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DESIGN AND MANUFACTURE OF A JUG PROTOTYPE AUTOMATED AGITATION

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Abstract: One of the limitations in academic training is carrying out laboratory practices. These not only confirm the theory but also allow to clarify and deepen the subject that is being addressed. In general, the equipment for carrying out practices is unaffordable for some educational institutions. In order to provide a solution to the lack of equipment to carry out laboratory practices at the TecNM-ITTehuacán (Tecnológico Nacional de México-Instituto Tecnológico de Tehuacán), a prototype of automated jars was designed, manufactured and tested. The equipment made consists of two automated jugs, it also measures the temperature and the ph of the mixture. The cost of the equipment was well below what is found in the market. The manufactured prototype is being used in the subject of Unitary Operations in the Chemistry area of the same institution, enabling its use in other subjects.

Keywords: Automated jars, microcontroller, mixing, coagulation, flocculation.

INTRODUCTION

To achieve a solid academic training, not only theoretical knowledge is necessary, but it must be complemented with internships, since they provide experience in different aspects of the study area (Kendra Cherry, 2022). There are some chemical processes that need to spin a liquid mixture at a certain amount of RPM (Revolutions per Minute) for a certain time. In addition to this, measuring the temperature of the mixture as well as measuring the ph value is also useful. Due to this, it is necessary to use equipment that has shaking jars that allow this process to be carried out. In the Electronics laboratory of TecNM-ITTehuacán, a team of automated stirring jars was designed to be used in the subject of Unitary Operations in the Chemistry area.

The jar test is a widely used technique to determine the dosage of chemicals and other parameters of a mixture; in it, it is about simulating the processes of coagulation, flocculation and sedimentation at the laboratory level (Lorenzo Acosta Yarinis, 2020). The effectiveness of this process is focused on having some jugs that allow them to be used by varying the RPM, generating a certain agitation, as well as the time of the same. The efficiency of the process is determined by the agitation of the mixture of water with the coagulant, which ensures that the concentration of the coagulant is uniform throughout the solution; the intensity and mixing time determine the adequate distribution of the coagulant (Tafur Bravo, 2014), (Diana Marcela Fúneque, 2018). Chemical factors such as pH, temperature, coagulant concentration, chemical application sequence, degree of agitation and sedimentation time influence this process (Tafur Bravo, 2014).

The information provided by the agitation process using a team of shaker jars, the performance of practices for a better academic training, the high prices of this equipment as well as the lack of them in the Chemistry laboratory of the TecNM-ITTehuacán led to the design and manufacture of automated stirring jar equipment.

The costs of this equipment are high due to various factors. Its manufacture, payment for its introduction into the country, installation, training, as well as preventive and corrective maintenance are just some of the factors that affect the rise in costs. Considering the above, in the Electronics laboratory of TecNM-ITTehuacán the possibility of manufacturing a prototype was considered as a first approach to this type of equipment, this in order to reduce equipment costs and thus have this equipment available for the realization of practices.

METHODOLOGY

The automated shaking jar equipment consists of two mixing jars whose shaking speed as well as the shaking time are values provided by the user through a matrix keyboard. It also has two sensors, the first for temperature and the second for ph; the temperature and ph values are displayed on an LCD. Figure 1 shows the block diagram of the equipment. The entire process is controlled by an MCU (Microcontroller Unit) or microcontroller.

SYSTEM CORE

An MCU was used as the core of the equipment, in particular the PIC 18F4550 from Microchips. This is in charge of reading the information provided by the user through the keyboard and controlling the operation of the equipment.

The user provides the desired stirring speed using a 4x4 matrix keyboard, which is given by the RPM as well as the desired stirring time; see Figures 3 and 4. For the equipment to perform the agitation, two 12 V DC motors were used, Figure 5. Once the MCU reads this information and decodes it, it then energizes the motor at the RPM number and the indicated time. To control the time that the motor must be kept working at the RPM given by the user, a clock module was implemented in the MCU. Said module is a software routine; which considers the time that was requested by the user. The MCU Timer0 can be used as a Timer (clock) or as a counter. In this project the MCU was used in 16-bit Timer mode; With the appropriate configuration, it allows you to count the time that the motor must remain on.

To count the number of RPM you can use a Hall effect sensor or an encoder with a horseshoe switch. The Hall effect sensor was parameterized but it presented considerable discrepancy in its measurements; the encoder

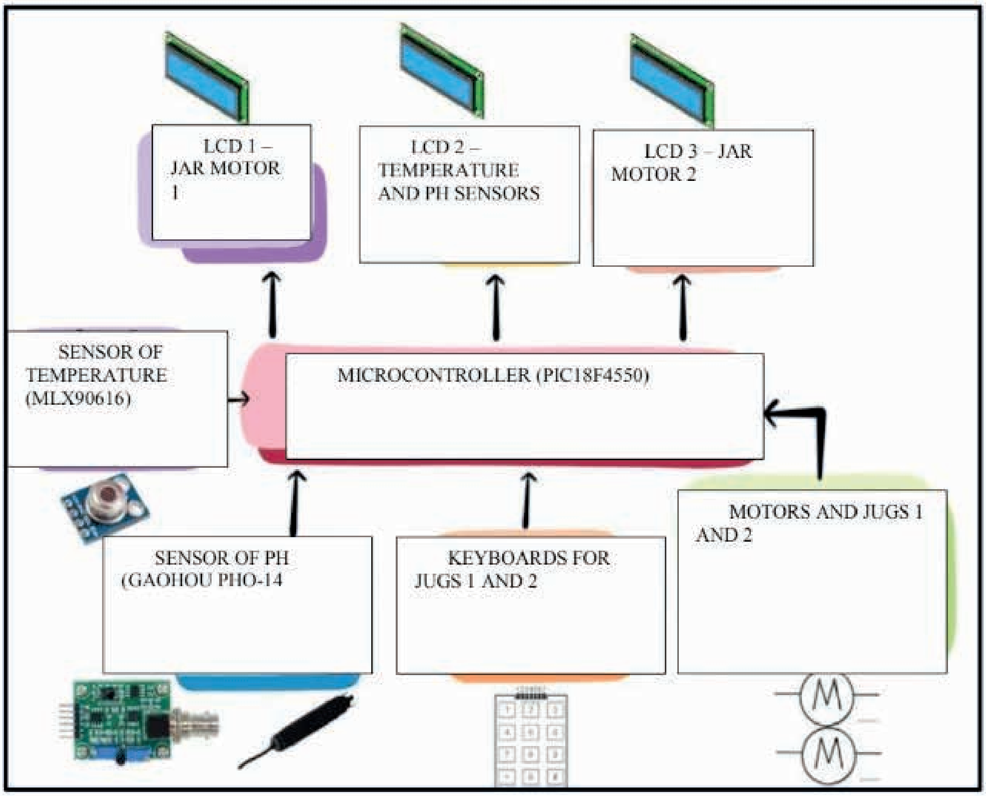

Figure 1. Equipment block diagram.

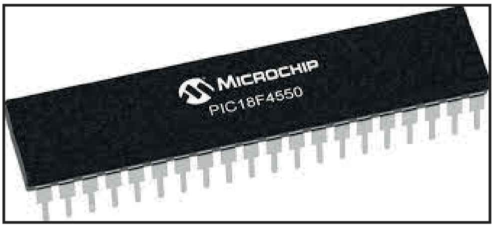

Figure 3. MCU used.

Figure 4. Matrix keyboard.

Figure 5. Motor 12 V CD.

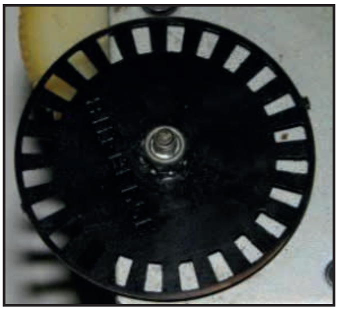

Figure 6. 24 slot encoder.

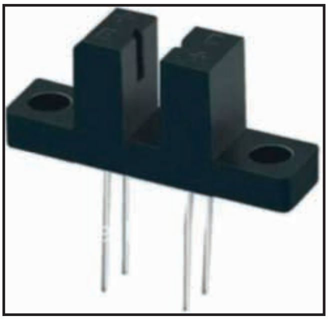

Figure 7. Horseshoe switch.

was more consistent with the measurements made, therefore the latter was used. Figures 6 and 7 show the encoder and switch used in this project; The encoder used is a 24-hole encoder, so 24 counted pulses are equivalent to 1 revolution.

To control the number of RPM to remain constant, a PID control routine was implemented in the MCU. The control of the motor can be carried out using the observer method or the classic PID (Proportional Integral Derivative) method, obtaining the motor parameters. Sometimes, the observer method is privileged because it is economical since it does not use encoders but only uses current sensors which are cheaper compared to the elements used by the classical control method. In the observer method, these are designed to estimate the electrical torque of the motor and then obtain the location of the poles. This method also uses the PI (Proportional Integral) control with the feedback of the states (Ramírez R., Valenzuela F. et. al., 2018). However, the classic PID control method was used in this project because a good part of its code was already available, it was only necessary to obtain the values of the control constants. The motor parameters to implement said routine were considered approximately (Solarte C Muñoz, 2023) since the motor data sheet was not available.

TEMPERATURE MEASUREMENT

To measure the temperature two conditions were imposed. The first, that the measurement was wireless to avoid contact between the sensor and the stirred mixture and thus not contaminate the mixture with the sensor. The second, that the measurement was permanent, i.e. let it be done at any time. To meet the first condition, a wireless sensor, the MLX90614, was used. This is a wireless digital temperature sensor that works in the range of -70 ºC to 382.2 ºC. The sensor uses IR (infra red) rays to measure temperature. This sensor communicates with an MCU through the I2C communication protocol. Table 1 shows the pin configuration.

The specifications of the MLX90614 sensor are:

- Operating voltage: 3.6 V to 5 V (available in 3 V and 5 V versions).
- Supply current: 1.5 mA.
- Object temperature range: -70° C to 382.2°C.
- Ambient temperature range: -40°C to 125°C.
- Precision: 0.02°C.
- Field of vision: 80°.
- Distance between object and sensor: 2cm-5cm (approximately).

PH MEASUREMENT

The ph measurement was carried out by the GAOHOU PH0-14 sensor; Since no wireless pH sensor was found, it was selected based on cost. Ph sensors are high in price and in short supply. There is a wide variety of ph measurement equipment but sensors alone, as such, are in short supply.

This sensor consists of a ph sensor and a signal conditioning card, thus simplifying the signal conditioning stage. The output of the sensor signal conditioning card provides a signal proportional to the measured ph value and this output can be connected to an MCU. The measuring electrode is made of glass, so it must be handled with great care as it is very fragile. Some specifications of this sensor are:

- Input voltage: 5 V.
- Output current: 5-10 mA.
- pH detection range: 0-14.
- Response time: < 5 s.

Number of the pin	Name	Description of the pin.
1	Vcc	Vcc can be used to power the sensor; typically Vcc = 5 V.
2	Land	Metal can also act as a ground.
3	SDA, serial data	Serial data pin used for the I2C protocol.
4	SCL, Serial Clock	Serial clock pin used for the I2C protocol.

Table 1. Description of the MLX90614 sensor pins.

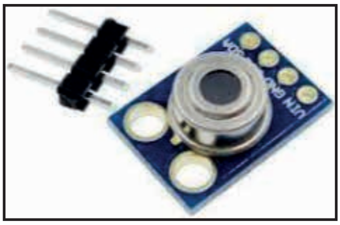

Figure 8. Sensor of temperature.

Figure 9. Sensor of ph.

Figure 10. LCD.

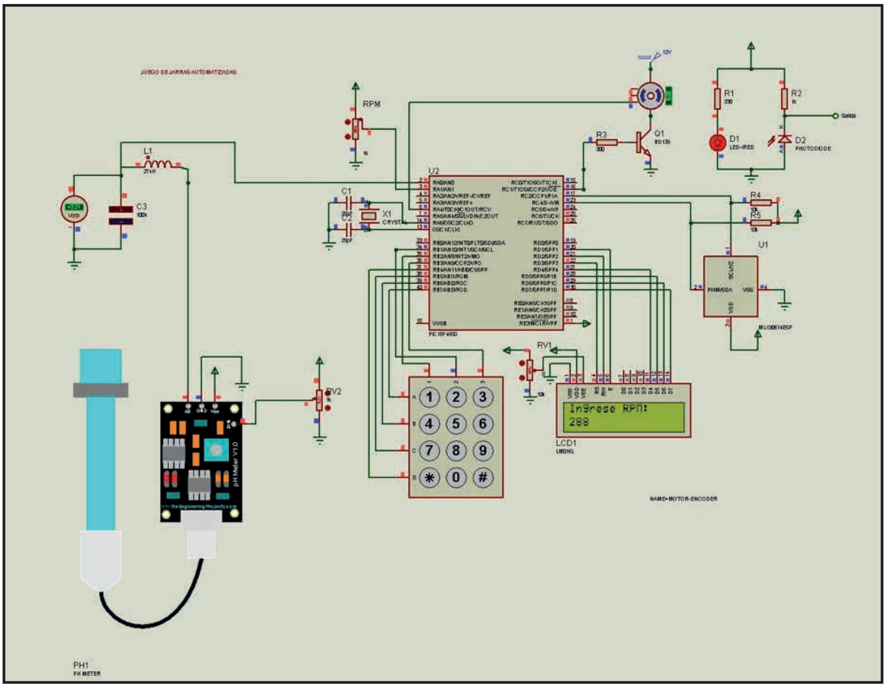

Figure 11. Equipment schematic diagram.

- Stability time: 60 s.

The ph sensor has a potentiometer to be calibrated. To calibrate the sensor, the electrode must be placed in a concentration with a known ph value and after that, turn the potentiometer knob clockwise or counterclockwise until it reaches the known ph value; then it will be calibrated.

LCD (LIQUID CRYSTAL DISPLAY)

To display both the options menu for each jar and to display the temperature and ph values, three LCDs were used; two LCDs to continuously display the RPM and stirring time of the mix and the third LCD to display the temperature and ph value.

Figures 8 and 9 show an image of the sensors used and Figure 10 the LCDs used.

ENGINES

The development of the project began with the testing of the engines. These were parameterized since their data sheet was not available. Once this stage was finished, we proceeded to write the program to manipulate the indicated RPM. The program for the control of the motors worked correctly after several tests and corrections. A PID control library was added to the program to give stability and control to the operation of both motors. The consistency stage for the RPM measurement took too long to work properly. This is partly because a set of belts and pulleys were added. The mechanical and docking part took too long to work properly. After making various adjustments to the bands and the mechanical part, the testing stage of the motors was successfully completed.

SENSORS

The program to use the temperature sensor was carried out. Since this sensor uses I2C communication, the MLX90614.c library was used. At the beginning there were some problems for the temperature measurement due to connection errors for the I2C communication, but once detected and corrected, this stage was overcome.

Regarding the ph measurement, the program for its use was also written. The pHMeterLibraryTep.hex library was used for such purposes. Several difficulties were encountered with this sensor. Its calibration at the beginning was somewhat complicated, it was difficult to stabilize its output. After manipulating the potentiometer knob for calibration, the sensor stabilized the output and from then on its use was easier.

Figure 11 shows the electrical diagram of the system and Figure 12 shows an image of the finished equipment.

USED TOOLS

As for the tools used for the development of this team were:

- CCS Compiler.
- Proteus 8.12.
- Pickit 3.

RESULTS AND DISCUSSION

After testing each stage of the equipment, it was fully integrated for its comprehensive testing. We proceeded to test the operation of the complete equipment, working the two jugs and the measurement of temperature and ph. At first the equipment worked partially and intermittently. It was detected that the problem was the false contacts that were in some connections, because everything was mounted on breadboards. Then we proceeded to generate the PCB circuit. Once said plate was available, all the elements were welded. So the equipment worked more consistently and permanently but still had some measurement errors at times. It was detected that there were some pins of some circuits that were not well soldered; these errors were corrected and finally the equipment worked correctly.

Figure 12. Team finished.

CONCLUSIONS

The automated jar equipment was successfully designed, built and tested. Various tests were carried out with the built equipment, concluding that it complied with what was required to carry out some practices. Due to the fact that the automated jug equipment was designed and manufactured in the Electronics laboratory of TecNM-ITTehuacán, it allowed costs to be significantly reduced and to solve the lack of this equipment to finally carry out practices related to said equipment.

The study program of the Chemistry area of TecNM-ITTehuacán is being explored to see in what other subjects the manufactured prototype can be used.

The circuits, sensors and actuators (motors) used for this project were affordable, considerably lowering the cost of the equipment. In addition to this, the cost per installation, preventive and corrective maintenance of the equipment, decrease considerably.

The manufacture of the different equipment necessary to carry out practices using the human and technical resources of each institution considerably reduces the costs of the equipment, positively impacting the provision of equipment for laboratory practices.

REFERENCES

Diana Marcela Fúneque. (2018). **Ensayo de jarras para el control del proceso de coagulación en el tratamiento de aguas residuales industriales**. ECAPMA, 1.

Kendra Cherry. (09 de 02 de 2022). **Very well mind**. Obtenido de verywellmind: https://www.verywellmind.com/kendra-cherry-2794702

Lorenzo Acosta Yarinis. (2020). **Sobre los derivados de la caña de azúcar**. *ICIDCA*, 3.

Ramírez R., Valenzuela F. et. al. (2018). **Control de velocidad de un motor CD basado en mediciones de corriente de armadura**. *Ingeniería Investigación y Tecnología*, 4.

Solarte C Muñoz. (25 de 01 de 2023). *http://repositorio.unicauca.edu.co*. Obtenido de Universidad del Cauca: http://repositorio.unicauca.edu.co:8080/xmlui/bitstream/handle/123456789/1488/ANEXO%20A.%20Guia%20parametrizacion%20de%20un%20motor%20DC%20de%20iman%20permanente%20.pdf?sequence=2&isAllowed=y

Tafur Bravo, L. K. (2014). **Alternativa para el tratamiento de aguas residuales cromadas con Quitosano extraído del exoesqueleto de camarón**. Bogotá: IBAGUÉ.