ARPN Journal of Engineering and Applied Sciences

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DESIGN AND IMPLEMENTATION OF A FUZZY CONTROL SYSTEM OF RELATIVE HUMIDITY AND TEMPERATURE FOR A NEONATAL INTENSIVE CARE INCUBATOR

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ABSTRACT

This project involves the design and implementation of two fuzzy logic controllers developed in a high performance microcontroller MSP430 series made by Texas Instruments. The whole system is able to monitor the status of two critical variables in the first days after birth of the preterm baby, temperature and canopy relative humidity through a remote server system in a software application designed on LabVIEW and communicated with the system wirelessly via XBee devices which use the IEEE 802.15.4 standard also known asZigBee protocol. The application developed in LabVIEW allows the storage of information in a database in MySQL. The equipment consist of an alarm module which works with both visual and sound alerts to avoid over heating or power supply malfunction.

Keywords: MSP430, fuzzy control system, ZigBee, LabVIEW.

1. INTRODUCTION

As the years passes the need to innovate invades in the minds of researchers and all those architects of humanity. The want to move forward and improve every day is no stranger to those who are part of the program of Electronic Engineering at Surcolombiana University. This is the cause to undertake such an ambitious project, the desire to venture into the use of new technologies in the field of programming and design of embedded systems.

Electronics today has reached most aspects of life, including medicine. Medicine is perhaps one of the areas of science that has most benefited from the progress that has presented the electronics field in recent decades. MRI, CT and many other imaging techniques have provided a great facility for monitoring human body without entering. The field of neonatology was no stranger to these developments; In 1880 Stephane S. Tarnier obstetrician developed the first prototype incubator, which consisted of a microenvironment that controlled the temperature inside through a double-walled tub where circulating hot water. Between 1926 and 1933 Blackfan demonstrated the importance of moisture to keep the right temperature that is why it was also needed to control this aspect [1].

It is estimated that each year 15 million preterm born children, about half of preterm infants die out of receiving simple, effective and inexpensive care, such as providing the newborn enough heat [2].

According to Dane, in 2009 in Colombia 126, 000 premature births were recorded; 23,125 in Bogota; 7, 312 in Medellin; 6, 027 in Cali; and 5, 310 in London, among others [3].

The project developed is addressed to design an electronic system for a prototype incubator to allow sensing and control of temperature and relative humidity inside the dome and is equipped with a user friendly interface for better monitoring and care newborn.

The equipment is provided with a wireless communication module, which is responsible for linking the system to a remote server for a total view of the operation of this through a visual interface developed in LabVIEW platform. It also has a set of alarms that give indication of a possible overheating of the dome.

The whole system is incorporated into a high-end microcontroller MSP430 family of ultra low power manufactured by Texas Instruments Company.

2. METHODOLOGY

The draft drawn allows measurement, fuzzy logic control and real time monitoring of the ambient temperature and relative humidity in the dome. The design consists of seven modules that work together providing adequate monitoring of the patient's environment. The block system diagram shown in Figure-1.

Figure-1. Electronic modules.

2.1 Hardware description

The electronic board has two sensors, a communications module XBeeS2 a high end MSP430F2416 microcontroller.

2.1.1 MSP430F2416 microcontroller

The MSP430F2416 microcontroller is a mixed signal that is part of the Texas Instruments MSP430 family. This microcontroller digitizes the signals delivered by the sensing modules to process Generates respective actions and Allows the display of signs such control.

2.1.2 AD590

It is responsible for the transducer to measure the temperature of the dome. The AD590 is a two terminal transducer whose operating range is comprised between -55 to 150 ° C. It has a sensitivity of 1uA / ° K and operates with supply voltages between 4 and 30 Volts.

2.1.3 HIH 4000-002

It is in charge sensor to detect humidity changes at the top. The HIH 4000- 002 has a high accuracy, a linear and fast response time and a working range from 0 to 100% within a temperature range of -40°C to 85°C.

2.1.4 XBeeS2

It's a device that supports wireless communication with the communication standard IEEE 802.15.4 or ZigBee operates with a supply voltage of 3.3V, transmission speed up to 250 Kbps and a range of 120 meters free online viewing.

2.1.5 Heating element

It is the final element of the fuzzy controller ambient temperature. It is based on a resistance heater designed to withstand up to 270 Watts of power and work to 127 VAC.

2.1.6 Humidifier

It is the final element of the fuzzy controller RH. The humidifier is based on a heater as 100,8Ω. The system has a pool of water that manages to humidifier fluid to generate steam.

2.2 Description of the software

The project code has been developed in IAR Embedded Workbench 5.30.1. This software supports programming in C language of different peripheral devices MSP430 family.

The system is equipped with a remote station that facilitates real-time monitoring of the total behavior of the system through an application developed in LabVIEW. This application is linked to the management system MySQL database to store all information regarding the patient and the values of the variables that are measured in order to allow further studies related to the behavior of the microenvironment of the neonate.

Within MSP430F2416 is included the fuzzy logic controller of the ambient temperature and relative humidity inside the dome. This control is based on the implementation of actions from the empirical knowledge of the system and not its mathematical model, which offers great advantages in developing drivers on certain systems [4].

2.2.1 Controller room temperature

To begin the design of fuzzy logic controller by the ambient temperature within the dome of the plant response to 110VAC excitation is obtained; this response is shown in Figure-2.

VOL. 10, NO. 2, FEBRUARY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

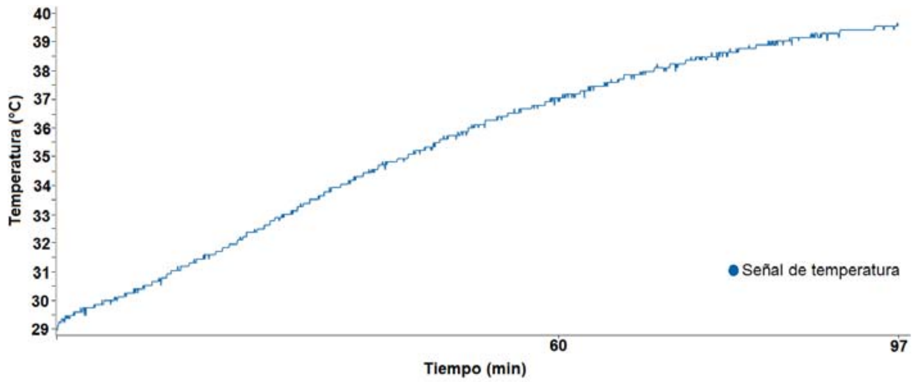

Figure-2. Temperature responses to a step 110VAC.

After learning about the behavior of the system membership functions for input fuzzy controller which is given by the difference between the measured temperature and the set point desired. It is also designed membership functions for controller outputs are determined [5, 6]. The membership functions for the input and output temperature of the fuzzy controller are shown in Figure-3 and Figure-4, respectively.

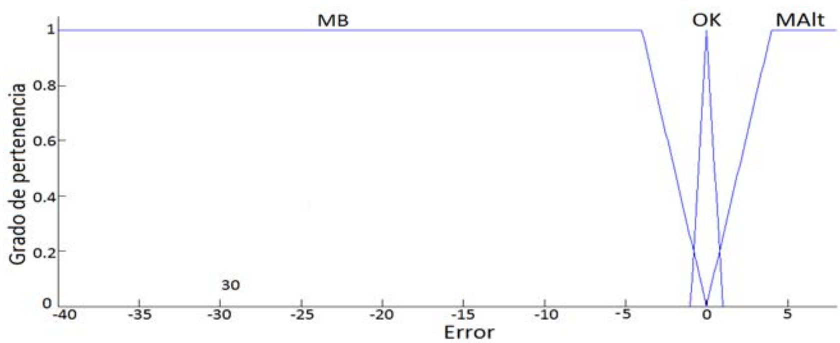

Figure-3. Membership functions for input temperature controller.

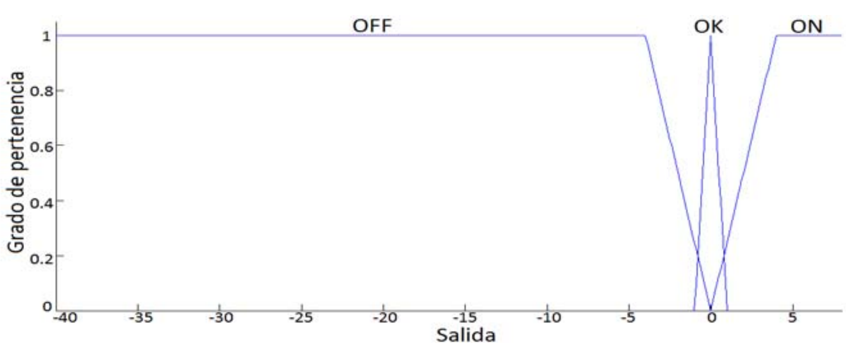

Figure-4. Membership functions for the output of the temperature controller.

With this set of membership functions for input and output of fuzzy controller rules relate both groups in order to provide a satisfactory control system are designed. The rules are set as follows:

IF (error is very low (MB) **THEN** (Power (ON))
IF (error is optimal (OK) **THEN** (Best (OK))
IF (error is very high (MALT) **THEN** (Off (OFF))

2.2.2 RH Controller

The control design to the relative humidity of the cupola is carried out following the same methodology as the room temperature control. The response of the plant with a 110VAC power is shown in Figure-5.

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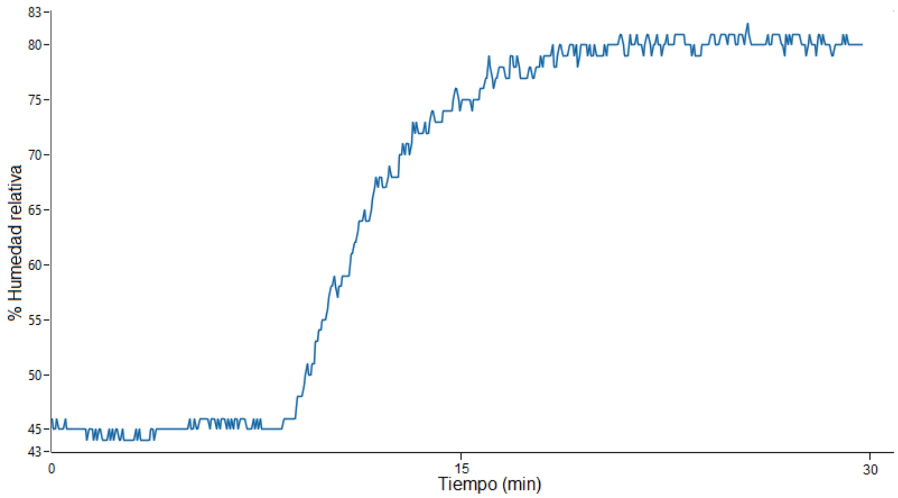

Figure-5. Relative % humidity response to step 110VAC.

Because the plant has greater relative humidity operating range and lower response time excitations, the design of this controller showed higher complexity compared to room temperature. Membership functions of the input and outputs of the controller are shown in Figure-6 and Figure-7, respectively.

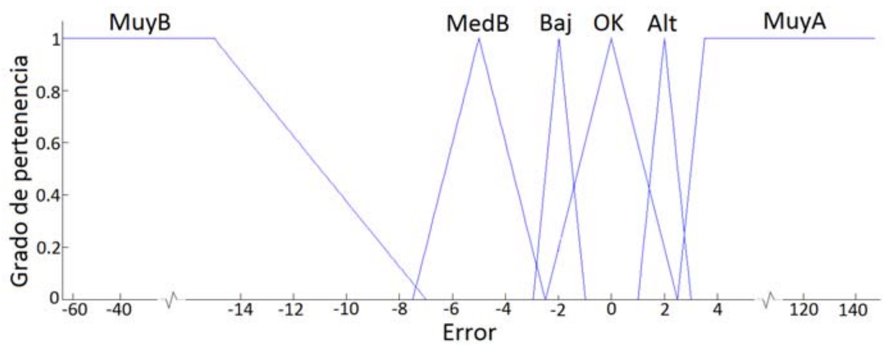

Figure-6. Membership functions for input fuzzy controller humidity.

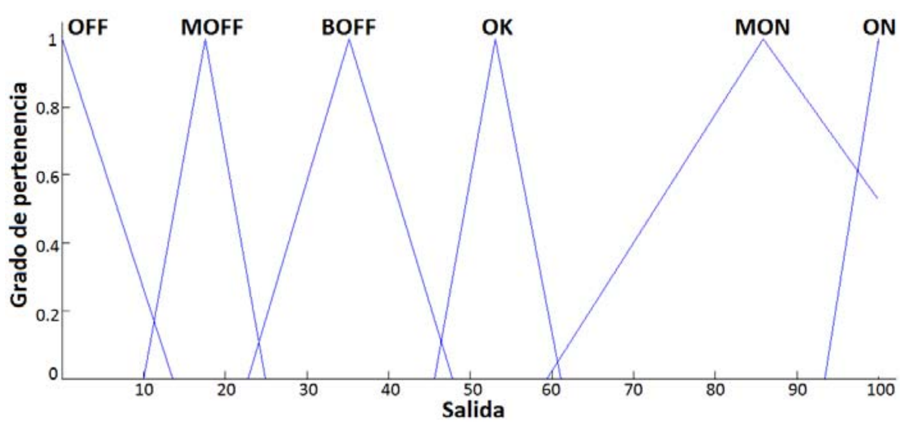

Figure-7. Membership functions for the fuzzy controller output moisture.

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The set of rules that determine the behavior of the controller were as follows:

IF (error is very low (MuyB) THEN (Off (OFF))
IF (Error is medium low (Medb) THEN (Half Off (MOFF))
IF (error is low (Low) THEN (Stop bit (BOFF))
IF (error is optimal (OK) THEN (Best (OK))
IF (error is high (H) THEN (Middle turn (MON))
IF (error is very high (Muya) THEN (Power (ON))

3. RESULTS

3.1 Fuzzy controllers

Fuzzy two controllers, one for ambient temperature and one for the relative humidity inside the dome design.

Temperature control provides full management microenvironment level. The temperature characteristics and transient and steady state system response to four different set points are displayed in Table-1 and Figure-9, respectively.

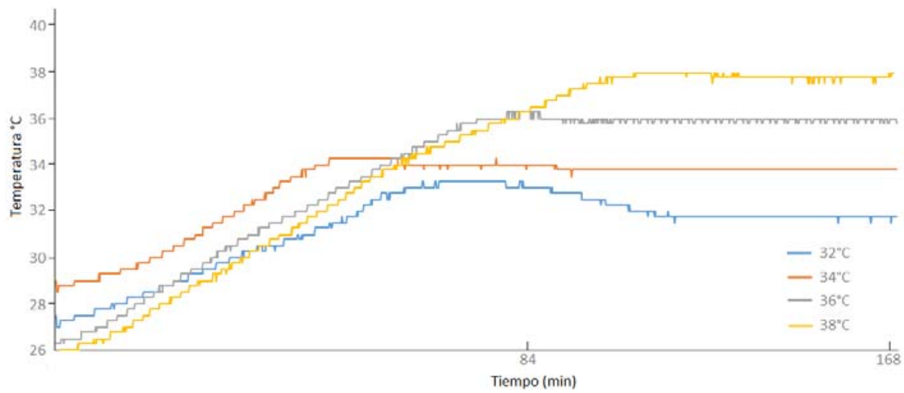

Figure-9. Results of temperature fuzzy control.

Table-1. Results of temperature monitoring diffuse.

N ° Proof	Set point (°C)	Settling time (sec)	Steady state error	Overshoot
1	32	5840	0,4%	2,6%
2	34	3192	0,4%	0,6%
3	36	4976	0,4%	0,6%
4	38	6608	0,4%	0%

The temperature tests are performed with four set points that provide insight controller operation throughout the operating range of the system. Table-1 shows that the settling time of the system is greatly reduced in test No. 1, 2 and 3 in respect of the system response without controller overshoot. It is never greater than 2.6%, which prevents damage the neonate by undesired temperatures and steady-state error is 0.4% which is equivalent to 0.2° C, which means that the system will maintain the desired temperature satisfactorily. As described above ensures that the infant is protected against possible changes in temperature within the microenvironment.

Furthermore, control of relative humidity inside the dome was also successful. The results obtained are presented in Table-2 and Figure-10.

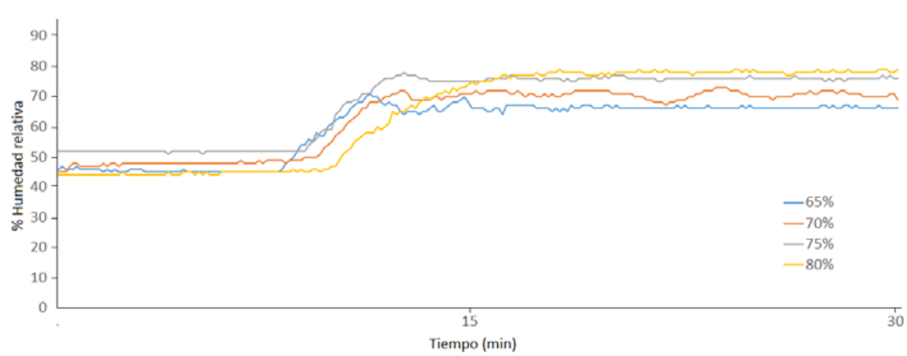

Figure-10. Results fuzzy control of relative humidity.

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Table-2. Results fuzzy control of relative humidity.

N ° Proof	Set point (% RH)	Settling time (sec)	steady state error	Delay (sec)	Overshoot
1	65	888	2%	472	15%
2	70	736	3%	520	2%
3	75	784	2%	528	3%
4	80	1048	3%	576	0%

Analyzing Table-2, which shows the results of the data obtained by performing four tests with fuzzy controller humidity over the range that this has concluded that the design of the driver was successful, given that the plant reached the sets points allowed, the steady-state error did not exceed 3% and the settling time decreased in all cases compared to the response of the plant without the controller, which is shown in Figure-5. sobreimpulsoalcanza 15% test No. 1 because control moderately high power delivery, thereby generating significant overshoot in the lower point September 70% relative humidity at the same time ensuring greater reach desired levels to 70%.

3.3 GUI

The system can be displayed by a computer at a remote station and observed through the application developed in LabVIEW where additionally all the information is stored in a database managed by MySQL. This allows us to observe the sensed values of the two variables (temperature and relative humidity dome) and the values of the sets pointsy also has visual alarm if unwanted environmental temperature values.

The application developed in LabVIEW is constituted by two windows, the panel for monitoring and recording the panel that can be seen in Figure-12 and Figure-13 respectively. The registration panel allows data entry of new patients, patients display have been entered into the dome and the information processed by the system variables, this in order to conduct further studies related to the behavior of the environment within the dome.

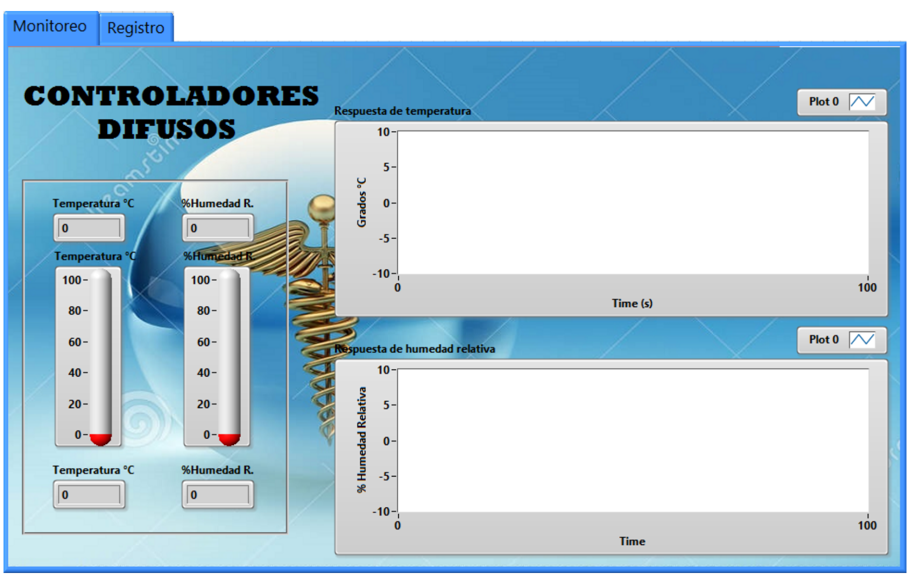

Figure 12. Monitoring panel.

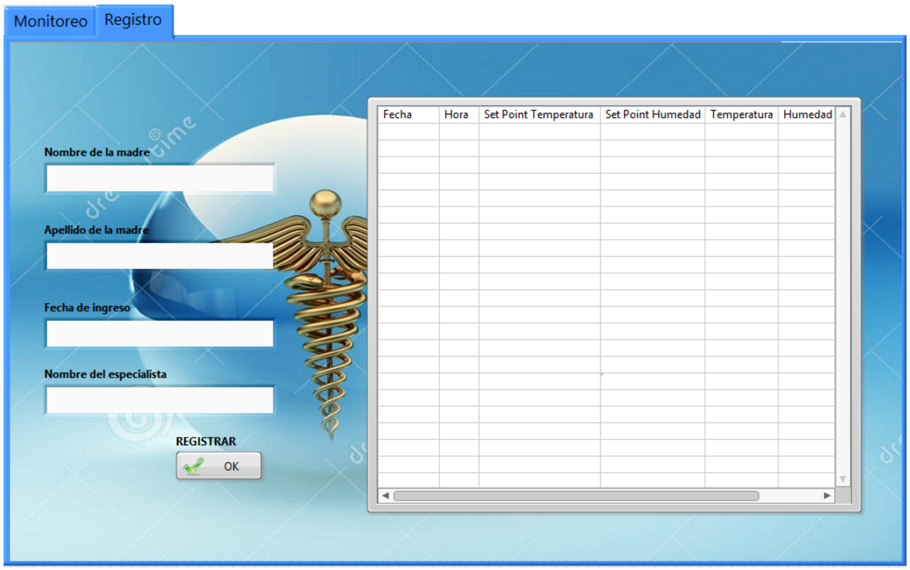

Figure-13. Panel registration.

4. CONCLUSION

A system for real-time monitoring of the ambient temperature and relative humidity, in addition to control by fuzzy logic of the two signals are successfully prepared.

Applications with high-end microcontrollers that provide the advantages of high speed, greater storage capacity and number of peripheral modules over the use of other microcontrollers, advantages that create higher quality projects and complexity were developed.

Using fuzzy logic controllers for the development of plants whose mathematical model is unknown but it understands their behavior is very efficient.

A database in MySQL that stores all information in the process of being useful for further analysis and studies on the behavior of the system where the infant was created.

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