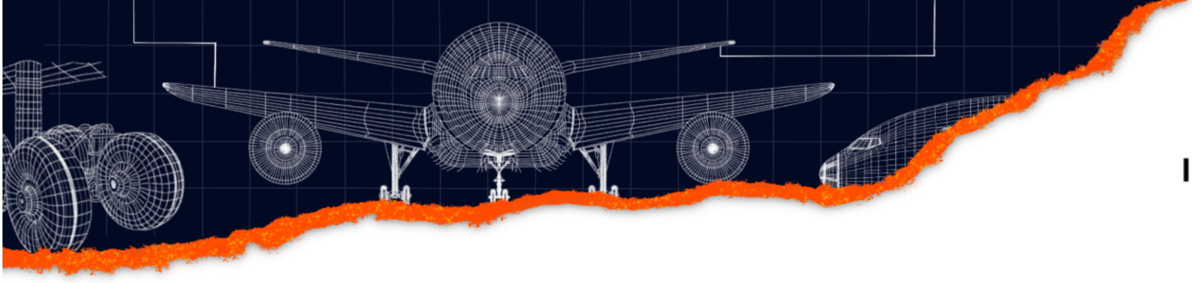

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TANK LEVEL CONTROL SYSTEM VIA ARDUINO

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ABSTRACT
Tank level control is very relevant in the industry, in addition to being widely used in residential applications. To assist in the control of systems, the Arduino platform can be used. Such a platform has stood out in the areas of computing and electronics for its ease of programming and has become an essential tool in the preparation of basic engineering projects. In this work, the Arduino platform was used to control the liquid level of a laboratory scale tank system. For this control, an on-off controller was implemented. A simulation was also carried out in Matlab with the objective of verifying the behavior of a system subject to different basic control actions. Through the simulation in Matlab, the particularities of the main control actions were verified, which allowed us to observe that the PID controller generates the best result and, therefore, is the most used in industrial control systems worldwide.

Keywords: Control System. Arduino. Level. Controller.

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INTRODUCTION

Liquid level control systems are widely used in industrial processes. In many situations, efficient control is essential for productive success and the use of automatic control systems is necessary. As well as in industries, other sectors such as residential and commercial also make use of liquid control systems and can benefit from systems that reduce the possible errors caused by manual process control.

In this context, it was sought to develop a liquid level control plant on a laboratory scale through the Arduino platform, in order to demonstrate that it can perform simple industrial processes at low cost and is an attractive and economical alternative in various conjunctures.

The basic operation of the plant consists of pumping liquid through the pipes of a reservoir to a controlled tank. For this, a variable rotation pump and level sensors are used, and all monitoring and control is done through the Arduino microcontroller.

GENERAL OBJECTIVE

Control and monitor the level of a tank from the development of a microcontrolled system through the Arduino platform.

SPECIFIC OBJECTIVES

- Set up a tank system on a laboratory scale;
- Assemble an electrical circuit with the Arduino;
- Program an on-off automatic control system;
- Simulate the response of different basic control actions in Matlab.

LITERATURE REVIEW

INDUSTRIAL CONTROL

Industrial control aims to reduce costs, optimize time, increase production, efficiency and quality through the use of software, new equipment and techniques. This term became known from 1950 with the development of electronics and today it is essential for the modernization of industrial processes.

MODELING

Mathematical models can be used to better understand a system to be developed. Through a model, built from known physical concepts and considerations, it is possible to simulate the process performed by a real system. Modeling allows you to satisfactorily describe liquid level systems.

Liquid Level Systems

Fluid flows are prone to certain general conditions, principles, and laws of dynamics. Therefore, it is important to divide the flow regimes into laminar and turbulent, based on the Reynolds number[4] (OGATA, 2003). For a Reynolds number between 3000 and 4000, the flow is turbulent and must be treated mathematically with nonlinear differential equations. For a Reynolds number less than 2000, the flow is said to be laminar and must be treated mathematically with linear differential equations. Industrial processes are usually turbulent (OGATA, 2003).

To describe dynamic characteristics of liquid level systems, it is convenient to introduce the concept of resistance and capacitance (OGATA, 2003).

C capacitance is defined as the variation in the volume of liquid capable of causing a unit change in height. Like this

$$C = \frac{\text{variação no volume, m}^3}{\text{variação na altura, m}} \quad . \tag{1}$$

Considering a flow through a small pipe connecting two tanks, resistance R is defined as the variation in the difference in level necessary to cause the unit variation in the rate of flow, i.e.,

$$R = \frac{\text{variação na diferença de nível, m}}{\text{variação na vazão em volume, m}^3\text{/s}} \quad . \tag{2}$$

For laminar flow, there are:

$$Q = KH \tag{3}$$

where:

Q = steady-state liquid flow rate, m^3/s; K = coefficient, m^2/s;

H = height of the steady-state liquid level, m. Then, define the resistance R as follows:

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[4] A dimensionless number used in fluid mechanics to calculate the flow regime. It is a relationship between inertial forces and viscous forces.

$$R=\frac{dH}{dQ}=\frac{H}{Q} \quad . \qquad (4)$$

For turbulent flow, we have:

$$Q=K\sqrt{H} \qquad (5)$$

where:

Q = steady-state liquid flow rate, m³/s; K = coefficient, m 2.5/ s ;

H = height of the steady-state liquid level, m.

So

$$dQ=\frac{K}{2\sqrt{H}}dH \quad . \qquad (6)$$

From equations 5 and 6,

$$R=\frac{dH}{dQ}=\frac{2\sqrt{H}}{K}=\frac{2\sqrt{H}\sqrt{H}}{Q}=\frac{2H}{Q} \qquad (7)$$

The value of the resistance R in turbulent flow depends on the flow rate and the height of the liquid level, but it can be considered constant if the variations in the level height and flow rate are small. In this case, the nonlinear relationship between Q and H can be linearized (OGATA, 2003). The linearized relationship is given by

$$Q=\frac{2H}{R} \quad . \qquad (8)$$

The differential equation of a linear or linearized system can be obtained from the input flow qi and the output flow q0 as follows (OGATA, 2003):

$$C\,dh=(qi-qo)\,dt \quad . \qquad (9)$$

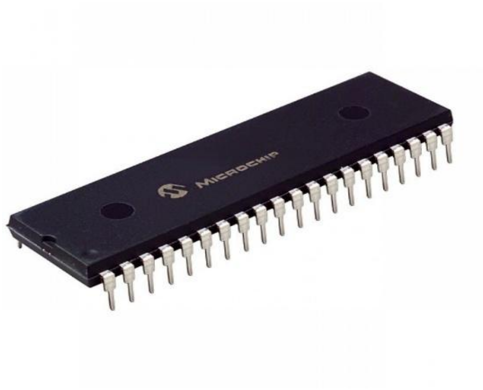
In this case, qi, q0 and h represent small deviations of the inlet flow, the outlet flow and the height of the level in relation to their values in steady state, respectively.

MICROCONTROLLER

A microcontroller consists of an integrated circuit that, through a programming language, executes a previously programmed logical sequence. According to Souza

(2001, p. 3): "In a nutshell, we could define the microcontroller as a "small" electronic component, endowed with a programmable "intelligence", used in the control of logical processes." Figure 1 shows a microcontroller:

Figure 1: Microcontroller.

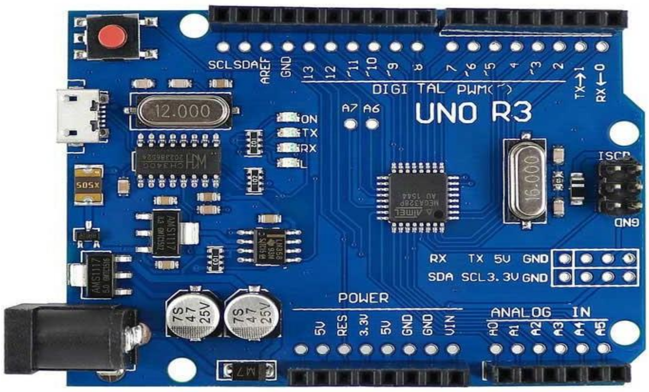


Source: Eletrodex.

Arduino

Arduino is an open-source electronic prototyping platform that stands out for its low cost and easy programming. Through this platform it is possible to interact with LEDs, sensors, motors and other electronic objects. Figure 2 shows an Arduino Uno board, model used in the present work, which features an Atmega328P microcontroller, in addition to 14 digital inputs and outputs, 6 analog inputs, USB communication, external power supply and power pins with 3.3V, 5V and Earth (GND). The programming language used in Arduino is the C++ language, with minor changes.

Figure 2: Arduino Uno Board



Source: Dealextreme

WATER PUMP

Water pump, also called hydraulic pump, is a device that adds energy to liquids, from mechanical energy. According to Monachesi (2005, p. 63): "In general, the term pump is attributed to any equipment capable of transferring energy from a certain source to a liquid, so that this liquid can perform a certain work."

In the present study, a pump model used to clean car windshields was used, as shown in figure 3. This type of pump works with a voltage of 12V with direct current and consumes a current of approximately 1A, in steady state. It has the advantage of its low cost and the ability to be fed with a voltage lower than the nominal, which makes it possible to control the filling speed of the upper tank through the PWM signal.

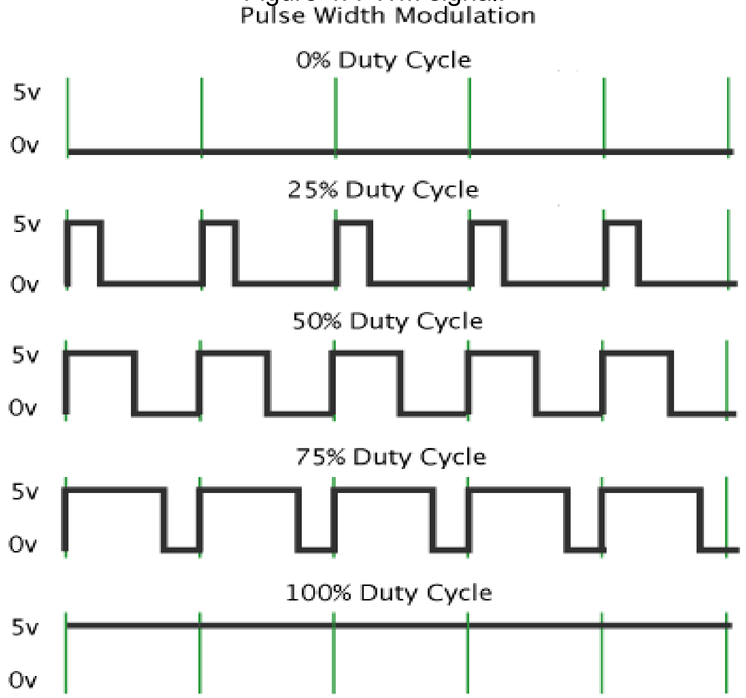
Figure 3: Water pump.

Source: Virtual Plastics

PWM

PWM (Pulse Width Modulation) is a technique used in digital systems that allows you to vary the average value of a periodic waveform. Used in various areas of electronics, it can be used in LED brightness control, motor speed control and other applications. The technique consists of fixing the frequency of a square wave and varying the time that the signal stays at a high logical level. This time is called the duty cycle, that is, it represents the active cycle of the waveform. Figure 4 shows an example of a PWM signal.

Figure 4: PWM signal.



Source: Natanael's Blog.

SENSORS

A sensor is a device that detects a physical/chemical stimulus and responds accordingly. Sensors are used in several areas to support process monitoring and control.

Level Sensor

A level sensor is a device used to control liquids in tanks and reservoirs. The level of liquids is detected by the movement of floats that generate a magnetic signal.

Since liquid level control is essential in industrial processes and in everyday life, level sensors are used to ensure that the volume in tanks or tanks remains within a tolerated range, so that processes can be carried out reliably.

Figure 5 shows a lateral level sensor, which works by magnetism. On the floating base of this sensor is a magnet, which switches when it reaches the end of the sensor and performs a predetermined task.

Figure 5: Side Level Sensor.

Source: Autocore Robotics.

Other examples of level sensors are: pressure sensor, ultrasonic sensor, capacitive sensor.

LAPLACE TRANSFORM

The development of control systems is facilitated with the use of the Laplace transform. Through this, differential equations can be transformed into algebraic equations. With this method, you perform normal algebraic operations in the domain "s" and then return to the domain "t" through the inverse. The Laplace transform of a function f(t) is defined as (OGATA, 2003):

$$F(s)=L[f(t)]=\int_0^{\infty} f(t)\, e^{-st}\, dt \quad . \qquad (10)$$

TRANSFER FUNCTION

Transfer function is the ratio between the Laplace transform of the output signal and the Laplace transform of the input signal of a system, considering all initial conditions null. Like this

$$G(s)=\frac{Y(s)}{X(s)} \quad . \qquad (11)$$

where

G(s) = transfer function;

Y(s) = Laplace transform of the system output signal; X(s) = Laplace transform of the system input signal.

CONTROL ACTIONS

A controller can be understood as a device that performs certain mathematical operations on the error signal e(t) with the objective of producing a u(t) signal to be applied in the plant in order to satisfy a certain objective. Such mathematical operations are called control actions. According to Ogata (2003):

> An automatic controller compares the actual value of the process output quantity with the reference quantity (desired value), determines the deviation, and produces a control signal that will reduce the deviation to zero or a small value. The way in which the automatic controller produces the control signal is called the control action.

From the mathematical operations, the following basic control actions can be identified:

a) on-off action;
b) proportional action;
c) comprehensive action;
d) derivative action;
e) proportional-integral action (PI);
f) proportional-derivative action (PD);
g) proportional-integral-derivative action (PID).

On-Off Action

The on-off control action is the simplest and most cost-effective control action. The control is done from a fixed point, the setpoint. In this type of control there are two positions: on and off. The output of the controller changes position as the error signal passes through the setpoint. This action can be observed in domestic control systems, such as the control of water levels performed by floats in water tanks or the control performed by thermostats in refrigerators.

Proportional Action

In this type of action, the output signal of the controller u(t) is proportional to the amplitude of the value of the error signal e(t) (OGATA, 2003). Like this

$$u(t)=K_p e(t) \tag{12}$$

where Kp represents the proportional gain.

Its transfer function is given by:

$$\frac{U(s)}{E(s)}=K_p \quad . \tag{13}$$

The error can be decreased by increasing the Kp gain, but it can never be cancelled out completely. In addition, in most physical processes, the exaggerated increase in the proportional gain can lead the system to instability, since the increase in the gain causes the accommodation time to[5] increase and, thus, the transient behavior of the closed-loop system[6] becomes more oscillatory.

Integral Action

In this type of action, the output signal of the controller u(t) is proportional to the integral value of the error signal e(t) (OGATA, 2003). Like this

$$u(t) = K_i \int_0^t e(t)\,dt \qquad (14)$$

where KI represents the integral gain.

Its transfer function is given by:

$$\frac{U(s)}{E(s)} = \frac{K_I}{s} \quad . \qquad (15)$$

The integral action tends to eliminate the stationary error, so that there is a readjustment in the measurement value equal to the set point. Therefore, this action is also called a reset action. The integral action acts in the process over time as long as the difference between the desired value and the measured value persists. Thus, the correction signal acts until the error is completely eliminated.

2.8.4 Derivative Action

In this type of action, the output signal of the controller u(t) is proportional to the derivative of the value of the error signal e(t) (OGATA, 2003). Like this

$$u(t) = K_d \frac{de(t)}{dt} \qquad (16)$$

where Kd represents the derivative gain.

Its transfer function is given by:

$$\frac{U(s)}{E(s)} = K_d s \quad . \qquad (17)$$

[5] Time for the system's response to be in the range between 2% or 5% of the final value.
[6] A closed-loop system is one in which the output or response influences the input of the system.

The derivative action is said to be anticipatory, as it makes the system react more quickly and anticipate the error. This action acts only during the transient response.

Proportional-Integral Action (PI)

The action of proportional-integral control is given by (OGATA, 2003):

$$u(t) = k_p e(t) + K_i \int_0^t e(t)\, dt \qquad (18)$$

Its transfer function is given by:

$$\frac{U(s)}{E(s)} = k_p + \frac{K_i}{s} \quad . \qquad (19)$$

Integral action tends to eliminate the stationary error, however, if applied in isolation, it tends to worsen the relative stability of the system, as it adds poles to it, tending to destabilize it. To alleviate this situation, the integral share is usually used in conjunction with the proportional action, in order to constitute the controller PI.

Proportional-Derivative Action (PD)

The action of proportional-derivative control is given by (OGATA, 2003):

$$u(t) = k_p e(t) + K_d \frac{de(t)}{dt} \quad . \qquad (20)$$

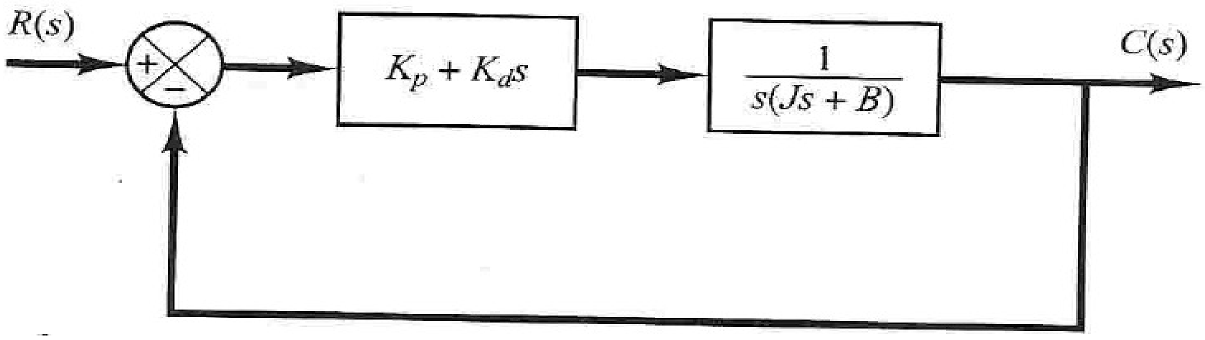
Its transfer function is given by:

$$\frac{U(s)}{E(s)} = k_p + K_d s \quad . \qquad (21)$$

The derivative action anticipates the control action, but acts only during the transitory response. Thus, derivative action is often combined with proportional action in order for the process to react faster. This combination increases the relative stability of the system and tends to make its transient response faster.

Figure 6 shows the block diagram of a PD controller.

Figure 6: Block diagram of a PD controller.



Source: Ogata.

Proportional-Integral-Derivative Action (PID)

The action of proportional-integral-derivative control is given by (OGATA, 2003):

$$u(t) = k_p e(t) + K_i \int_0^t e(t)\, dt + K_d \frac{de(t)}{dt} \quad (22)$$

Its transfer function is given by:

$$\frac{U(s)}{E(s)} = k_p + \frac{K_i}{s} + K_d s \quad (23)$$

The PID controller combines the advantages of PI and PD controllers. The accuracy of the system is linked to the integral action, which tends to eliminate stationary error. The derivative action, on the other hand, contributes to the increase of the relative stability of the system and the anticipation of its response.

METHODOLOGY

It was sought to develop a microcontrolled system through the Arduino platform in order to reproduce a level control system on a laboratory scale. A simulation of the process was also carried out through the Matlab software and, for this, a PID controller was used.

The methodology used in this project involved the following steps:

a) Lifting of materials that ensure a good quality to the project with low cost;
b) Analysis of the project, with the prediction of possible difficulties and implementation errors;
c) Project implementation.

MATERIALS AND METHODS

Water Pump

In the present project, a water injection pump used to clean car windshields was used. This pump operates at 12V and an external source of direct current was used for its activation. Figure 7 shows the pump used.

Figure 7: Water pump.

Source: Author himself.

Side Level Sensor

2 level sensors with floats and normally open (NO) and normally closed (NC) contacts were used. Each sensor was fixed at one end of the tank, in order to mark the minimum and maximum levels of liquid. One of the sensors appears in figure 8.

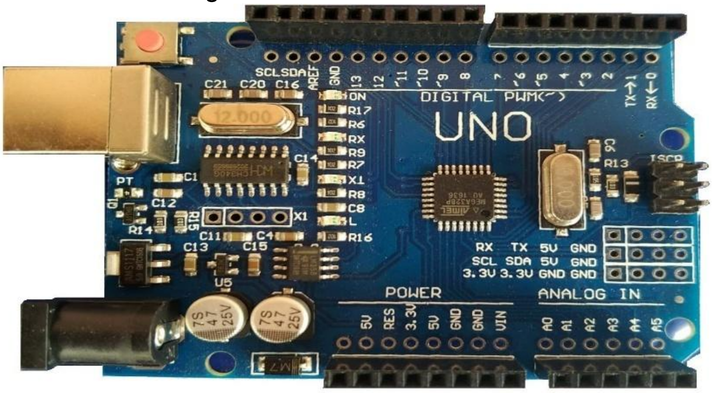
Figure 8: Lateral Level Sensor.

Source: Author himself.

Arduino Microcontroller

Despite being relatively new, the Arduino microcontroller is gaining more and more market share. In the present work, the Arduino Uno model was used due to its small dimensions, USB connector for connection to a microcomputer, simple programming and low cost. Figure 9 shows the license plate used in the work.

Figure 9: Arduino Uno board.



Source: Author himself.

Resistor

Resistors are used for the purpose of limiting the current in certain parts of the circuit, in order to prevent the burning of other components such as LEDs. In the present project, resistors of 220 K Ω and 10 K Ω were used, as shown in figure 10.

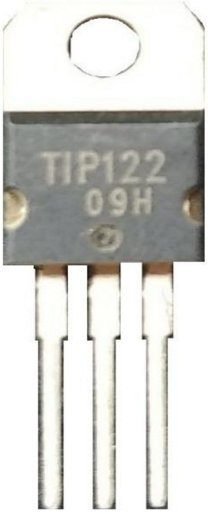
Figure 10: Resistors.

Source: Author himself.

Transistor

The transistor is an electronic component used mainly as an amplifier and switch for electrical signals. In the present study, a Darlington transistor model TIP 122 was used to drive the water pump. The TIP 122 is a high-gain, power transistor, being internally formed by two transistors, which generates a current gain. The TIP 122 transistor supports the passage of an electric current of 5A, higher than that required for the operation of the pump. Figure 11 shows the model used.

Figure 11: Transistor TIP 122.



Source: Author himself.

Power Supply

A stabilized honeycomb source with an output voltage of 12V and a maximum current of 5A was used in the project, as shown in figure 12.

Figure 12: 12V 5A stabilized supply.

Source: Author himself.

IMPLEMENTATION

Tank System

Two tanks were used to assemble the system, as shown in figure 13. The upper tank is controlled and has the following dimensions: diameter (D) = 18 cm and height (H) = 22 cm. The lower tank works only as a reservoir.

Figure 13: Tank System.

Source: Author himself.

Tank Transfer Function

To obtain the tank transfer function, a graph was initially made relating the height of the liquid level and the tank outlet flow. For this, some data were collected. These data are presented in Table 1.

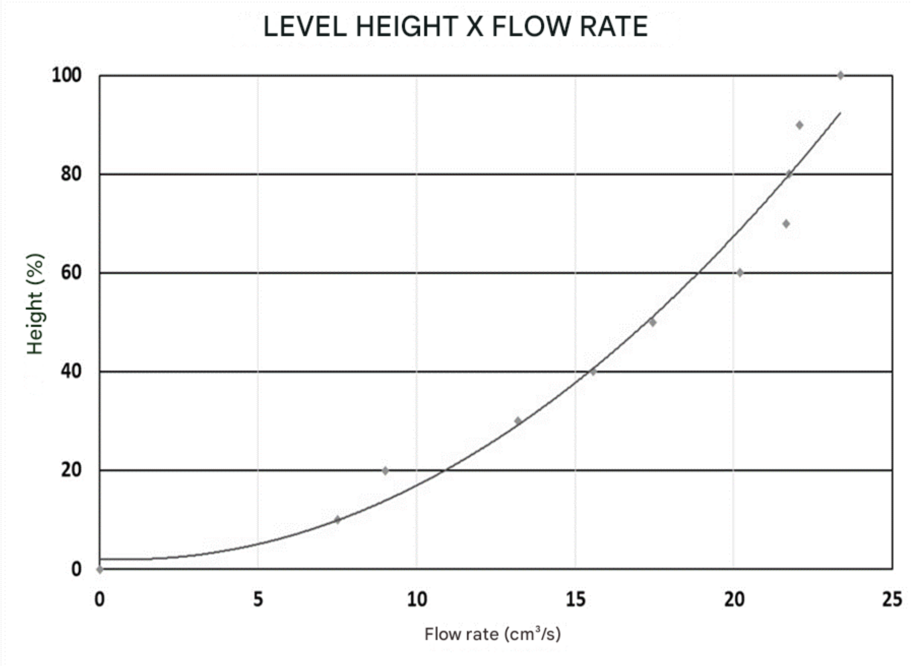
Table 1: Relationship between liquid level height and flow rate.

Level Height (%)	Time(s)	Flow rate (cm^3/s)
0	0	0
10	26,63	7,51
20	22,18	9,02
30	15,16	13,19
40	12,84	15,58
50	11,46	17,45
60	9,90	20,20
70	9,23	21,67
80	9,19	21,76
90	9,06	22,08
100	8,56	23,36

Source: Author himself.

Keeping the water outlet valve open, the height of the liquid level of the tank was varied and for each height the time taken to complete 200 cm^3 in a graduated container was measured. Thus, the outlet flow rate for each height of the liquid level was obtained. Figure 14 shows the graph that relates the height of the level (H) and the outlet flow (Q0).

Figure 14: Curve that relates the height of the liquid level and the outlet flow of the tank.



Source: Author himself.

For the mathematical modeling, the tank was considered to have 50% of its total volume, a situation in which its level height is 11 cm and its flow is 17.45 cm³, as seen in figure 14. Thus, the resistance R was calculated according to equation 7:

$$R = \frac{2 * 11 \text{ cm}}{17{,}45 \text{ cm}^3/\text{s}} = 1{,}26 \text{ s/cm}^2 \quad . \tag{24}$$

The capacitance C of a tank, defined as the change in the amount of stored liquid required to cause a unit change in the height of the liquid level, basically represents the cross-sectional area of the tank. As the tank used in the work has a cylindrical shape, the capacitance C is given by:

$$C = \frac{\Delta V}{\Delta H} = \pi \frac{d^2}{4} \quad , \tag{25}$$

where:

V = volume, m³;

H = height, m;

d = diameter, m.

Thus, substituting the diameter value, we have:

$$C = \frac{\pi * 0{,}18^2}{4} = 0{,}0254 \text{ m}^2 = 254 \text{ cm}^2 \quad . \tag{26}$$

With the admission of small deviations in the inlet flow, in the outlet flow and in the height of the level in relation to their values in steady state, the system was considered linear, which allowed the use of equation 9. From the definition of resistance, the relationship between qo and h is given by:

$$q_0 = \frac{h}{R} \quad . \tag{27}$$

By substituting equation 27 into equation 9, we obtain:

$$C\, dh = \left(qi - \frac{h}{R}\right) dt \quad . \tag{28}$$

For a constant value of R, we have the following differential equation for the system:

$$RC \frac{dh}{dt} + h = Rq_i \quad , \tag{29}$$

where RC is the constant of the system. With the application of the Laplace transform in the previous equation, we obtain:

$$(RCs+1)\, H(s) = RQ_i(s) \quad , \tag{30}$$

where H (s) = L[h] e Qi (s) = L[qi] . Considering qi the input and h the output, the transfer function of the system is:

$$\frac{H(s)}{Q_i(s)} = \frac{R}{RCs+1} \tag{31}$$

By replacing the values of the resistance R and capacitance C, the tank transfer function is found:

$$\frac{H(s)}{Q_i(s)} = \frac{1{,}26}{320{,}04\, s+1} \tag{32}$$

Pump Transfer Function

To obtain the pump transfer function, the PWM signal on the Arduino UNO board was used. The active cycle of the waveform was varied from 0 to 100%, in order to obtain an average output voltage in the pump that varied from 0V to 12V, a maximum value at which the output always remains at a high level. On the Arduino Uno, the value 0 makes the output always remain at a low level, in which case the voltage is zero and the value 255 causes the output to always remain at a high level, in which case the voltage is maximum. To calculate the average value of the output voltage of the PWM signal, the following equation was used:

$$V_{out} = \left(\frac{\text{duty cycle}}{100}\right) * Vcc \quad (33)$$

where:

Vout = output voltage, V;

duty cycle = PWM active cycle value, %; Vdc = supply voltage, V.

For each value of output voltage applied to the pump, the time taken to complete 200 cm^3 in a graduated container was measured, and thus the output flow rate for each voltage value was obtained. The data obtained are shown in Table 2.

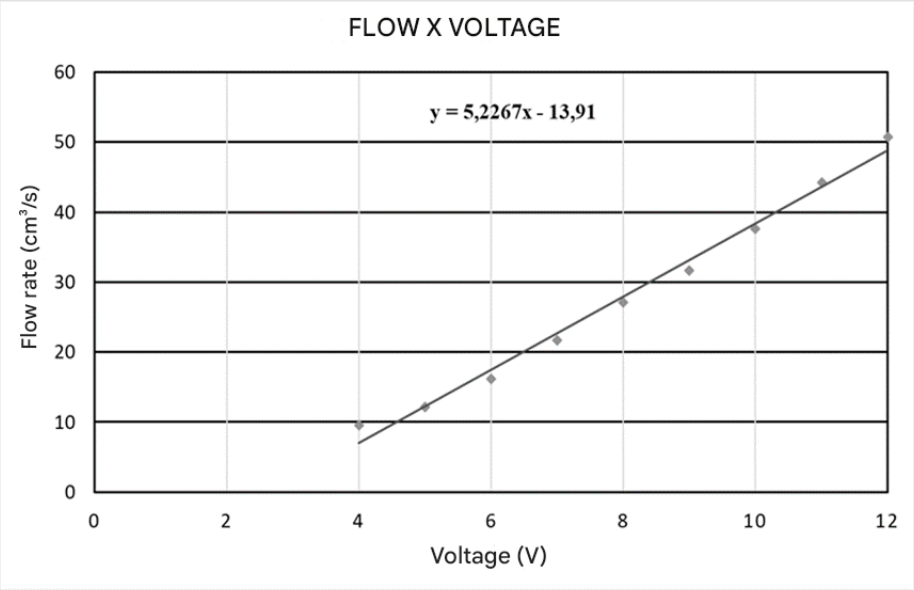
Table 2: Relationship between pump voltage and flow rate.

Duty Cycle (%)	Voltage (V)	Time(s)	Flow rate (cm^3/s)
0	0	-	-
8,33	1	-	-
16,67	2	-	-
25	3	-	-
33,33	4	20,84	9,60
41,67	5	16,39	12,20
50	6	12,36	16,18
58,33	7	9,21	21,72
66,67	8	7,37	27,14
75	9	6,31	31,70
83,33	10	5,32	37,59
91,67	11	4,52	44,25
100	12	3,94	50,76

Source: Author himself.

Figure 15 shows the graph that relates the voltage applied to the pump (V) and the output flow (Q0).

Figure 15: Curve that relates the voltage in the pump and the flow.



Source: Author himself.

From the trend line of the previous curve, the following relationship is obtained:

$$Q = 5{,}23\, V - 13{,}91 \quad . \tag{34}$$

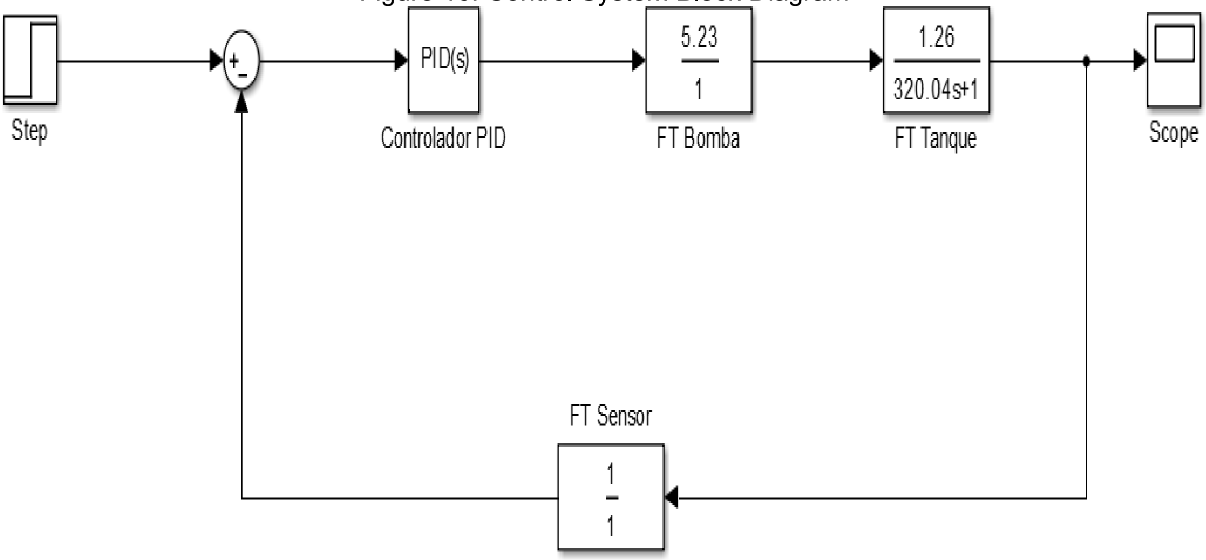
As seen in section 2.7, to find the transfer function of an equation one must consider all null initial conditions. Thus, to obtain the transfer function of equation 34, the term constant is disregarded. Finally, with the Laplace transform application, there is the pump transfer function:

$$\frac{Q(s)}{V(s)} = 5{,}23 \quad . \tag{35}$$

Simulation in Matlab

From the obtaining of the tank and pump transfer functions, the simulation was carried out in the Matlab software. This simulation aimed to verify the behavior of a controlled system. For this, the Simulink tool was used. The block diagram developed is shown in figure 16. The unit step function was considered as input and any effect of the sensor on the response of the control system was disregarded.

Figure 16: Control System Block Diagram



Source: Author himself.

PHYSICAL SYSTEM

Tank System

As seen in section 3.2.1, two tanks were used to assemble the system. The lower tank functions only as a reservoir and in the upper tank two level sensors and a tap were installed, which was fixed to the lower part of the container. One of the sensors was installed at the top of the tank and the other was installed at the bottom, in order to mark the level of the controlled tank as full or empty, respectively.

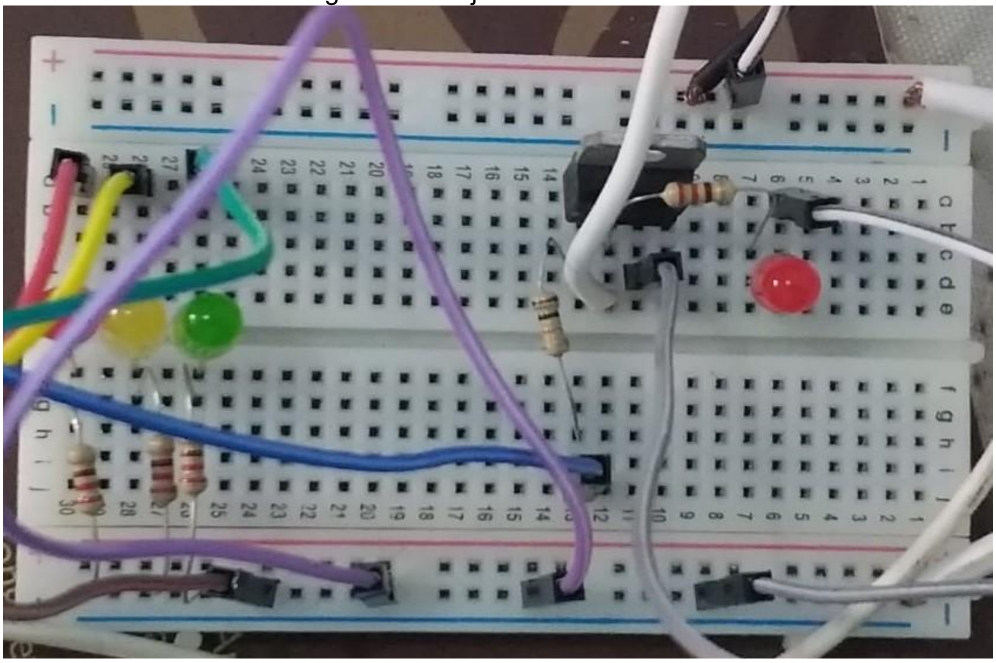
Water Pump On-Off Control

Due to the limitations of the components used in the project, the control action used in the practical demonstration was the on-off action. With this control, the water pump is activated when the upper tank level is empty and its shutdown occurs when the level is full. To drive the pump, a TIP 122 transistor was used, which works as a switch for the passage of current between the source and the water pump. At the base of the transistor, a 10 K resistor was Ω connected at one end and at the other was connected the digital port 9 of the Arduino board. To signal the operation of the water pump, an LED was used.

Protoboard

A protoboard is a board with holes and conductive connections used in the assembly of electrical circuits. A simple and low-cost protoboard model was used in the present project. The job control board is shown in figure 17.

Figure 17: Project Control Board.



Source: Author himself.

Programming

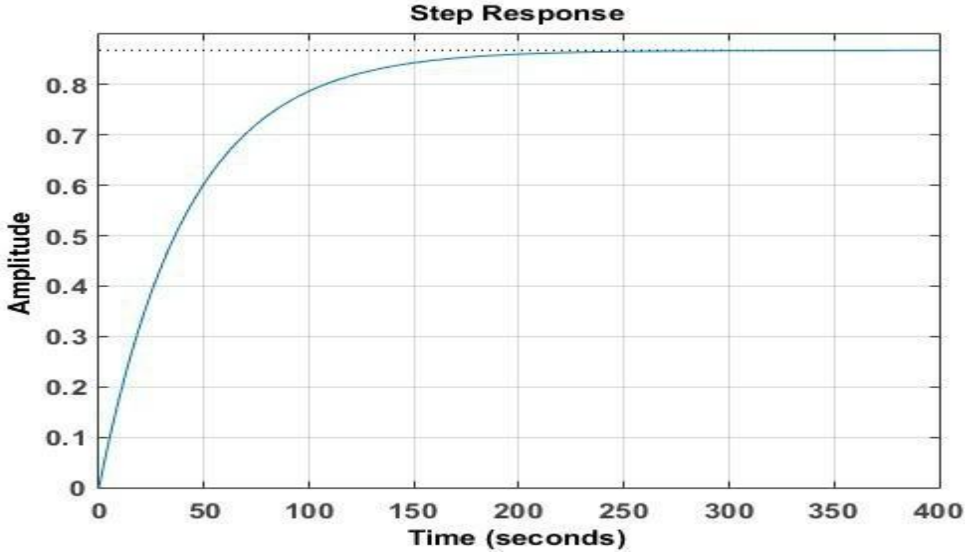
The project programming was done in the integrated development environment of the microcontroller itself, the Arduino. According to the programming code, the water pump is turned on the moment the liquid level is low and is turned off when the liquid level is high. The low or high level reading is done by the level sensors, installed at the top and bottom of the controlled tank. Appendix A presents the programming code.

RESULTS AND DISCUSSION

In the simulation in Matlab, in order to demonstrate the characteristics of the basic control actions, the behavior of the system in the absence of control and with the following controls was considered: proportional (P), proportional-derivative (PD), proportional-integral (PI) and proportional-integral-derivative (PID).

Figure 18 shows the behavior of the system in the absence of control. In this case, there is a large stationary error and a long response time of the system, which takes time to stabilize.

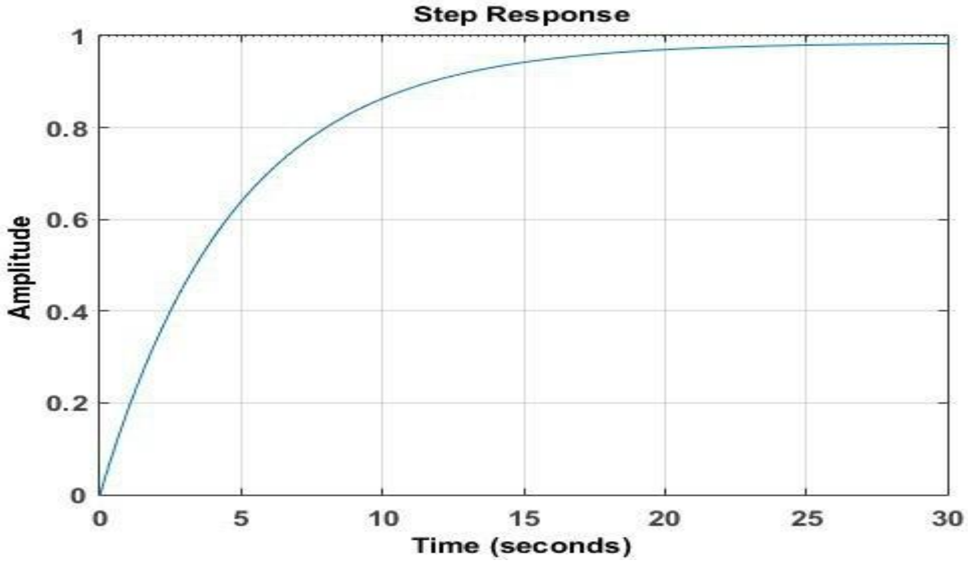
Figure 18: System behavior in the absence of control.



Source: Author himself.

In order to reduce the response time of the system, proportional control was adopted. This control causes the system to stabilize more quickly, but still generates a considerable stationary error, as can be seen in figure 19.

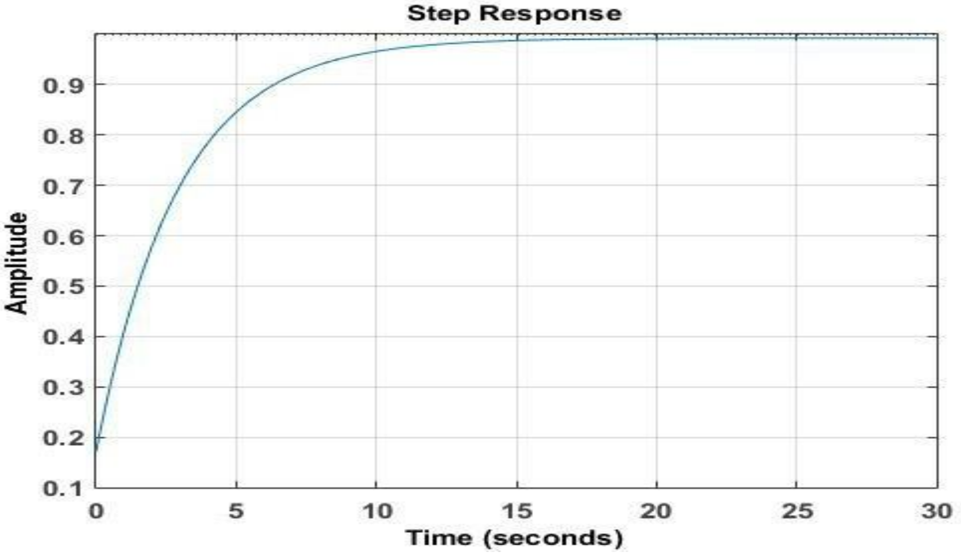
Figure 19: System behavior with control P, with Kp=10.



Source: Author himself.

As seen in section 2.8, the exaggerated increase of the proportional gain in isolation can lead the system to instability, but the combination with derivative control allows an increase in the gain K_p. Thus, PD control makes the system response even faster. In addition, this combination increases the relative stability of the system, as shown in Figure 20.

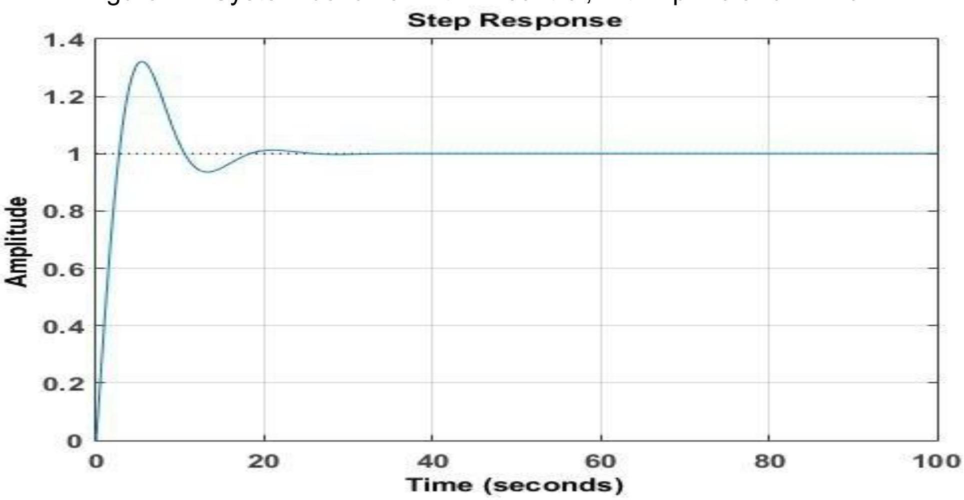
Figure 20: System behavior with PD control, with Kp=20 and Kd=10.



Source: Author himself.

The PI control, illustrated in figure 21, tends to eliminate the stationary error, but it also tends to worsen the relative stability of the system.

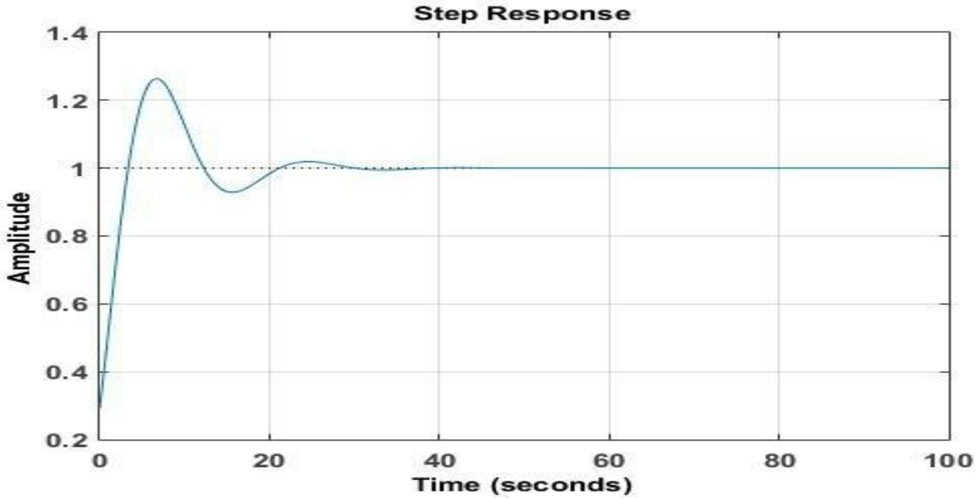
Figure 21: System behavior with PI control, with Kp=20 and Ki=10.



Source: Author himself.

Finally, PID control combines the advantages of the previous controls, so that stationary error is eliminated, system response is anticipated, and relative instability, although it still exists, is lower than that of the system with PI control. Figure 22 shows the behavior of the system with PID control.

Figure 22: System behavior with PID control, with Kp=20, Kd=20, and Ki=10.



Source: Author himself.

Through the simulation in Matlab, a situation in which the behavior of a system subject to different basic control actions was compared, it was observed that the PID control generates the best result, with greater precision, although the PI control presents a very close response. With the choice of random values of Kp, KI and Kd it was possible to perceive the different characteristics of systems with proportional, proportional-derivative, proportional-integral and proportional-integral-derivative controllers.

It was observed that the P control decreases the response time of the system, but still generates a stationary error. The addition of derivative control allows an improvement in the relative stability of the system and makes the response time even shorter. The combination of proportional and integral gains increases system instability, but eliminates stationary error. PID control, generated by the combination of proportional, integral, and derivative gains, minimizes oscillation, eliminates error, and anticipates system response. Due to its characteristics, PID control is the most used in the industry and has been used worldwide in industrial control systems.

With the physical system, it was possible to observe the importance of Arduino in the execution of low-cost projects and in the simulation of industrial processes on a laboratory scale. Through the on-off action, a tank level system was controlled, in order to prevent the tank from overflowing in case of high level and the pump from running dry in case of low level. Figure 23 shows the level control system of the present work.

Figure 23: Level Control System

Source: Author himself.

CONCLUSION

The present work demonstrated that the Arduino microcontroller can perform simple industrial processes at low cost, being an economically viable alternative with satisfactory results for several projects.

During the development of the liquid level control plant, difficulties were encountered in activating the water pump. The solution to this problem was the use of a transistor, which supports the passage of an electric current greater than that necessary for the operation of the pump.

Due to the characteristics of the control plant components, it was not possible to implement a PID control in the physical system. The programming allowed the execution of the on-off control, in which the activation of the water pump occurs when the liquid level reaches its minimum value and the shutdown occurs when the level reaches its maximum value.

With the simulation in Matlab, it was possible to observe the particularities of the main control actions and compare their results. With the simulation it was possible to verify the efficiency of the PID controller, which presents the best results and, therefore, is so used today in industrial control systems.

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