control of the robot requires for its operation data such as initial position or desired position (which are dictated by the user), and making use of mathematics; it uses operations such as inverse kinematics, direct kinematics, PID calculation (Proportional, Integral and Derivative), to define the voltage for the torque of the motors, find the position, regulate the speed and acceleration in the trajectory defined by values in radians.

Results

In the electrical part we found complete functionality of the electrical systems that allowed a correct communication to the PLC. This allows us to work successfully from the computer with a time lag of less than 1 second between the action requested in the computer and the action performed in the mechanical system of the robot.

From the communication with Matlab, the previous tests to the system mentioned in this article, which only requires the manipulation of a single value were successful, achieved movement in the robot from the MATLAB program, Figure 10 presents an example of the visualization of the communication.

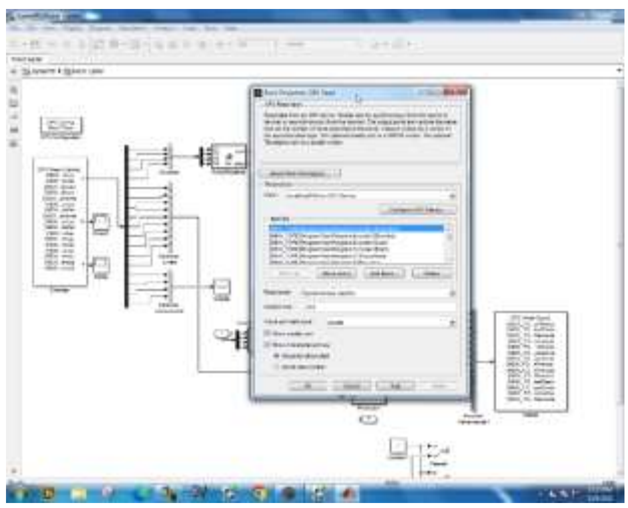

Figure 10 The labels created in a program must be able to be shared and visualized in MATLAB

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Conclusion

We know that the implementation of this control system for a robotic system is feasible, and useful for the academic area studying robotics, however, the complete control system employing PID back analysis by MATLAB is still under development with good expectations from the project.

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