Fuzzy Logic Based Dryer Controller

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Abstract

The relative humidity sensor changes its capacitance with the humidity. The humidity sensing circuit is constructed around a 555 timer with astable operation. It produces a rectangular wave. In order to achieve the perfectively symmetrical square wave as well as to reduce the frequency value, CD4017BC that is divided by 10 Johnson counter with 10 decoded outputs and a carry out bit is added to the timer's output. The resultant frequency is applied into the computer system integrating with the fuzzy logic. Fuzzy Logic determines the frequency value and its rate of change which are input to the fuzzy logic control system that determines the real world constraint of the dryer's heating rate to the dryer driver circuit which is constructed with the pulse width modulation (PWM) technique. Input and output operations to and from the computer system are carried out via parallel interfacing and Turbo C++ programming.

1. Introduction

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem.

Fuzzy logic allows for set membership values between 0 and 1, shades of gray as well as black and white, and in its linguistic form, imprecise concepts like "slightly", "quite" and "very". A fuzzy system is formed of output and input variables. For each variable, fuzzy set that characterize those variables are formulated, and for each fuzzy set a membership function is built. After that, the rules that relate the output and input 2variables to their respective fuzzy sets are defined. The computational evaluation of a fuzzy system is formed of fuzzification(construction of output variables that define the study), inference(fuzzy reasoning application on fuzzy output) and defuzzification (translation of linguistic value to numerical value).

Basically, there are certain difficulties in modeling and simulating complex real-world systems for control systems development. Fuzzy control provides a formal methodology for representing, manipulating and implementing a human's heuristic knowledge about how to control a system. This thesis tries to develop a moisture control system using fuzzy logic system to control the heating rate [1].

2. Background theory

2.1. General fuzzy system

Fuzzy controller is composed of the following four elements:

1. A rule-base (a set of If-Then rules), which contains a fuzzy logic quantification of the expert's linguistic description of how to achieve good control.
2. An inference mechanism (also called an "inference engine" or "fuzzy inference" module), which emulates the expert's decision making in interpreting and applying knowledge about how best to control the plant.
3. A fuzzification interface, which converts controller inputs into information that the inference mechanism can easily use to activate and apply rules.
4. A defuzzification interface, which converts the conclusions of the inference mechanism into actual inputs for the process[2].

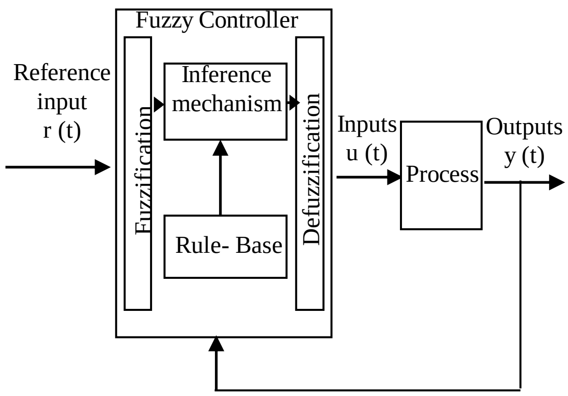


Figure 1. Fuzzy controller

2.2. Membership value assignment for moisture value

To construct the membership functions for current moisture values are partitioned into eight levels to fit for the inputs membership functions. These values are categorized into four membership functions; Very Small (VS), Small (S), Medium (M) and Large (L). The VS membership function defines value 0 has fuzzy value '1', value 1 has fuzzy value '0.5' and all other voltages have fuzzy value zeros, and other membership functions as well.

The membership functions for moisture value are graphically represented in Figure 2. In this graph, the x-axis represents the moisture value and the y-axis represents the corresponding fuzzy values according to the relative membership functions.

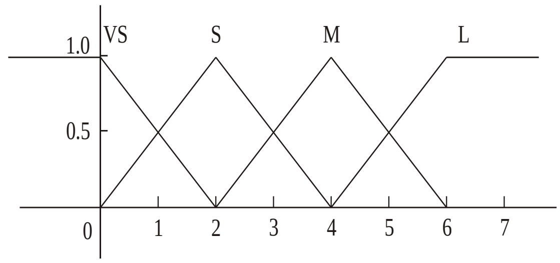


Figure 2. Membership function of moisture value

2.3. Membership value assignment for moisture's rate of change

All the membership functions categorizing moisture's rate of change with corresponding fuzzy values graphically represented in Figure 3.

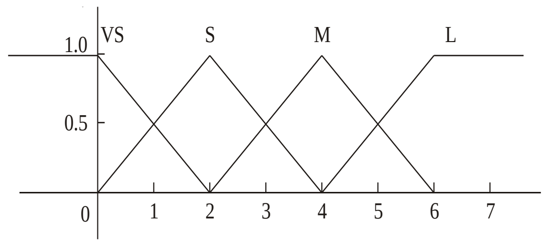


Figure 3. Membership function of moisture's rate of change

2.4. Membership value assignment for duration of path

The fuzzy logic outputs determining the width of the pulse have to control the speed of the heater. The membership functions of the durations of the pulse have to categorize the durations for both positive and negative values. All the membership functions for the fuzzy output (duration of pulse) with corresponding fuzzy values are graphically represented in Figure 4.

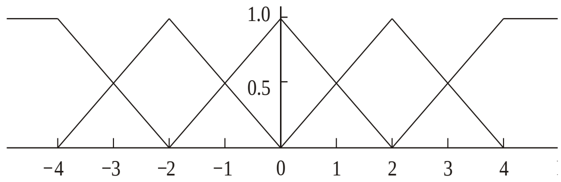


Figure 4. Membership function of duration of path

2.5. FAM table of the system

The fuzzy logic of the system contains two fuzzy inputs (moisture value and its rate of change) and one fuzzy output (duration of the pulse). The two fuzzy inputs are partitioned into four membership functions and the fuzzy output is partitioned into five membership functions. To fit for this situation, the fuzzy associative memories (FAM) table is designed as in Table 4. The input membership functions are taken as input of the FAM table and the output of the FAM table is partitioned into five regions; Fast Big (FB), Fast (F), Zero (Z), Slow (S) and Slow Big (SB).

Table 1. Fuzzy Associated Memories (FAMs) table of the system

	VS	S	M	L
VS	Z	F	FB	FB
S	S	Z	F	FB
M	SB	S	Z	F
L	SB	SB	S	Z

2.6. Example calculation

As the condition of moisture and its rate of change are 1 and 3 respectively, the fuzzy output, the duration of pulse, can be computed as follows: First of all, the two voltages are fuzzified to get the corresponding fuzzy values with respect to the membership functions concerned. Then according to the rule base (FAM table) together with the inference mechanism (Max-Min), output membership function together with the output fuzzy value, is obtained. This output is defuzzified and the direction and duration of pulse to drive the DC motor is achieved.

Initial Moisture Value = $V_1 = 1$

Initial Rate of Change = $V_1 = 3$

The duration of pulse width is to be computed.

V_1 fires VS at (0.5) and S at (0.5)
V_2 fires S at (0.5) and M at (0.5)

According to the FAM table, the fuzzy values must be plotted on the output membership function.
If V_1 = VS (0.5) and V_2 = S (0.5) then
Output P = S (0.5)
If V_1 = VS (0.5) and V_2 = M (0.5) then
Output P = SB (0.5)
If V_1 = S (0.5) and V_2 = S (0.5)
then Output P = Z (0.5)
If V_1 = S (0.5) and V_2 = M (0.5)
then Output P = S (0.5)
By the centroid method;

$$P = z^* = \frac{\int \mu_{\underset{\sim}{C}}(z) * z dz}{\int \mu_{\underset{\sim}{C}}(z) dz} \quad (1)$$

$$P = \frac{\int_{-4}^{4} -3*0.5*0.5(2+1) - 2*0.5*0.5(4+2) - 2*0.5*0.5(4+2) + 0*0.5*0.5(4+2)}{\int_{-4}^{4} 0.5*0.5(3) + 0.5*0.5(6) + 0.5*0.5(6) + 0.5*0.5(6)}$$

$$P = \frac{-8.25}{5.25}$$

$P = -1.57$ ms

From the above calculation, it is found that fuzzy output for the duration of the pulse has a level of 1.57 ms.

Table 2. All possible output values

V_1 \ V_2	1	2	3	4	5	6	7
1	0	1	1.57	2.33	2.6	3	3
2	-1	0	1	1.57	2.33	2.6	3
3	-1.57	-1	0	1	1.57	2.33	2.6
4	-2.33	-1.57	-1	0	1	1.57	2.33
5	-2.6	-2.33	-1.57	-1	0	1	1.57
6	-3	-2.6	-2.3	-1.57	-1	0	1
7	-3	-3	-2.6	-2.33	-1.57	-1	0

Table 3. Fuzzy output and corresponding pulse width

Fuzzy Output	Active Width (ms)	Inactive Width (ms)	Direction	Duty Cycle	Waveform
0	30	120	Alternate	20%	
1	50	100	Up to the sign bit	33%	
1.57	78.5	71.6	Up to the sign bit	52%	
2.33	116.5	33.5	Up to the sign bit	77%	
2.6	130	20	Up to the sign bit	86%	
3	150	0	Up to the sign bit	100%	

3. System Implementation

3.1. Relative Humidity Sensor

Based on a unique capacitive cell, these relative humidity sensors are designed for high volume, cost sensitive applications such as office automation, automotive cabin air control, home appliances, and industrial process control systems. They are also useful in all applications where humidity compensation is needed [4].

3.2. Astable Operation of 555 Timer

The device is connected for astable operation as illustrated in Figure 5. The timing resistor is now split into two resistors, R_a and R_b, with the discharge transistor (pin 7) connected to the junction of R_a and R_b. When the power supply is connected, the timing capacitor C charges towards 2/3 Vcc through R_a and R_b. When the capacitor voltage reaches 2/3 Vcc, the upper comparator triggers the flip-flop and the capacitor starts to discharge towards ground through R_b. When the discharge reaches 1/3 Vcc, the lower comparator is triggered and a new cycle is started.

The capacitor is then periodically charged and discharged between 2/3 and 1/3 Vcc respectively. The output state is HIGH during the charging cycle for a time period t_1, so that

$$t_1 = 0.693 (R_a + R_b) C \quad (2)$$

The output state is LOW during the discharge cycle for a time period t_2 is given by

$$t_2 = 0.693 R_b C \quad (3)$$

Thus, the total period charge and discharge is

$$T = t_1 + t_2 \quad (4)$$
$$= 0.693 (R_a + R_b) C \quad \text{(seconds)}$$

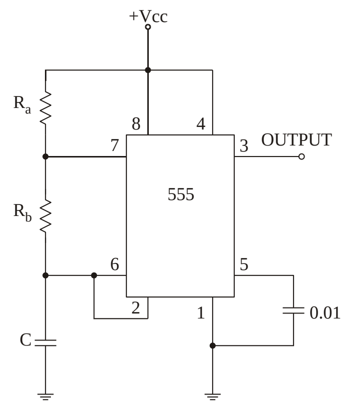
So that the output frequency is given as

$$f = 1/T = \frac{1.443}{(R_a + 2R_b)C} \quad (5)$$

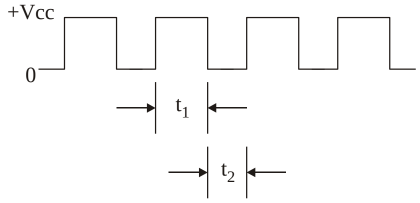
The duty cycle D of a recurring output is defined as the ratio of the HIGH time to the total cycle,

$$D = \frac{t_1}{T} = \frac{R_a + R_b}{R_a + 2R_b} \qquad (6)$$

Thus, by making R_b large with respect to R_a, a symmetrical square wave with a duty cycle of almost 50% can be obtained.[3].



(a) Charging period



(b) Charging period

Figure 5. The 555 timer connected for astable operation

3.3. CMOS IC for frequency division

One of the application of a flip-flop is diving (reducing) the frequency of a periodic waveform. When a pulse waveform is applied to the clock input of 4017 IC, the counter counts up. The 4017 is a 5 stages divided-by-10 Johnson counter with 10 decoded outputs and a carry out bit.

This counter and divider is cleared to their zero count by a logical "1" on their result line. This counter is advanced on the positive edge of the clock signal when the clock enable signal is in the logical "0" state[5].

3.4. Membership value assignment for moisture value

To construct the membership functions for current moisture values are partitioned into eight levels to fit for the inputs membership functions. These values are categorized into four membership functions; Very Small (VS), Small (S), Medium (M) and Large (L). The VS membership function defines value 0 has fuzzy value '1', value 1 has fuzzy value '0.5' and all other voltages have fuzzy value zeros, and other membership functions as well. All the membership functions categorizing the moisture values with corresponding fuzzy values are summarized in Table 4.

Table 4. Membership value for moisture value

Membership Functions	Moisture Value							
	0	1	2	3	4	5	6	7
Very Small (VS)	1	0.5	0	0	0	0	0	0
Small (S)	0	0.5	1	0.5	0	0	0	0
Medium (M)	0	0	0	0.5	1	0.5	0	0
Large (L)	0	0	0	0	0	0.5	1	1

3.5. Membership value assignment for moisture's rate of change

All the membership functions categorizing moisture's rate of change with corresponding fuzzy values are summarized in Table 5.

Table 5. Membership values for moisture's rate of change

Membership Functions	Moisture's Rate of Change							
	0	1	2	3	4	5	6	7
Very Small (VS)	1	0.5	0	0	0	0	0	0
Small (S)	0	0.5	1	0.5	0	0	0	0
Medium (M)	0	0	0	0.5	1	0.5	0	0
Large (L)	0	0	0	0	0	0.5	1	1

3.6. Membership value assignment for duration of path

The fuzzy logic outputs determining the width of the pulse have to control the speed of the heater. The membership functions of the durations of the pulse have to categorize the durations for both positive and negative values. All the membership functions for the fuzzy output (duration of pulse) with corresponding fuzzy values are summarized in Table 6.

Table 6. Membership value for duration of path

Member-ship	Durations of Pulse								
	-4	-3	-2	-1	0	1	2	3	4
Left Big (LB)	1	0.5	0	0	0	0	0	0	0
Left (L)	0	0.5	1	0.5	0	0	0	0	0
Zero (Z)	0	0	0	0.5	1	0.5	0	0	0
Right (R)	0	0	0	0	0	0.5	1	0.5	0
Right Big (RB)	0	0	0	0	0	0	0	0.5	1

3.7. Microcontroller

A microcontroller can be viewed as a set of digital logic circuits integrated on signal silicon 'chip'. The great advantage of this is that in order to change the circuit's structure and operation, all that is needed is a change in the program very little, if any, circuit hardware modifications are necessary.

PIC microcontrollers are produced by microchip and it can be divided into three types:

1. Baseline
2. Mid-range
3. High performance

PIC16F628A (mid-range microcontroller types) is chosen for Computer Control Voice System because the system requirements is enough and the cost of mid range microcontrollers is low in comparison with high performance microcontroller.

The PIC16F628A is 18-pin Flash-based members of the versatile PIC16F627A/628A/648A family of low-cost, high-performance, CMOS, fully static, 8-bit microcontrollers. All PIC microcontrollers employ an advanced RISC architecture. The PIC16F628A has enhanced core features, an eight-level deep stack, and multiple internal and external interrupt sources. The separate instruction and data buses allow a 14-bit wide instruction word with the separate 8-bit wide data[6].

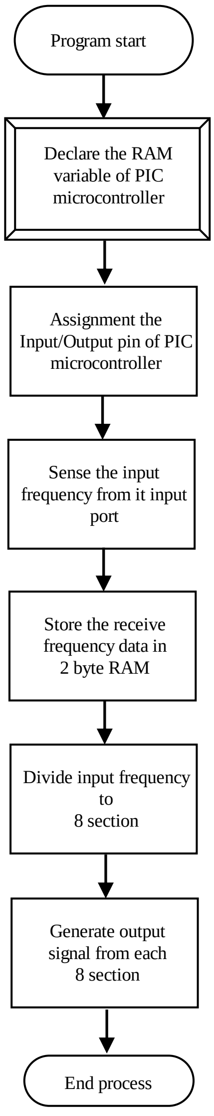


Figure 6. The flow chart of frequency sensing

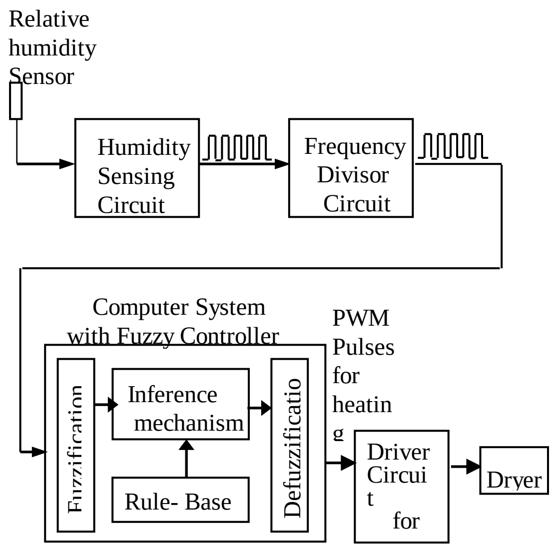


Figure7. Block diagram of fuzzy logic dryer controller

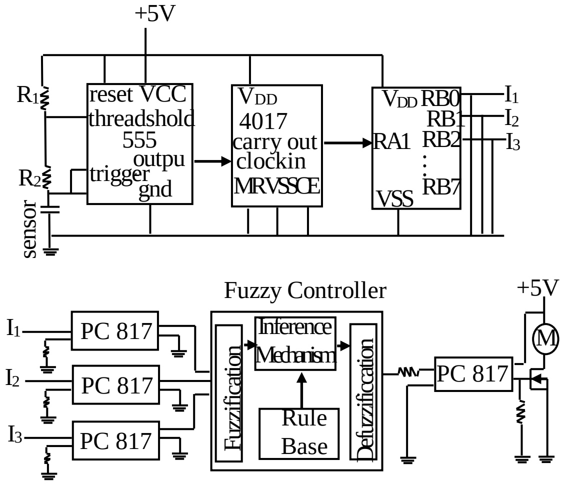


Figure **8.** Complete circuit diagram of the system

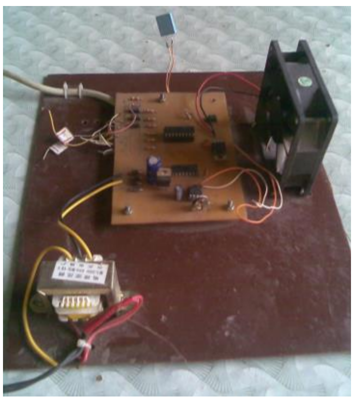


Figure 9. Real complete circuit

4. Conclusion

Drying system with fuzzy logic has some advantages such as the intellectualization level and the low power consumption then the system without fuzzy logic.

The fuzzy System, including fuzzy logic and fuzzy set theory, provide a rich and meaningful addition to logic. The mathematics generated by these theories is consistent, and fuzzy logic may be a generalization standard of classic logic. Many systems may be modeled, simulated, and even replicated with the help of fuzzy system, not the least of which is human reasoning itself.

In this system, there are only eight different values for moisture values and its rate of changes. These eight value levels are partitioned into four membership functions, the fuzzy values assigned are limited, only three different fuzzy values, 0, 0.5 and 1 which are limited.

There are only five membership functions of the duration of the pulse. Only three different fuzzy values assigned to the nine different durations partitioned with five output membership functions become restricted.

When all the possible combinations of different values are calculated, it is found that there are only six different fuzzy outputs.

The FAM table's entries, membership functions partitioning the output durations of the pulse can also be extended for the future analysis of the system. Such extended system can be said to have more fuzzy features.

The DC motor applied in this system's prototype has a small toque and cannot start to rotate instantly with the small duration driving pulse.

DC motor used to blow the heater must be a heavy duty, high toque DC motors. The pulse width modulation (PWM) DC motor driver circuit must also be adapted to be suited with such DC motors.

5. References

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