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Article

Logic control design for calcium chloride dosing hopper for TCO Group

Diseño de control lógico para tolva dosificadora de cloruro de calcio para TCO Group

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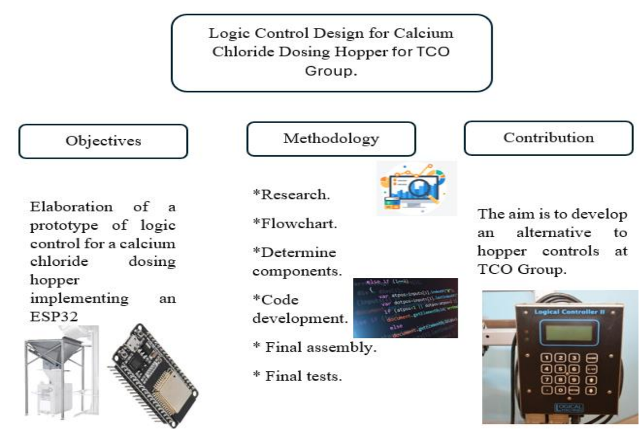
Abstract

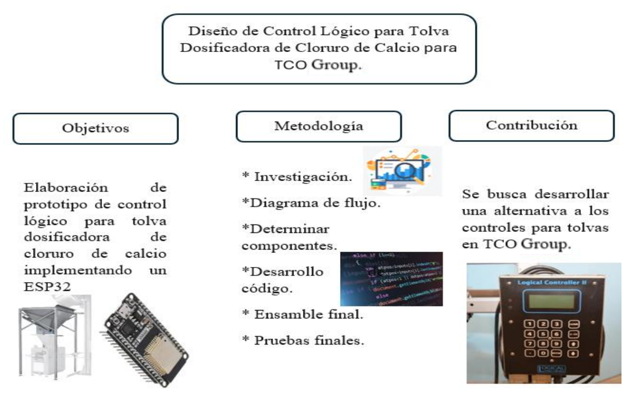
This paper highlights the implementation of the project "Logic Control for Calcium Chloride Dosing Hopper" in order to demonstrate the process to be followed for the development of this project that has been very useful for the company TCO Group, looking for a more economical alternative to the existing logic controls. The diagrams used, connections, programming, among other elements, are explained.



ESP32, Prototype, Dosing hopper

Resumen

En el presente escrito se pone en evidencia la realización del proyecto "Control Lógico para Tolva Dosificadora de Cloruro de Calcio" con la finalidad de demostrar el proceso a seguir para la elaboración de este proyecto que ha sido de gran utilidad para la empresa TCO Group, buscando una alternativa más económica a los controles lógicos ya existentes. Se explican los diagramas utilizados, conexiones, programación, entre otros elementos.



ESP32, Prototipo, Tolva dosificadora

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Introduction

In the field of industrial automation, the design and implementation of control systems play a key role in improving the efficiency, accuracy and reliability of processes.

In this context, this paper presents a project for the design of a logic control for the operation of a dosing hopper.

Dosing hoppers are essential devices in many industrial processes, as they allow the precise metering and delivery of materials along a production line. However, the effectiveness of these operations is highly dependent on the quality of the control system used.

One of the problems encountered at TCO Group is the high cost of the logic controls used for the hoppers, as the conditions in which the company operates (humidity factor and calcium chloride chemical) make exposing these controls risky for the company.

In conjunction with this, there are no electrical diagrams or operations manual, which can cause problems when carrying out any type of repair or for learning how the control works.

Proposal

The idea accepted by the company is to create their own logic control, which allows them to carry out the basic functions of the controls they currently have, but at a much lower cost (it is estimated at no more than 2,000 pesos per control).

This offers the possibility of not only reducing costs, but also of having a more user-friendly control system for the maintenance personnel, as well as the generation of the electrical diagrams needed for future occasions.

Methodology

As a start, a flow chart was developed to define the process to be followed in this project, showing step by step the development for the adequate design during the prototype elaboration. (Gómez & Molina, 2022)

Box 1

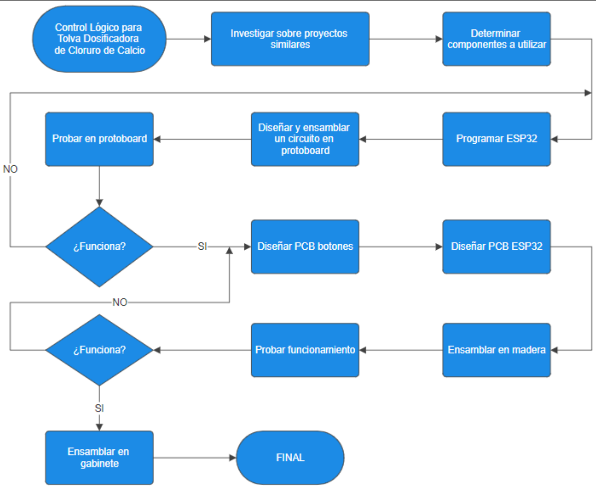

Figure 1
Flow chart

Research design

For the development of the project it is necessary to combine knowledge of analogue electronics and embedded systems, specifically the microcontroller (ESP32) linked to the IDE Arduino software, in order to obtain the dosing functions required by the company, among which is the calibration of the scale and the correct reading of the weight.

The ESP32 is chosen because it has a dual-core processor and a processing speed that allows it to execute the actions we need for the tasks to be executed in acceptable time. It also takes into account the Wi-Fi and Bluetooth capabilities that are already built in, allowing you to add connectivity capabilities to the project in the future. Similarly, it is relatively inexpensive compared to other microcontroller options with similar capabilities, and simple to program, as it is compatible with the Arduino development environment.

Programming

The language used in the code provided is C/C++, which is commonly used in the development of firmware and embedded software for microcontrollers such as the ESP32. A code was created with the purpose of obtaining the functions requested by the company TCO, which consist of the calibration of the load cell, the control of the vibration that is in charge of making the material fall, and the correct reading of the weight. A link is left where you can access the programming files for the Arduino IDE.

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How it works

The process starts by turning on the microcontroller to display a welcome message with the name TCO Group (name of the company), to subsequently display the weight reading provided by the load cell and the HX711 module. However, random values will be displayed because it is necessary to perform a calibration.

To do this we enter with button 3 (calib) and a menu will be displayed where by pressing button 2 (tare) we can scroll between three different weights to calibrate (500g, 1000g and 2000g). Once we get to the desired weight, we press button 1 (mode) which is configured to function as a "select" to select the weight. At this point we must have an object whose weight we are sure of and which is equal to the values we have in the programme for a correct reading and calibration. Knowing this, a message will appear asking us to place the object on the load cell for a few seconds. After this time, a message will appear asking us to remove the object and wait a few more seconds. At the end it will take us to the first screen where the weight must be at 0 to be able to measure any weight that we place on it.

It is at this moment that dimmer number 2 with high vibrations is activated through the relay module, as in the program it is declared that it is activated from -300g to 280g. Once this weight is achieved, dimmer 2 is deactivated and dimmer number 1 with low vibrations switches on from 281g to 450g, which is the weight requested by the company for its product in the 500g presentation.

If we look at the code, we notice that the dimmers seem to be operated in reverse according to this description, because in theory if we want to operate any component it is necessary to declare it as "HIGH" and to turn it off as "LOW", however, in the process we realised that the relay module works with an "inverse logic or is normally closed", so it is necessary to invert the code statements, since when we set HIGH the current that energizes the relays makes the pins separate and therefore does not allow energy to pass, contrary to when we set LOW, since not receiving energy the pins are kept together and the current can pass without any problem.

Having clarified this, we end this description by explaining that when the 450g is reached, both dimmers are deactivated until the material is unloaded from the scale and the process starts again.

Design and testing

Once the code shown in the previous section was finished, the next step was to perform the first tests on our breadboard. To do this, a circuit was made for the 3 buttons that includes the control and the LCD screen, using the online program ***Wokwi.***

Box 2

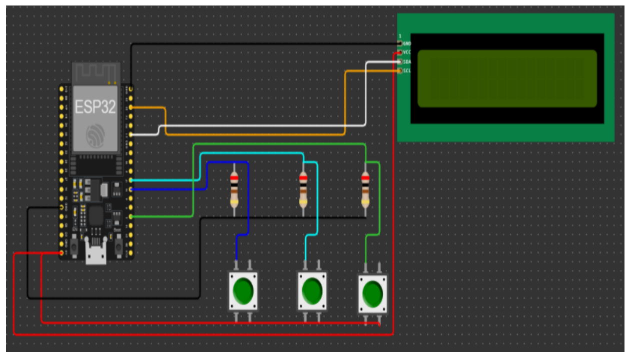

Figure 2
Diagram of buttons and LCD

With this, we transfer the circuit to a breadboard.

We test the correct functioning of the display.

Box 3

Figure 3
LCD test

Then we make the connections for the load cell, which will be in charge of reading the weight values with the help of the HX711 module.

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Box 4

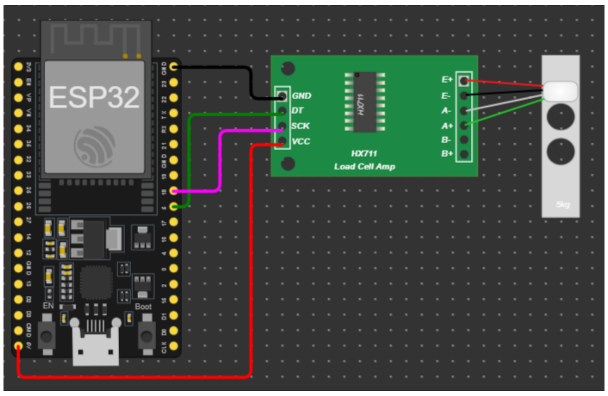

Figure 4
Load cell connection

We confirm that it starts to show the weight on the display.

Box 5

Figure 5
Weight reading test

Next, we check that the readings of the cell are correct, thanks to the calibration and measurement with a 5Kg weight that was within our reach.

At the end of all these tests, we have a diagram that includes the connections of all the electronic components.

Box 6

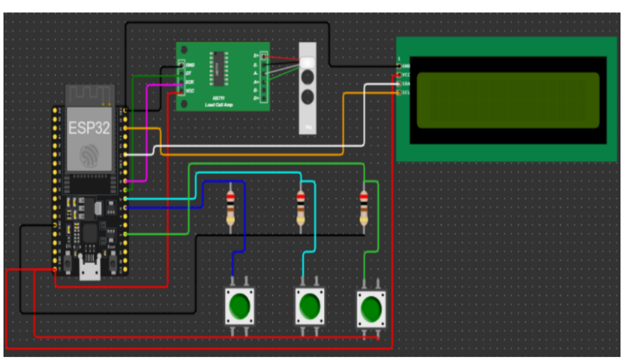

Figure 6
Electronic diagram

We then went on to create a diagram that includes the rest of the components to be used, such as the vibrator, the two analogue dimmers together with the electronic diagram previously created. To do this, a **link** is attached where you can find the different diagrams and diagrams that were drawn up, as well as the code in text format. Now we will test that the change between the dimmers is carried out correctly according to the weight that we declared in the programming, for it, images are attached where we observe the change in the relay module, where we confirm that everything works as it should.

Plates

The design for the buttons board we used the program SolidWorks to draw the tracks that we needed, taking into account that here it is necessary to include a feeding line, a negative line and to consider the resistances that go between the connections of the pins of the ESP32 and the buttons.

Box 7

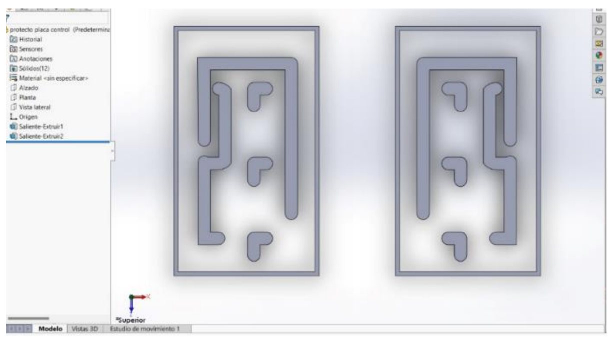

Figure 7
Button board design

Now that we have the design, we can move on to the process of making the circuit on the phenolic board. To do this, we follow the steps listed below:

- Print the design on transfer paper.

- Attach the print to the phenolic board with some adhesive tape.

- Wrap the plate with notebook paper.

- With a clothes iron, heat the area where we have the design for about 7 minutes, making a firm and constant pressure so that the ink adheres to the plate.

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- Carefully remove the tape and paper.

- In the areas where the ink did not stick completely, we fix it with a black permanent marker to complete the ink areas.

- Pour ¾ parts of ferric acid to ¼ of water into a plastic container.

- Put the plate with the design already stuck to the acid and shake gently for about 10 minutes.

- Carefully remove the plate from the acid with gloves and clean it properly.

Once these steps were completed, the result of our plate was as shown in figure 14.

Box 8

Figure 8
Button plate

For aesthetic purposes, the copper that remained around the plate was removed with the help of a Dremel and sandpaper.

With the same Dremel we proceed to drill the holes with a 1 mm drill bit where the components will go. Afterwards, we placed and soldered the components.

For the second board, using everything we had available, I made the decision to do it on a breadboard due to lack of resources. The idea is to have a board where the pins can be soldered in a safe and secure way, without damaging the ESP32. That's why we use male and female pinheads to insert the microcontroller.

With all this in mind, the circuit on the board looked like this, with the addition of terminal blocks to connect power cables from the ESP32 later on.

Box 9

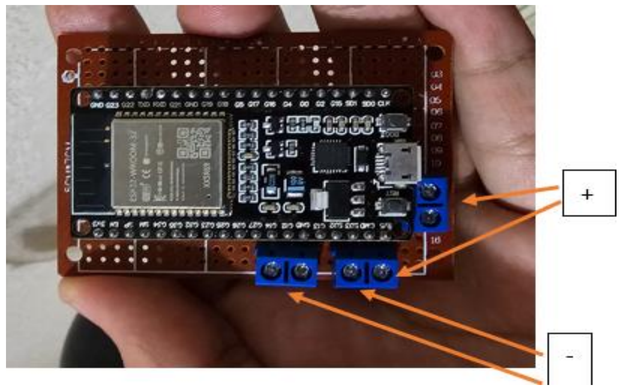

Figure 9
Button plate welding 2

Now we can solder the components we need on each pin, based on the diagrams described above.

The next step was to fix all the components to be used in wood, cutting it to size and painting it blue for better presentation (see annex 1).

With the help of screws and pins to fix the components, we obtained the result shown in figure 10.

Box 10

Figure 10
Wooden assembly

This same wood had to be inserted into a cabinet, so it had to be cut to the measurements needed to achieve this. With the help of screws and an acrylic base, the wood was fixed to the cabinet (see annex 2).

At the bottom, the necessary holes were drilled for the power plug and the cables for the load cell.

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Results

One of the aims of the project was to provide the necessary diagrams to be able to replicate the control we produced at any time, or to find faults if required. I consider this objective to have been achieved, since, as we saw earlier, different electrical diagrams and schematics were produced and used in this control.

We were also asked to develop the program for this project in a microcontroller that would give better results than the Arduino Nano that was originally used. This point was undoubtedly a success, as we were able to run the program on an ESP32, giving us faster read and response times than the Arduino Nano, based on the previous experience of the maintenance staff, as the tests documented on this same project at an earlier stage were lost at some point. However, we are told that the system is faster and more efficient than what was initially available.

One of the most important challenges was the development of the PCB boards, as this time we used SolidWorks software for the buttons, something that was new to us up to that point and which we overcame successfully. For the ESP32, there are not many softwares where this component is included for PCB, and due to the lack of time, I opted to use an already drilled board, adding terminals to supply the necessary components with the 5V that this microcontroller offers, as well as GND if required.

We obtained a logic control capable of performing the actions that are necessary for the TCO printer in its process of dosing calcium chloride, which we verified by seeing that everything worked properly: the screen gave us the corresponding messages and menus, the buttons performed their actions properly, the weight readings were correct, so this point is to highlight within the results of the project.

With more detailed tests, we were able to observe that the hoppers that had the controls that were previously used, managed to get around 200 bags per hour, while with our control they were around 185-190 bags per hour, considering that the level of production is very good if we take into account that our prototype only costs 9% of what the other controls cost.

Conclusions

Based on the main objective of the project "Elaboration of a prototype of a logic control for a calcium chloride dosing hopper implementing an ESP32 in a period of 4 months for TCO Group, Mérida, Yuc.", I can conclude that I have fulfilled it successfully, since we have respected the deadline that was intended from the beginning, doing each of the tasks that were required in the control. A first functional prototype control for dosing hoppers was obtained at the TCO Group company, with the aim of having an alternative with similar efficiency to the controls already in use there, with much lower costs and with the benefit that it can now be manufactured by the same maintenance personnel, with the different diagrams that were drawn up in the process, the list of materials required and the programming carried out exclusively for this project.

Technology nowadays gives us many possibilities to carry out projects, and although I was limited in certain things by the availability and time at some points in the process, the project could be done without so many complications. However, I consider it necessary to mention a series of recommendations that could make this project a lot better.

- The idea was to set a deadline of 4 months to create this control, because for the professional residency it takes about 500 hours divided into 4 months, which did not allow me to finish perfecting or testing the device in hoppers one hundred percent, despite having verified that the basic actions work properly. So, clearly, with a little more time, it is certainly possible to obtain an even more efficient control with the certainty that there are few failures that could occur, with a better design, and even adding more functions to the programming.
- Much of the material used for this project was reused, as they were components that the company had had at its disposal for some time. Many of them had some wear and tear due to the humidity of the place. All this leads me to think that with brand new components, we could avoid certain problems, such as the noise in the LCD that I originally intended to use, or facilitate the soldering process in some components that were already affected by rust.

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- I was able to get a program that manages to perform the basic actions of the controls already in place in the company. That is why I think that with more time and more tests, we can include more functions, such as the cutting speed, fully automated opening of the solenoid valves and that they are not in a separate system, and even control the vibrator without analogue dimmers, giving way to a more automated hopper depending only on the control.
- I got the PCB boards for the buttons and microcontroller to work correctly. But obviously we can achieve a more professional result that even to the eye looks better. For this, you can choose to make the boards in more specialised software, and using CNC machines have boards with the measurements, holes and tracks that we need with a higher precision and with a more attractive design.

Declarations

Conflict of Interest

The authors explicitly declare that they have no conflict of interest related to the research presented in this article. There are no competing financial interests or known personal relationships that could have influenced the objectivity, integrity or interpretation of the results and conclusions presented in this paper. This statement confirms the authors' transparency and impartiality in communicating the research findings.

Authors' contribution

Tun-Ordoñez, Jorge Sprewell: Definition of Objectives: Definition of the intended objectives at the start and scope of the calcium chloride dosing system project for the company TCO Group. Project Management: Coordinating the different activities, processes, work assignment and monitoring the correct development of the project as established (time and form). Circuit Design and Coding: Responsible for the development of all electrical and electronic circuits, as well as the programming of the microcontroller.

Manrique-Ek, Josué Abraham: Drafting and Documentation: Responsible for all documents necessary to support the project through evidence and development proposals. Coordination of documentation and project development: Responsible for the revision of all the bibliographic material used, as well as the supervision of the documents requested and the progress of the project.

Cardozo-Aguilar, Guadalupe: Project supervision: In charge of verifying the correct functioning of the project, complying with the specifications requested. Review of electrical diagrams: Gives the go-ahead to the different diagrams and diagrams where the connections of the device are shown, validating them for their implementation and exposure in the documentation.

Gomez-Ku, Ricardo: Validation of results: Checks and determines satisfactory results of the project, complying with the established objectives. Drafting of conclusions and recommendations: In charge of analysing the results for the generation of conclusions, highlighting possible fields of improvement in the project.

Availability of Data and Materials

Data generated during this research will be [available upon request / deposited in a public repository / shared with interested parties]. Access to data will be granted in accordance with ethical considerations, privacy regulations and any relevant institutional or legal restrictions.

Funding

The realisation of the project was possible thanks to the financial support of the company TCO Group through the maintenance manager Ing. Noe Avila Balverde, in addition to leaving at our disposal the components and materials already held in the company. Documentation and other expenses were paid for by the research team itself.

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Annexes

Annex 1. Wood used

Annex 2. Cabinet

Abbreviations

1. ESP32: is the name of a family of low-cost, low-power SoC (System on a chip / 32-bit System on a Chip) chips with WiFi and Bluetooth technology.

2. LCD: stands for Liquid Crystal Display.

3. PCB: stands for Printed Circuit Board.

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