UNIVERSIDAD RICARDO PALMA
COLLEGE OF ENGINEERING

PROFESSIONAL DEPARTMENT OF ELECTRONIC ENGINEERING

RESEARCH WORK
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RESEARCH WORK TO OBTAIN THE ACADEMIC DEGREE OF BACHELOR IN ELECTRONIC ENGINEERING

TITLE	: PROTOTYPE OF AN AUTOMATIC SYSTEM, WITH PLC S7-1200, FOR MIXING PAINT BASED ON THE ARTISTIC PRIMARY COLORS, RED, YELLOW & BLUE
COURSE:	ENGINEERING RESEARCH WORKSHOP II
LINE OF RESEARCH	: INSTRUMENTATION AND AUTOMATION SYSTEMS
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1. INTRODUCTION

2. PROBLEM STATEMENT

2.1. Formulation and determination of the problem

Painting is the art that uses pigments to make any kind of graphic representations. The result of these is also called paint. Paint is that fluid that we apply in thin layers on a specific surface. Choosing any type and / or color we can make mixtures, which can achieve good results and thus be able to innovate in different spaces that we want in our home or any other environment.

Many places where paint is sold do not have an automatic mixing system, so they opt to perform this process manually, which generates a delay, that is, an increase in time at the time of mixing the paint based on what the customer requires.

Therefore, a prototype of an automatic paint mixing system would be more efficient, would help optimize production, physical wear and decrease material waste, compared to a manual mixing. The proposed prototype will be developed in the Control Laboratories of the College of Engineering, so that students can observe and learn how an automatic paint mixing system works using a programmable logic controller such as the PLC S7-1200.

1.1.1. General Problem:

How to implement a prototype of an automatic system, with PLC S7-1200, for paint mixing based on the artistic primary colors, Red, Yellow & Blue?

Specific Problems:

How to program in TIA PORTAL V14 software to have a correct operation of the paint mixing?

How will the proposed prototype be implemented in the Control Laboratory of the College of Engineering?

How would the operation of the proposed prototype be verified by setting specific quantities for paint mixing?

2.2. Importance and justification of the research work

This project is very important because with the use of equipment and / or programs that are in the Control Laboratory as the PLC S7-1200, SIEMENS power supply and Tia Portal V14 software, implemented in this prototype of an automatic system for mixing paint, will be of great help to all students who want to practice instrumentation and automation systems, in order to have a better understanding of the process that is being applied in this project. At the same time, the proposed prototype tries to take care of the environment because, by automating the paint mixing process, it will reduce the waste produced by the mixture, reducing toxic gases, which are harmful to the environment.

2.3. Objectives

2.3.1. General Objectives:

To implement a prototype of an automatic system, with PLC S7-1200, for the mixing of paint based on the artistic primary colors, Red, Yellow & Blue.

2.3.2. Specific Objectives:

Program in the TIA PORTAL V14 software to have a correct operation of the paint mixing.
Implement the proposed prototype in the Control Laboratory of the College of Engineering.
Verify the operation of the automatic system by setting specific quantities for paint mixing.

3. THEORETICAL FRAMEWORK

2.1. Conceptual framework

3.1.1. Control Systems

In [1], Bolton (2001) states that "a control system is when the output is controlled in such a way that there is a particular change in a defined manner".

In [2], Perez, A., Perez, E. & Alberto, M. (2008) (p.7) indicate that a control system "is an arrangement of physical components connected in such a way that the arrangement can command, direct or regulate, likewise or to another system. These systems command direct or control dynamically".

"For control systems there is the problem of selecting a suitable input that makes the plant respond in the desired way, thus obtaining an output with certain desired characteristics" (Alberto, et al, 2008).

Classification of control loops:

a) Open Loop Control

An open loop control is one where the output signal does not intervene on the control action itself or signal, i.e., the output and reference input are not compared.

Figure N° 1: Open Loop Control System

Source: Alberto, M. et al, 2008, p10..

This system tends to be very thrifty, but at the same time it turns out to be imperceptible to disturbances, being conveniently applied when one is absolutely certain that there are no disturbances acting on it.

b) Closed Loop Control

A closed loop control is one where the output signal does not intervene on control action or signal. It is worth mentioning that both the controlled signal and the output must be fed back, and then compared with the reference input, where a reference signal is sent, which is proportional to the difference between the input and output. Finally, we modify the output and reduce the error.

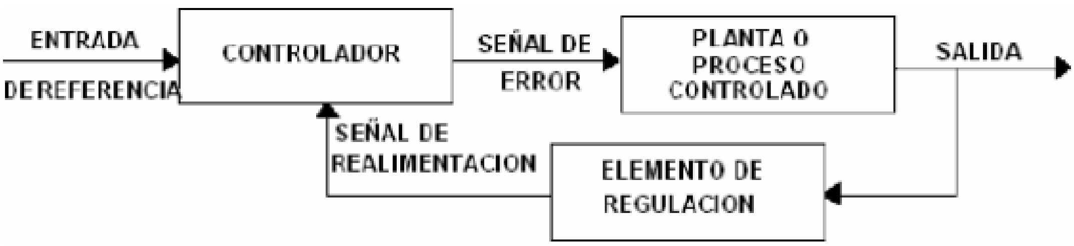

Figure N° 2: Closed Loop Control System

Source: Alberto, M. et al, 2008, p11.

3.1.2. Hardware PLC Simatic S7-1200

In [3], Maloney (2006), indicates that "the programmable logic controller is that compact equipment where all the components for the development of different automation and control tasks are located, where the decision making is through coded instructions, stored in a chip and executed in a microprocessor; and if the change of the control system is required, it will only be necessary to change the instructions through software."

This is a solid device with a small size, which can provide solutions to simple processes in the industry, this equipment is produced by Siemens, in the CPU 1214C model, which has an AC power supply as input.

In [4], According to Siemens (2018), the Simatic S7 1200 with CPU 1214C has:

- Integrated ethernet interface via profinet protocol.
- 64bit processing capability.
- 10 relay type digital outputs at 2Amp.
- 14 digital inputs at 24volt DC.
- 02 analog inputs from 0 to 10volt DC.
- 24volt DC power supply output.
- 85 to 264volt AC power supply. 19
- Web server.

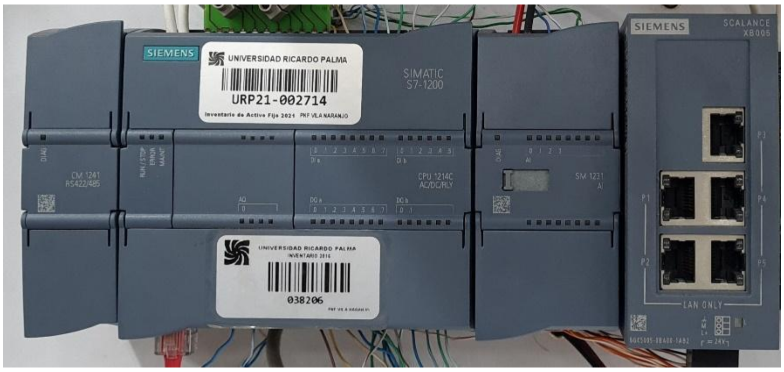

Figure N° 3: PLC S7 1200.

Source: Own

3.1.3. Switching Power Supply

In [5], "Switching power supply is that power supply that converts alternating voltage to direct voltage".

In this research project we are using a switching power supply model 6EP1332-1SH51 of Siemens brand, which will help us in the operation of the mini pumps and motor. In this way, these can be activated according to the programming done in the TIA PORTAL V14 software.

Figure N° 4: Stabilized Power Supply LOGO! Power 24 V / 4 A
Source: Own

3.1.4. Motorized Valve

In [6] and [7] a motorized valve is understood as the assembly formed by:

a) The valve itself
b) The actuator
c) The yoke

The bridge is separated because it is the link between the valve and the actuator. It is a purely passive component, but of great importance in the diagnosis since the deformations produced in it are used to determine the forces exerted by the stem.

Figure N° 5: Motor-driven electric ball valve

Source: https://n9.cl/7yp2v

3.1.5. Geared motor

It is a homogeneous and compact machine, which combines a motor and a speed reducer. These are made in one piece and are used to automatically reduce the speed of a piece of equipment.

Figure N° 6: Geared motor

Source: https://acortar.link/c5yVwT

2.2. State of art

- ### 2.2.1. National Antecedents

In [8], the automation of a system was designed, which aims to have a safe, efficient and economical processing. It is based on the three primary colors, magenta, yellow, and cyan, which depend on 3 different quantities, which can be selected by means of an interface, where both the control device and the user are located.

In [9], a system was developed to control and monitor the mixing of low density liquids. For this, an application was designed, which focuses on three dispensers, which use valves that allow regulating the desired amount of liquid. At the end of this process, the liquid will be mixed, in which an agitator and motor will be used to regulate the homogeneity and speed of the final product. Part of this automation project was used a PLC and HMI where it will be possible to observe, control and monitor the mentioned process.

- #### 2.2.2. International Antecedents

In [10], a programmable logic control laboratory prototype was developed based on an automatic system in liquid mixing and bottle filling, the prototype performs an automation of the control and mixing of two different liquids in bottles, in order to achieve quality control, which reduces human intervention and improves productivity.

4. SOLUTION APPROACH

4.1. Description and characteristics of the solution or product to be obtained

The type of research is applied and technological. As for the research method, it is empirical and experimental.

In the present project the PLC S7 - 1200 is used to control different devices, which, when selecting the desired mixture, the programmable logic controller will operate the necessary valves in a set time. Subsequently, once the last valve is closed, the Simatic S7 - 1200 Controller will drive the motor for a set time; and at the end of this process, a sound alarm will be turned on to indicate that the mixture is ready.

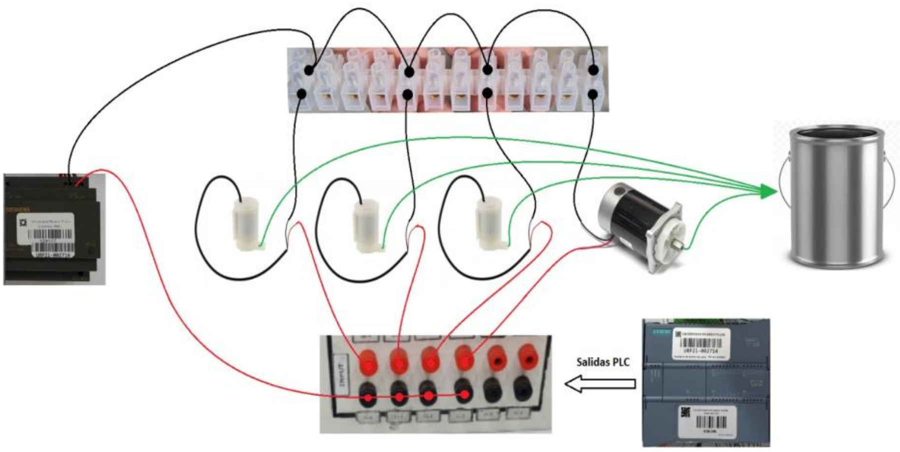

Figure N° 7: Pictographic diagram

Source: Own

4.2. Methodology of the solution

For the present project the ladder programming language was used in the PLC S7 - 1200 linked to the HMI, where the mixtures that can be obtained are shown. The system works as follows: First one of the options displayed on the HMI must be selected, this will cause the programmable logic controller to activate the required valves, which are previously programmed to open for a certain time, this varies according to the valve and the selected mixture. After the closing of the last valve, the gear motor will be activated for 10 seconds, since that is the time programmed for all the mixes. Finally, when the motor is deactivated, an audible alarm will sound to indicate that the process has been completed.

TABLE 1. PROPORTION FOR THE MIXTURE OF ARTISTIC PRIMARY COLORS

Color	Mezcla
Naranja claro	4 de amarillo + 1 de rojo
Naranja	2 de amarillo + 1 de rojo
Naranja oscuro	2 de amarillo + 4 de rojo
Rosa claro	6 de blanco + 1 de rojo
Rosa	3 de blanco + 2 de rojo
Marrón	2 de azul + 1 de rojo + 2 de amarillo
Marrón rojizo	2 de azul + 2 de rojo + 2 de amarillo
Marrón amarillento	2 de azul + 2 de rojo + 4 de amarillo
Verde oliva	2 de azul + 1 de amarillo
Verde claro	1 de azul + 3 de amarillo
Verde	1 de azul + 2 de amarillo
Azul verdoso	1 de verde + 1 de azul
Azul celeste	2 de blanco + 1 de azul
Azul marino	1 de azul + 1 de negro
Gris	2 de blanco + 1 de negro
Violeta	2 de rojo + 5 de azul
Ocre	4 de amarillo + 1 de negro + piza rojo y azul
Crema	1 de negro + 1 de blanco + 4 de amarillo
Marfil	1 de negro + 1 de blanco + 4 de amarillo + piza de rojo
Negro	1 de amarillo + 1 de rojo + 2 de azul

Source: https://www.distrimar.es/como-hacer-mezcla-colores-para-obtener-otros.html

TABLE 2. REPRESENTATION OF THE MIXTURE OF ARTISTIC PRIMARY COLORS

COLORES		VÁLVULAS
1	Naranja	Válvula N° 1 (RED): Se activará durante 4.2 segundos. Válvula N° 2 (YELLOW): Se activará durante 8.4 segundos. Tiempo total de activación de las válvulas: 12.6 segundos
2	Naranja oscuro	Válvula N° 1 (RED): Se activará durante 8.4 segundos. Válvula N° 2 (YELLOW): Se activará durante 4.6 segundos. Tiempo total de activación de las válvulas: 12.6 segundos
3	Marrón	Válvula N° 1 (RED): Se activará durante 2.52 segundos. Válvula N° 2 (YELLOW): Se activará durante 5.04 segundos. Válvula N° 3 (BLUE): Se activará durante 5.04 segundos. Tiempo total de activación de las válvulas: 12.6 segundos
4	Verde	Válvula N° 2 (YELLOW): Se activará durante 8.4 segundos. Válvula N° 3 (BLUE): Se activará durante 4.2 segundos. Tiempo total de activación de las válvulas: 12.6 segundos
5	Azul verdoso	Válvula N° 2 (YELLOW): Se activará durante 6.3 segundos. Válvula N° 3 (BLUE): Se activará durante 6.3 segundos. Tiempo total de activación de las válvulas: 12.6 segundos
6	Violeta	Válvula N° 1 (RED): Se activará durante 3.6 segundos. Válvula N° 3 (BLUE): Se activará durante 9 segundos. Tiempo total de activación de las válvulas: 12.6 segundos
7	Negro	Válvula N° 1 (RED): Se activará durante 3.15 segundos. Válvula N° 2 (YELLOW): Se activará durante 3.15 segundos. Válvula N° 3 (BLUE): Se activará durante 6.3 segundos. Tiempo total de activación de las válvulas: 12.6 segundos

Source: Own

4.3. Design of the solution or product

In the following timing diagram, a PLC switch was used as a button to select the desired mix, however, a 100 millisecond pulse was produced when switching on and off manually. This pulse activates the motorized valves; they are held open for the time set by their off-delay timer (TOFF). The TOFF with the longest time is connected to the gear motor in charge of the mixing; a delay-on-delay timer (TON) is set so that it does not turn on until the last valve is deactivated and then a TOFF is set to establish the motor on time. Finally, the parallel alarm is connected to the motor together with its corresponding TON and TOFF to indicate that the process has been completed.

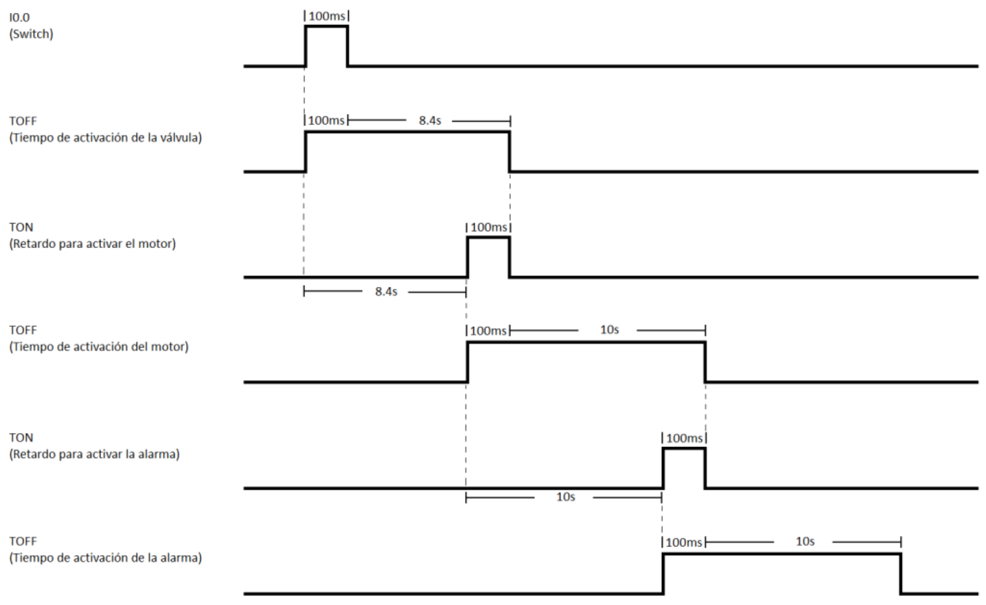

Figure N° 8: Timing diagram (Orange color mix)

Source: Own

5. TESTS AND RESULTS

This part of the research work shows the results obtained from all the tests carried out in the implementation and programming in the TIA PORTAL V14 software. A value is established based on the proportion, according to table 2, for the mixture of artistic primary colors, which serves to know how long the valve has to remain open to supply a certain amount of paint.

4.1. Ladder Programming

Figure N°9 and Figure N°10 show the programming applied for the first mixture, in this case it is the orange color. First, we select the desired mixture, the PLC S7-1200 activates the mini-pumps of the colors that will be necessary; according to the time determined in Table N°2. The mini-pumps are connected to a timer that determines how long they are active. Then, when the last mini-pump is deactivated, the motor is activated; since a TON timer was placed on it, which acts as a delay so that the motor and the mini-pump are not activated simultaneously. In the same way as the mini-pumps, the motor has a timer, which determines the time of operation.

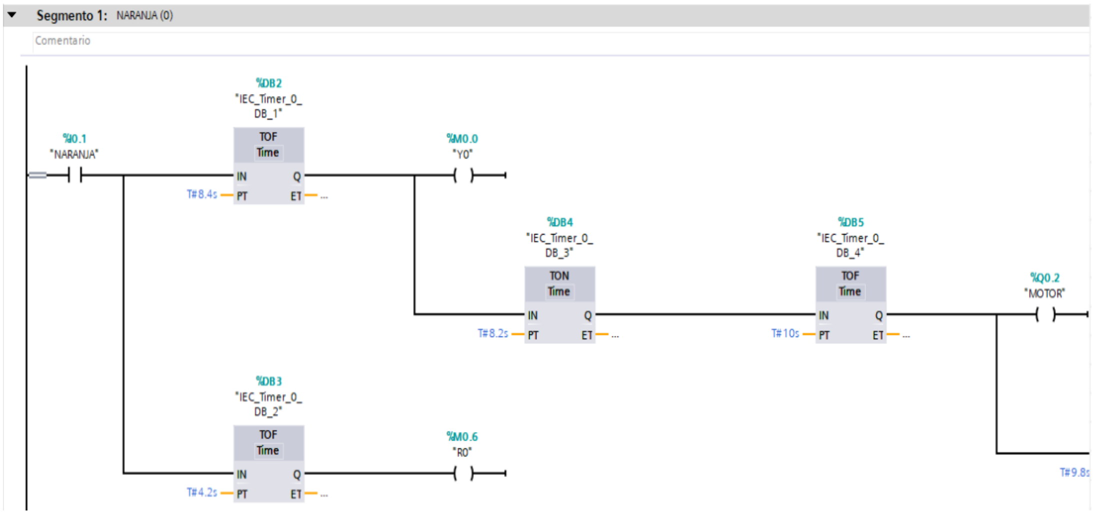

Figure N° 9: Ladder programming in TIA PORTAL V14

Source: Own

Finalmente, cuando se desactiva el motor, se enciende la alarma que posee doble timer uno de de retraso y otro de tiempo de funcionamiento, este por un tiempo de 10 segundos, el cual indica la finalización del proceso.

Figura N° 10: Programación Ladder en TIA PORTAL V14

Source: Own

6. CONCLUSIONS

It was correctly programmed in the TIA PORTAL V14 software, using the ladder programming language, where we had a good performance of the automatic system proposed.

It was possible to implement the prototype of an automatic paint mixing system based on artistic primary colors in the Control Laboratory of the Engineering Faculty. The prototype is composed of three recyclable containers of distilled water of 1 liter each, a 20 input terminal block, 16 awg copper wires, three mini pumps of 5V each and three flexible PVC tubes. In addition, the 24VDC LOGO! Siemens power supply was used to power the 3 mini pumps and thus have a correct operation of the prototype.

We established specific quantities for paint mixing and verified the correct operation of the automatic system. Therefore, we can observe in real time how we obtain the final product, according to the selected mixture, as shown in Table 2. It is worth mentioning that the present prototype was implemented in a two-level shelf of 50cm length x 50cm width x 100cm height.

7. RECOMMENDATIONS

A pump must be sized according to the conditions and characteristics of the process, for this work a 5V mini pump was used for better performance.

It is recommended to implement the work in the Control Laboratory of the College of Engineering, as this provides security and all the necessary tools and equipment facilities for the implementation of the same.

In order to optimize the automatic system, it is recommended to use the HMI touch screen in the laboratory to make it more intuitive.

It is recommended to perform tests to know how long a valve should be active for the final mixture to have a quantity of 350 ml. From this time and the proportions required for each mixture, proceed to perform the necessary operations for the correct programming of the automatic system.

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