USE OF MICROCONTROLLERS FOR CONTROL AND AUTOMATION IN MACHINERY AND COMPUTER EQUIPMENT BUSINESS COMPANIES *

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Abstract
Automation is in everywhere nowadays, including within companies and industries, and is therefore fundamental and essential for production, quality and process control of them. There are many ways to automate a production line or a machine can be through relay logic, Programmable Logic Controllers (PLCs), and even more modern microcontrollers with native Internet of Things (IoT) support can be used. What are the advantages and disadvantages of each approach? A PCB was created using more modern microcontrollers programmed in C, C ++ and Whiting language to simulate a replacement of a PLC in an actual machine. Having a very positive result, being able to handle the machine manually via Wi fi besides being able to also perform a real-time monitoring of the machine's motors through the mobile phone, thus entering the IoT and fitting into the Industry 4.0.

Keywords: *Microcontrollers; Automation; Industrie 4.0; Control.*

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1 INTRODUCTION

The 4th Industrial Revolution is the focus of companies today to take their productions to a total independence of human work and, consequently, one of the most prominent areas in engineering of recent years is automation. Applied to various types of problems ranging from residential automation to the control of large electromechanical systems, control and automation represent a gain in agility and economy in engineering solutions.

The popularity of the microcontrollers used for automated solutions is also increasing this scenario. This popularization comes from what is known as Arduino work kits. In 10 years, from 2005 to 2015, more than 500,000 Arduino boards were sold worldwide, disregarding the similar boards that came out of it [1].

From this, become possible to replace older control systems (which usually have high deployment costs) such as Programmable Logic Controllers (PLCs), for simpler systems and, if well programmed and scaled, as robust as.

This work proposes a viable alternative, of easy implementation, good reliability and more economically advantageous for the replacement of PLCs by modern microcontrollers. For this, the project is based on a machine that uses engine control system using a PLC for the polishing and lateral finishing of granite plates, which is manufactured and sold by the company Aço Art. Mechanical, Industry and Commerce, located in Vargem Alta, ES. Chosen strategically for a remote control that satisfactorily replaces a PLC used in an industrial machine, already deployed in the market.

2 DEVELOPMENT

2.1 Characteristics of the studied machine

The machine studied is called RPB 11 SLIM which is one of the more than 40 models produced by the company Aço Art (Figure 1). The machine have 1.580mm x 3.440mm in size and is composed of 11 1.5 CV AC motors that are positioned laterally in the machine and driven one by one by pneumatic pistons responsible for making the lateral finishing of the granite or marble plates that they rub by means of the diamond tools placed in these motors through a conveyor belt that carries the material without polishing of one side and the ready delivery in the other side of the machine making a line of work [2].

Figure 1. External Machine View.

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2.2 Programmable Logic Controllers (PLCs)

In this machine there is a WEG TPW04-32BT-A CLP that does the control and automation receiving data from the sensor so that the motors are turned on and the pneumatic pistons activated in the right time, being fundamental for a correct and quality polishing (Figures 1 and 2).

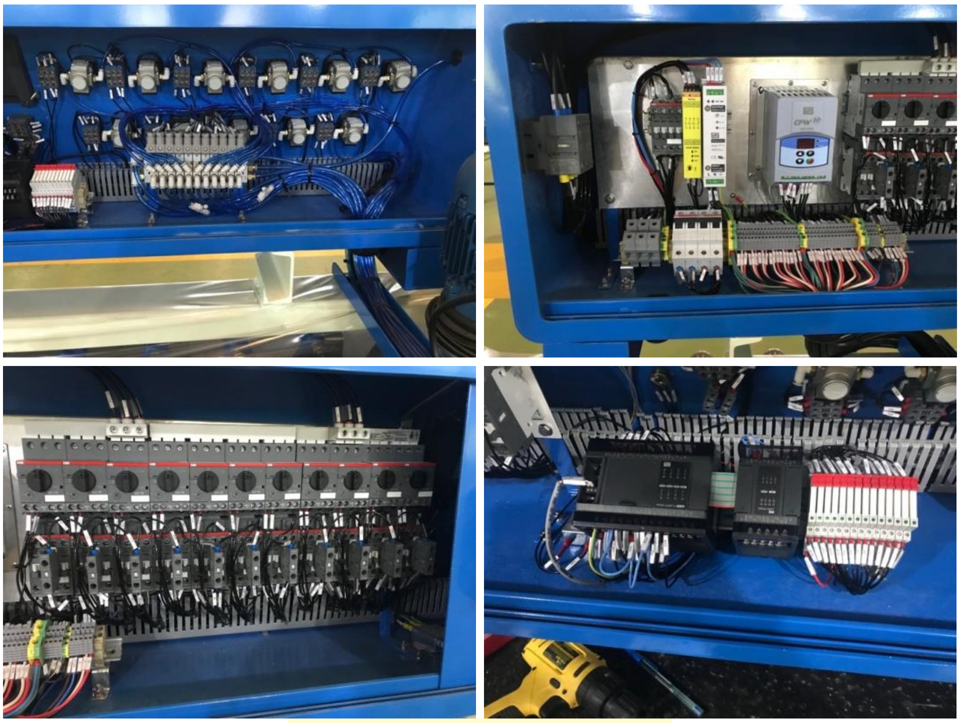


Figure 2. Internal machine view.

The PLC is a solid state device, microprocessor, capable of storing instructions for the implementation of control functions, such as logic sequence, timing and counting, as well as performing logic and arithmetic operations, data manipulation and network communication [3]. It is now the most widely used industrial process control technology because it has multiple advantages over relay-based systems, such as reliability, flexibility, lower cost, communication capacity, fast response time and ease of checking defects [4].

The WEG TPW03 PLC has positive features with possibility of expansion, as well as functions for several types of projects, which functions far beyond the requirements demanded by most of the projects in which it is used, as it is in the machine studied in this work [5]:

- Key Features: optimized high-speed counter, pulsed output and interpolation function for position control; supports multiple communication protocols.
- Optimized Basic Functions: High processing speed 0.18 microseconds / step; High memory capacity; Program memory up to 24K steps, basic instructions, arithmetic, sine, cosine, tangent, communication commands, floating point and PID; Ease of installation of the expansions of inputs and outputs; Expandable up to 384 points; It has RTC, PWM, run / stop key, flash memory, etc; Various types of expansion cards: digital, analog and communication function; compatibility with TPW03 application software and expansion cards.

Although they are less expensive compared to relay-based systems, PLCs still have high deployment prices for small projects and small entrepreneurs, opening an opportunity for another follow: modern microcontrollers that do not need such a high level of expansiveness, memory and processing speed.

2.3 Microcontrollers

The microcontroller is a programmable integrated circuit that contains all the components of a computer, with emphasis on CPU, memory, input and output ports, A/D and D/A converters [6].

2.3.1 ESP Category

The ESP category originated from Espressif Systems, a multinational semiconductor company established in 2008, based in Shanghai and offices in Greater China, India and Europe, this company is responsible for the creation of the popular series of chips, modules and boards of development ESP8266 and ESP32 [7].

For the project was chosen the module ESP 32S Inside, also known as: NodeMCU-32S, composed with the chip microcontroller ESP-WROOM32.

NodeMCU (Figure 3) is an open source platform designed for use in the development of IoT (Internet of Things) projects. This board was developed in 2014 and since then, competes with other microcontrollers on the market. This platform is basically composed of an ESP-WROOM32 controller chip, a micro USB port for power and programming, an integrated serial USB converter, a native Wi-Fi network, protection shields and voltage regulators. As with other family cards, NodeMCU is also compatible with the Arduino development environment, making it possible to use several libraries designed for the Arduino IDE [8].

Figure 3. NODEMCU-32S [9].

According to the Datasheet of the company Espressif Systems [10] the ESP-WROOM32 microcontroller has the following characteristics:

- Main processor: LX6 32-bit Dual-core, operating 2-240 MHz; Secondary processor: ULP (Ultra Low Power coprocessor); FLASH: 4MB; RAM: 520kB; GPIO: 34, with 3.3V and 12mA; ADC: 18, with 12-bit resolution; DAC: 2, with 8-bit resolution; WiFi: 2.4 GHz, 802.11 b / g / n; Bluetooth: Bluetooth Low Energy v4.2 (BLE); 4 64-bit timers (ESPRESSIF SYSTEMS, 2019).

The ESP32 is also efficient in a business and even industrial environment. According to the company (Espressif Systems, 2019) "The ESP32 is able to operate reliably in industrial environments with an operating temperature ranging from -40 ° C to + 125 ° C. Powered by advanced calibration circuits, the ESP32 can dynamically remove imperfections from the external circuit and adapt to changes in external conditions "[7].

2.4 Prototype Development

In order to implement a lower cost system, easier maintenance, good reliability and more optimized to replace the current WEG TPW04-32BT-A PLC control system, a prototype was proposed in order to analyze the feasibility of the project control technologies. The simulation was performed with the actual machine parts, including electrical systems, sensors and pneumatic systems (Figure 4).

(a) (b)

Figure 4. (a) Pneumatic actuator; (b) Pressure regulators.

The pneumatic drive shown in Figure 4 (a) consists in 4 ports, two NO (Normally open) and the other two NC (Normally Closed), which, when energized, the door NO closes and the door NC opens, allowing a reverse passage when it is de-energized. The pressure regulators shown in Figure 4 (b) are fundamental for regulating the pressure within the pneumatic system to the pistons, thus avoiding a possible accident or damaging the system.

The contactors shown in the figure (Figure 5) are used to energize and de-energize equipment by receiving an electrical signal on their coils. The motors are connected in the three-phase contactors and pneumatic drivers in the single-phase contactors.

(a) (b)

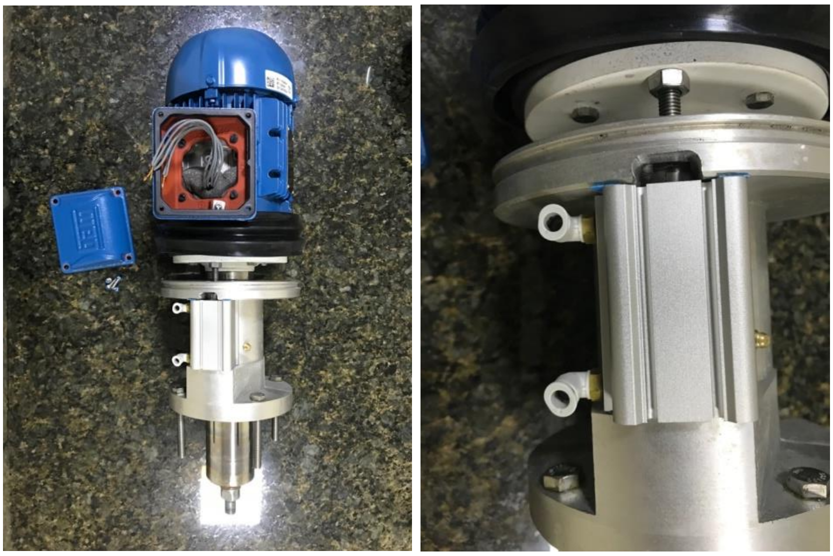
Figure 5. (a) Single-phase contactors; (b) Three-phase contactors.

The Figure 6 (a) shows the three-phase WEG general switch used in the design as a key energizing or not the power system, and the Figure 6 (b) is a switching power supply that receives 220V AC input and given 24V DC output used for contacting single-phase contactors.

(a) (b)

Figure 6. (a) Three-phase circuit breaker; (b) Switching power supply 220 / 24V 10 A.

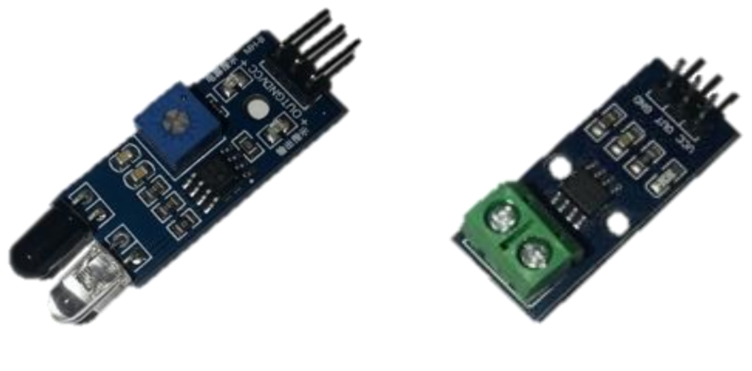
The assembly of 1.5-volt three-phase motors together with the aluminum blocks and the pistons (Figure 7-a) make the motor advance or retract according to the command given to the piston (Figure 7-b). Attached to the aluminum block is the two-way pneumatic piston for advance or retract of the engine in the plates of marble or granite.



(a) (b)

Figure 7. (a) 1.5cv three-phase motor; (b) Pneumatic piston.

The Infrared Module (Figure 8-a) recognizes the plate when it enters in the conveyor belt, thus knowing the beginning and the end of the plate, this information will be essential for the programming logic. The AC Current Sensor module (Figure 8-a) is responsible for measuring the individual current at each phase of AC electric motors.



(a) (b)

Figure 8. (a) Infrared Module; (b) AC Current Sensor Module.

2.5. Three-wire Diagrams

The three-wire diagram shown below (Figure 9) shows the power connection scheme of motors, inverters, contactors, and three-phase power supply.

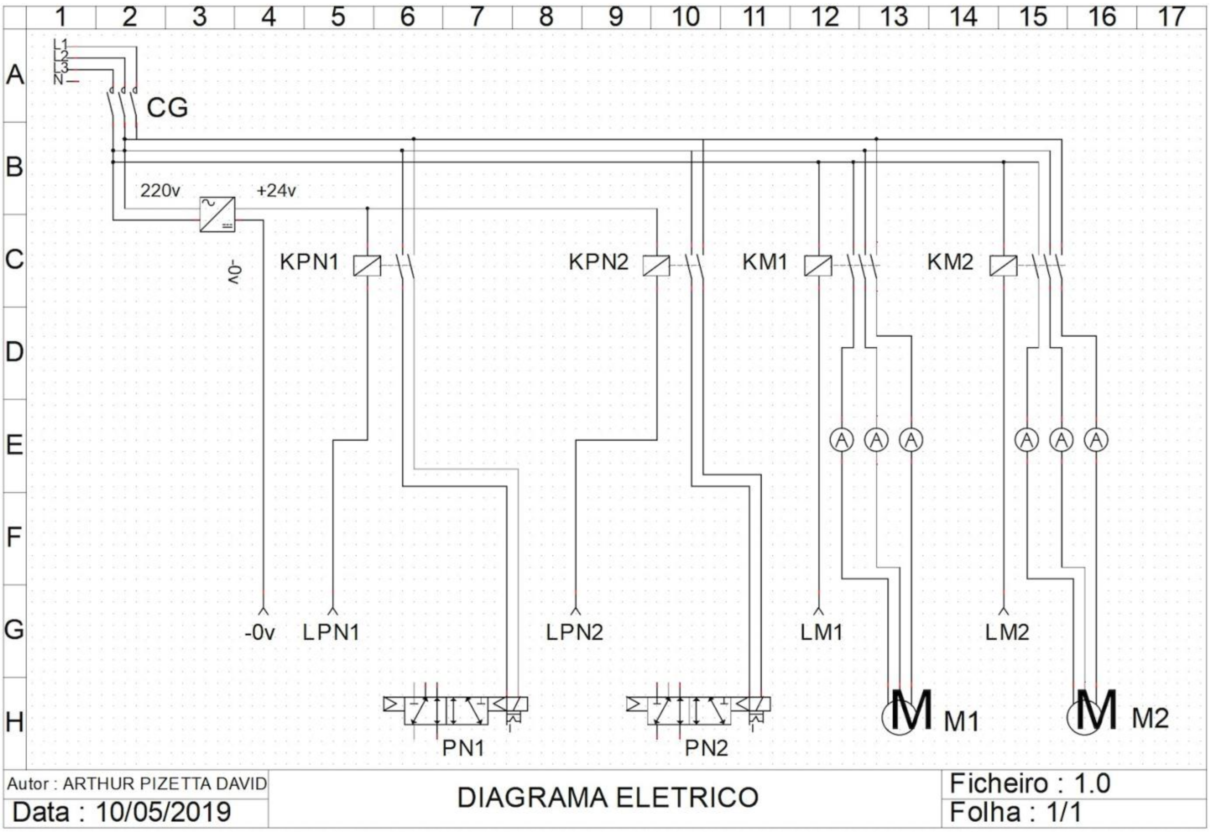


Figure 9. Three-wire Diagram.

Where:

- CG - The three-wire scheme starts with a three-phase general switch ensuring ON / OFF of the three phases of the entire power system.
- KPN1 and KPN2 - They are the single-phase contactors, in the above diagram there are two contactors and four contacts, since they were connected two by two allowing to be activated by only one port of the controller. These are

responsible for passing the phases to the pneumatic actuators PN1 and PN2 respectively.

- The switching power supply is connected to two phases been energized with 220V AC and converted it to 24V DC output, being the positive for the coils of the single-phase contactors KPN1 and KPN2, and then on the terminals of the controller LPN1 and LPN2 respectively being switched by the controller, when necessary, with the negative of the switching power supply.
- M1 and M2 – The 1.5cv three-phase motors are powered by two contactors KM1 and KM2, that connect them to the three-phase network;
- KM1 and KM2 - Three-phase contactors have their drive coils connected one side in the phase and the other side in the controller ports LM1 and LM2 respectively, which are then switched by the controller when necessary. When switched, they allow the passage of three-phases to energize the motors M1 and M2 respectively.
- Part of the connections can be seen is the Figure 10.

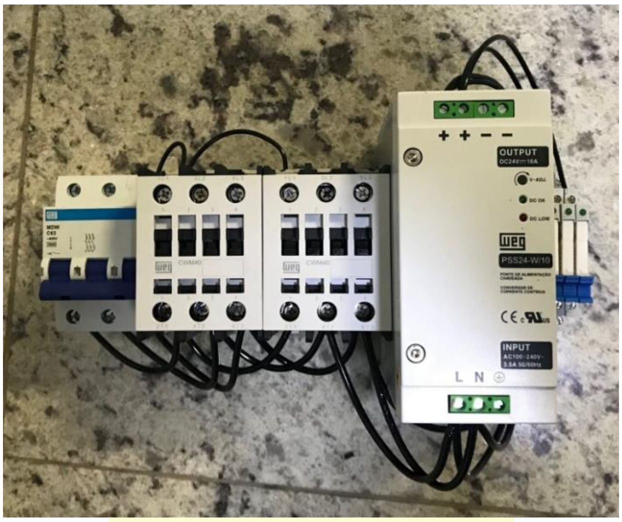


Figure 10. Electrical Connections.

Between each phase of the motors and their contactors were installed an intrusive current sensor that send in real time to the controller the amount of current passing in each phase, this will be essential for the protection of the motors.

2.5 Circuit of the Controller

The developed circuit uses electronic components such as relay, transistors, resistors, ICs, a NodeMCU32S and modules with sensors of AC electric current, the language used for implementation of control logic in the NodeMCU32S was the C, C ++ and also the Wiring.

Protection system inside the controller circuit. The controller was dismembered in two main circuits, the control and the drive. These are separated by PC817 SHARP ICs also known as insulating optocouplers, these are made up of an infrared light-emitting diode and a NPN silicon phototransistor which thus isolates the circuits electrically but keeps them interconnected. They are widely used in relay controls, motors and other devices. Figure 11 below shows where the logic circuit has been separated, they are illustrated by red rectangles and numbered as: 1 control circuit and 2 electric drive circuit.

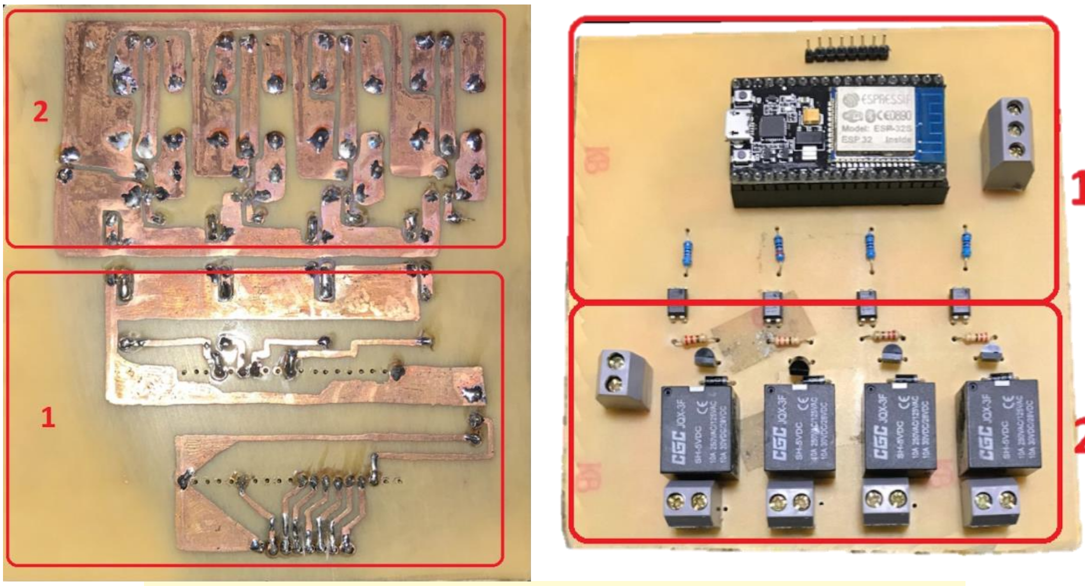


Figure 11. PCB Circuit. 1 - control circuit; and 2 - electric drive circuit.

For better protection was used diodes positioned in parallel with the relays thus preventing possible leakage currents of the inductor inside the relay, thus ensuring a perfect operation of the electric circuit.

According to previous analysis in the field, during the 30 years of the company the main cause of engine burn in the projected machines, including RPB 11 SLIM, is the fall of one of the phases. Thinking of a simple and inexpensive way to solve this problem without having to use a motor circuit breaker, the AC current sensor modules were used in this project. Installed in each phase of the motors after the contactors, in order to find out if there is current passing in each phase while the engine is operating, because if a phase falls the software created will generate an alert, and if the phase does not return the motor will be off in 5s thus ensuring that the motor is not damaged.

2.5 Electrical / Electronic Schematics

In order to make the drive through the electric / electronic circuit the three-phase contactors KM1 and KM2 are connected to the LM1 and LM2 ports respectively, which are related to the motor drives, and the single-phase contactors KPN1 and KPN2 on the LPN1 and LPN2 ports, which are referenced to the pneumatic system. The Figure 12 shows the schematic of the executed project.

For the activation of the relays a BC548 transistor was used for each relay, its collectors being fed by a source with a voltage of 5V. By feeding the bases of the transistors, these begin to work as a key allowing to energize the relays with 5V through the emitters of each BC548. There is a safety diode in parallel with each relay prevented so that leakage currents can originate from the inductors located internally in the relays.

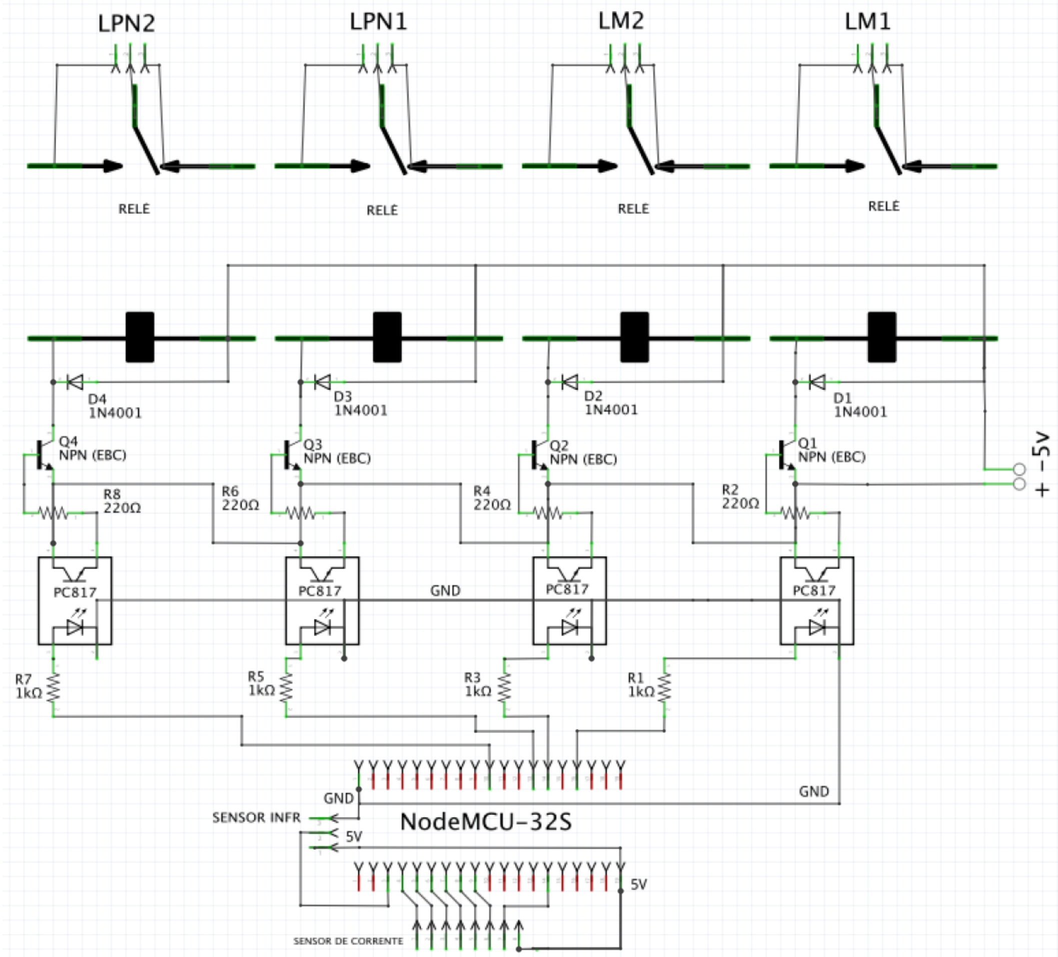


Figure 12. Electrical / Electronic Schematics.

Transistor base drives are made through the PC817 ICs, known as insulation optocouplers. Its drive operates with a digital signal being generated by the I / O ports of the NodeMCU32S on the Anode of each IC as currently desired, along with the grounding of the Cathode, thereby exciting the photo-sensitive transistor within the ICs. Which in turn has its Collector powered with 5V and its emitter connected to the BC548 transistor base thus energizing it.

1KΩ and 220Ω resistors were used only to have a load control, although they are not really needed for circuit operation, but safety is never too much.
The Infrared sensor module is energized by 5V being originated directly from the NodeMCU32S as well as its ground, it sends a digital message (HIGH / LOW) to the pin 36 of the microcontroller that reads and calculates the size of the stone plate.

The Current Sensor Modules are similar to the Infrared Sensor Module, being energized by 5V and grounded in the microcontroller but sending analog messages to the (Analog Digital Converter) ADC ports: 39, 34, 35, 32, 33, and 25.

And finally, the commands are sent by the NodeMCU32S through its logic I / O ports, the ports 15 and 2 being for the activation of the relays of the LM1 and LM2 connections respectively, and the ports 0 and 4 for the activation of the relays of the LPN1 and LPN2 respectively. The executed circuit is shown in Figure 13.

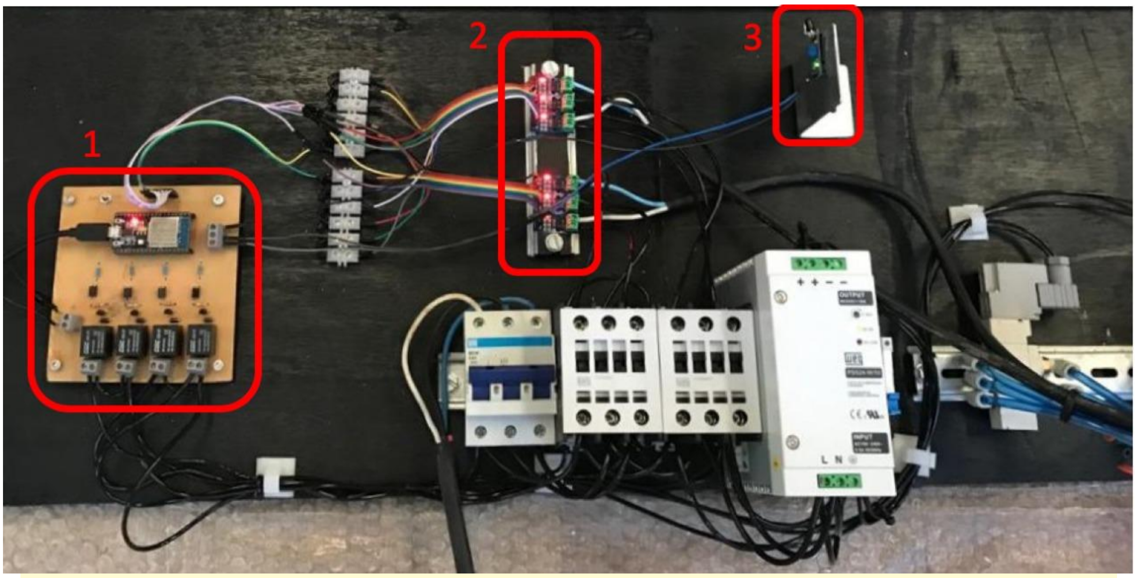


Figure 13. Electrical / Electronic Cirtcuit as executed. 1 Controller Circuit; 2 Current Sensors; 3 infrared sensor

2.5 Control Dashboard

As a complement to this project, in addition to making drives, controls and calculations, the transmission of data via Wi-FI to Ethernet will be carried out, so that data such as current and motor drive, where it will have access for visualization through a login and password so that monitoring can be performed remotely by the computer one even behind a mobile, be it an Android or an IOS.

2.6 Project Cost

It has also been shown to be more economically advantageous as can be analyzed in Table 1 below.

Table 1 – Cost Table

COST TABLE	VALURES	SYSTEM WITH 2 ENGINES	SYSTEM WITH 11 ENGINES
LOGICAL CIRCUIT PROPOSED			
BASE SHIELDS FOR 2 ENGINES	R$ 290,00	R$ 290,00	R$ 290,00
COST FOR EACH ADDITIONAL ENGINE	R$ 60,00	R$ -	R$ 660,00
CURRENT SYSTEM			
PLC WEG TPW03	R$ 3.350,00	R$ 3.350,00	R$ 3.350,00
COST FOR EACH ADDITIONAL ENGINE	R$ 150,00	R$ -	R$ 1.650,00
DIFFERENCE OF VALUES:		R$ 3.060,00	R$ 4.050,00

3 FINAL CONSIDERATIONS AND CONCLUSIONS

The goal of this project was to create a real prototype (Figure 14) that would demonstrate the feasibility of using modern microcontrollers in industrial and business environments as well as a possible and probable step towards a future of automation and control. After the tests were performed, the simulation showed to be capable of servicing the machine RPB 11 SLIM if it were installed. In addition, it's physically feasible.

The next step of this project would be the complete installation of this system in the machine, testing it on the field, thus capturing data and making fine adjustments in order to standardize the electrical / electronic system of RPB 11 SLIM with the developed project.

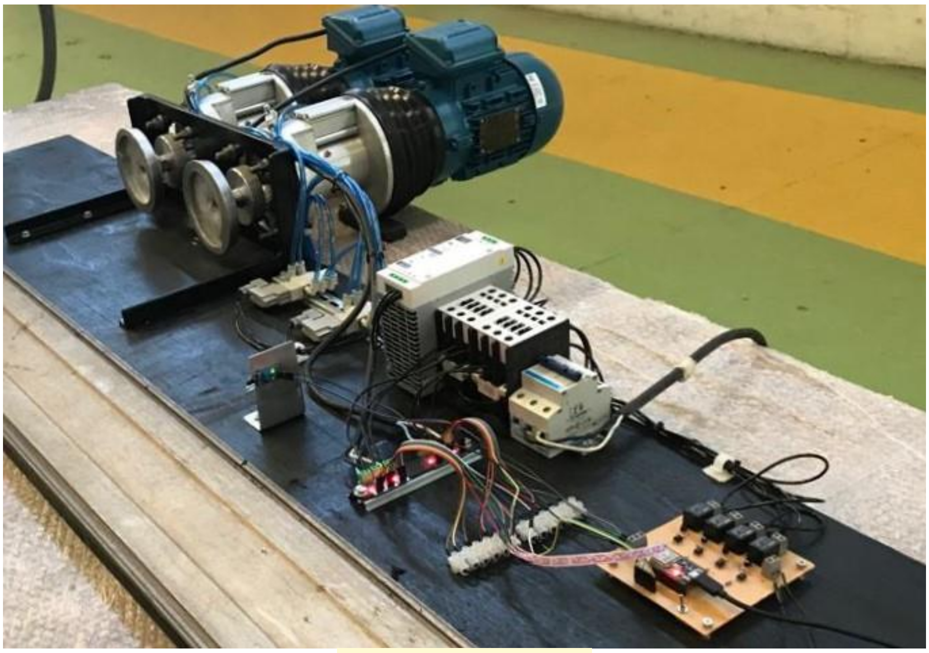


Figure 14. Prototype.

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