Creating an ethernet communication between a Simatic S7-1200 PLC and Arduino Mega for an omnidirectional mobile platform and industrial equipment

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Abstract. The degree of automation in the industry increases more and more every year, trying to reduce more and more or even eliminate the collaboration with the human operator. The basis of all automatic industrial equipment is PLCs. This paper presents a method of extending the number of inputs and outputs of a Siemens Simatic S7-1200 PLC, using an Arduino Mega development board and an Ethernet communication. Following the realization of this communication, the number of inputs and outputs will increase considerably, being able to connect various sensors used for the construction of an omnidirectional mobile platform, but also for equipment for industry. The advantages of using this communication are multiple, both from a financial point of view and from the point of view of the flexibility and integration of robotic systems in industrial equipment.

1. Introduction

Mechatronics and robotics as rather new branches of technical sciences have created a big demand of communication protocols between the devices within industrial systems [1]. The digital industry is undergoing a major transformation due to recent developments in information technology and communication. They have a massive impact on all known technological aspects, having a connectivity with a speed impossible to achieve in the past. As a result, the barrier between the two physical and digital worlds is getting smaller. This leads to rapid progress, which generates new trends in the industrial world, such as: Cyber-Physical Systems (CPS), Internet of Things (IoT), cloud computing, Industry 4.0 and Smart Grids (SG) [2, 3].

The Industry 4.0 concept will create new skills requirements in the future with the digitization of future production. The demands on the use of emerging technologies will put pressure on the type of qualification and finding new employees with superior cognitive skills and abilities. It also requires interdisciplinary thinking, a high dissemination capacity and the ability to put into practice, but also to have a tactical and highly operational understanding in order to be able to easily develop and implement all Industry 4.0 solutions [4].

For automation and monitoring of industrial equipment, PLCs are used due to their proven reliability and flexibility over time. In the traditional scheme, it is specified that production systems must operate for a long time with high reliability. Of these consonants, programmable logic controllers (PLCs) are the most widely used automation devices in industrial processes. As for open source
hardware, Raspberry Pi, Arduino, Beagle-Bone Boards, Intel Edison or Phidget, are devices that were not created for an industrial purpose. The best-known example is Arduino, a cheap development board based on a powerful Atmega microcontroller. In terms of use in research and development but also academia, Arduino is a major trend that has become a powerful tool to develop and create various applications in the fields of automation or data acquisition. It is well known that programming and configuring Arduino chips is easy and flexible [5].

From the point of view of Arduino software, it has the same IDE interface (Integrated Development Environment) which is used for all types of development boards and is compatible for several types of operating systems. This IDE is open source with a friendly interface that is easy to use. C / C ++ are the programming languages used, which allow the user to create from scratch a simple program based on procedures in a single file, to a more complex program oriented on objects from several types of files. Other advantages of the Arduino development board are the information that is easy to find and in large quantities about it, information being available on the manufacturer's website, but also in books in the form of tutorials with applicability in various fields. Another reason why the Arduino development board is so popular is the number of tutorials and courses that are often found for free. These courses are aimed at people specializing in electronics and robotics, but also teachers or students who want to use the platform for education and research [6].

2. Design of the communication hardware system

2.1. Industrial communication in the perspective of Industry 4.0

For future Industry 4.0 technologies, engineers need to improve all their professional, social and personal skills. They need an interdisciplinary knowledge of production systems and processes, automation technology, information technology, ergonomic principles, etc. In addition, communication and cooperation skills in interdisciplinary groups are also important. The future modern engineer who is part of Industry 4.0 must have a holistic view of complex production systems [7,8].

![Figure 1. Critical aspects related to production, technology, and personnel [7].](image)

Figure 1 illustrates this overview showing the need for aspects related to production, technology, and the qualification of engineers. This paper will refer to the technology for the development of communication and industrial interfaces, integrated into Industry 4.0. Nowadays, equipment will experience a massive development, and the elimination of the human factor from production processes is becoming increasingly evident. Thus, the integration of robots on production lines is becoming an increasingly intense trend in the industrial world. Autonomous mobile robots also have a new perspective, which know a rapid development in terms of their integration in the industry [7].
2.2. Communication block diagram between Simatic S7-1200 PLC, Raspberry Pi B and Arduino Mega

Figure 2 below shows a demonstration communication model between the control system of an omnidirectional mobile platform consisting of a Raspberry Pi mini-computer and an Arduino Mega development board, with a Siemens S7-1200 PLC found on most industry equipment. The need for such communication becomes necessary when you want a connection between an industrial equipment and a mobile robot or when you want to use the PLC to order actuators for robotics, or to monitor special sensors also in robotics which have special communications such as a gyroscope sensor with I2C communication. In these block diagrams we have a 22V LiPO battery, to which are connected two voltage regulators, one step-up and one step-down. The step-up controller is used to power the PLC at a voltage of 24V, and the step-down controller is used to power the Arduino development board with 5V and the Raspberry Pi B mini-computer.

![Communication block diagram](image)

**Figure 2.** Communication block diagram for an omnidirectional mobile platform with a Simatic S7-1200 industrial PLC.

3. Ethernet communication between Raspberry Pi B and Simatic S7-1200

This paper presents the communication between Arduino and Simatic S71200, which is done through Raspberry Pi because the data transmission between Arduino and S7-1200 can be done only through a database created in TIA Portal. The database is updated all the time with new values. Because the computing power of the Arduino board is limited, there is a fairly significant delay. This delay can lead to many errors in dynamic processes. Using Raspberry Pi we greatly reduce this delay but due to the fact that Node-Red uses java the processor will be quite demanding and that is why it is recommended to use a Raspberry Pi with higher performance than the latest generation. The Raspberry Pi 3 Model B is a mini-computer based on a 64-bit Broadcom BCM2837 64-bit Core CPU and has 1GB of RAM. It also offers Wi-Fi and Bluetooth Low Energy features to improve functionality and the ability to power more powerful devices through USB ports. Also, this model has 4 × USB 2 ports and extended GPIO with 40 pins.

The Siemens Simatic S7-1200 PLC is an industrial programmable controller with a 1215C DC / DC / DC CPU −40 ... + 70 °C with conformal coating based on 6ES7215-1AG40-0XB0. It has 2
ethernet ports with PROFINET. This PLC has 14 digital inputs, 10 digital outputs, two 0–10 V analog inputs and two 0–20 mA analog outputs. The programming memory capacity is 125 KB.

The first step to achieve communication between the two devices was to install the Raspbian operating system on the Raspberry Pi. After installing this OS, an interface program between PLC and Raspberry is necessary (this is Node-RED).

Node-RED is a programming tool for connecting hardware devices, APIs and online services in a simple and fast way. It has a friendly interface and offers an editor, which makes it easy to connect streams along with a wide range of nodes in the palette that can be implemented at run time.

After installing the Node-RED program, the next necessary step to be able to communicate with the Siemens Simatic S7-1200 PLC is to install a library specially created for this type of PLC. To install this library, the following steps should be performed:

- Open the Raspbian programming console;
- Enter the Node-RED directory using the command: `cd $HOME./node-red`;
- Then install the library using the command: `npm install node-red-contrib-s7`.

After the installation is complete, a Raspberry Pi reset is required. In order to be able to communicate with the PLC, it is necessary to configure the mini-computer with a fixed IP, which is of the same IP class as the PLC with which to communicate. This operation is shown in Figure 3a. Immediately after setup, a Raspberry reset is required to take over the new settings. You can also use a router that can be configured via DHCP to always assign a type of IP to both the PLC and the mini-computer. The advantage of using a router is that there is also internet access, if it is necessary to install a new library for Node-RED. Figure 3b shows how to define GPIO pins in Raspberry Pi, how they can be defined as input or output pins depending on what type of block are selected from the Node-RED.

Figure 3. Initial Raspberry Pi settings: a) Static IP setting, b) GPIO pin setting.
Figure 4. Communication settings between Raspberry and PLC: a) IP PLC setting, b) Defining the variable in the PLC.

Figure 5. Making connections between GPIO pins and PLC variables in node-red.

The necessary settings for the s7 in and s7 out block of the Node-RED are presented in Figure 4a, where the IP of the PLC is defined as well as the type of communication that can be serial via the USB port or ethernet via TCP-IP. After this configuration it is necessary to define the place where the information is transmitted, more precisely the variable from PLC. This step is shown in Figure 4b. The connections made between the input and output pins of the mini-computer and the PLC variables are illustrated in Figure 5. Here one can see that Node-RED makes this interface and gives real-time information about the connection status but also about the input and output status from raspberry pi.

4. Communication between Simatic S7-1200 and Arduino Mega

Due to the fact that the Raspberry Pi does not have pins dedicated to analog inputs and outputs, it is necessary to use more expensive shields or analog-to-digital converters, for these reasons the use of an Arduino board is advantageous to use for that it has a large number of analog inputs and outputs and the acquisition cost is low, but the software part is easier to use and specialized libraries are made for sensors used in robotics. This type of communication between PLC and Arduino Mega will be done through the Raspberry Pi mini-computer using the whole Node-RED interface program. The reason or need for such a connection arises due to the need to integrate in the industry different types of robots that use such control boards for their control. Arduino Mega is a development board based on an Atmega microcontroller with a large number of inputs and outputs, but the main advantage is the price which is considerably lower than an output input module for a PLC. The reliability of this component can be considerably increased, if it is provided with a stabilized power supply and if an interface with optocouplers is made on the input and output side. To achieve this communication, a new library that
must be installed in Node-RED is needed. Following the instructions above, the command to install this library is: \textit{npm install node-red-node-serial port}. It is important to note that when this command is run, an internet connection is necessary. Once the library is installed, the Arduino board must be connected to the Raspberry Pi via USB, as shown in Figure 2. Then, in Node-RED the block connections between the serial input or output port and the input and output blocks of the PLC should be made, as exemplified in Figure 6.

Figure 6. The connection between the serial blocks and the s7 blocks.

A program must be written on the Arduino development board that will define the pins on the board as input or output and also transmit or receive on the serial port the information from the PLC. In this case, according to Figure 2, pins from the Arduino were defined as output, pin 23 being digital and pin A13 being analog. In PLC, these will be input pins that will be stored in variables IW6 and IW8. Also, the inputs from PLC M0.0, M0.1, M0.2, M0.3, M0.4 will control the outputs on the Arduino, in this case 5 LEDs that will be connected to pins 22, 30, 38, 46, and 52. These types of variables are defined in PLC tags according to Figure 7 and their status can be tracked in real time as shown in Figure 8.

Figure 7. The connection between the serial blocks and the s7 blocks.
5. Conclusions
This paper presents a communication model between a Siemens Simatic S7-1200 PLC and an Arduino Mega development board via a Raspberry Pi mini-computer model B. This communication helps facilitate the integration of robots that were not created for industrial purposes in the industry, and further develop the new concept of Industry 4.0. Both Arduino and Raspberry Pi are low-cost components that use open source software. This is also ideal for education and research. Also, this type of communication offers PLCs the possibility to expand to a large number of inputs and outputs at considerably lower costs than the use of special modules for PLCs. This work was carried out following a research on an omnidirectional mobile platform on which an industrial PLC was integrated having as main advantages the following:

- wired communication with other industrial equipment through the PROFINET protocol;
- connection of special industrial sensors that use the IO-LINK protocol;
- using special functions in the TIA Portal, such as Auto-tuner PID, to automatically find the parameters needed for a high-performance PID controller;

The most important advantage is that they can connect a wide variety of sensors and actuators without the need for special modules. The obtained results will be used to achieve a communication between an omnidirectional mobile platform that is controlled by a PLC and an industrial equipment that also uses a PLC. Further, starting from this work, a Wi-Fi communication will be realized, in which the omnidirectional mobile platform can communicate in real time at the same time with several industrial equipment’s that are based on PLCs.

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Figure 8. The connection between the serial blocks and the s7 blocks.