**Step 4: Fuzzy Logic Controller**

Develop a fuzzy logic Controller to control the motor (Fan) speed. The Controller should use the temperature (TEMP) and light intensity (LI) as inputs and should return the pulse width needed to drive the fan motor to the required speed. Then determine the 3-dimensional surface control surface.

LM34  
10mV/oF

+5V

Gain  
=?

0.4V-2.9V (SE3)

0v – 1V (Nexys4)

60 oF-135 oF

+5V

Dark to Very Bright

0.4V-2.9V (SE3)

0v – 1V (Nexys4)

8

pw

Controller

Binary to BCD  
Converter

Character  
Generator

VL

12

ADC

8

8

T

L

8

8

S

L

VT

12

12

DT

DL

DPW

8

W

LCDI

dataout

control

4

3

DIN

5

ADD

clk

PWM  
Generator

PWM

Speed  
Meter

8

T

filter

pe

w

clk

clk

12

DS

**Fuzzification**

Fuzzification calculates degree of membership for each input versus each relevant membership function. The temperature range is 50 degree Fahrenheit to 150 degree Fahrenheit (mapped to 0 to 255)

255

0

0

255

45

127

145

hot

Temperature (T)

warm

cold

µ

191

63

109

209

255

0

0

45

127

145

bright

normal

dim

µ

191

63

109

209

Light Intensity

255

**Fuzzy Inference (Rule Evaluation)**

Fuzzy Rule Evaluation applies these degrees of membership to the rules and derives fuzzy output values  
using the minimum/maximum strategy. To evaluate a rule the degree of membership for the inputs are compared and the lowest degree of membership is picked. This value is then compared with the corresponding output; if it is larger than it then it should replace the output value.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Light Intensity | | |
|  |  | bright | normal | dim |
| temperature | hot | Blast Rule1 | Blast Rule2 | Fast Rule3 |
| warm | Fast Rule4 | Medium Rule5 | Slow Rule6 |
| cold | Slow Rule7 | Stop Rule8 | Stop Rule9 |

**3.3. De-fuzzification**

A designer can specify the output membership functions with trapezoidal or triangle shapes. However  
this complicates the calculations using the center of gravity (COG) method. To simplify these calculations, the output membership functions can be specified as singletons. The output can be calculated as the singletons’ weighted average.

64  
26

pw

stop

slow

medium

blast

fast

255

128  
27

192  
26+27

255  
28-1

µ

1



Use the speed- pw graph obtained in the previous step to locate your five singletons.

L

Degree of membership

DMdim

DMnorm

DMbright

8

8

8

8

T

Degree of membership

DMcold

DMwarm

DMhot

8

8

8

8

coldR 🡨DMcold,  
warmR 🡨DMwarm,  
hotR 🡨DMhot,  
dimR 🡨DMdim,  
normR 🡨DMnorm,  
brightR 🡨DMbright

Cs0

Cs1

hotR<brightR

Rule1🡨 hotR

Rule1🡨 brightR

yes

no

Cs2

hotR<normR

Rule2🡨 hotR

Rule2🡨 normR

yes

no

Cs3

hotR<dimR

Rule3🡨 hotR

Rule3🡨 dimR

yes

no

Cs4

warmR<brightR

Rule4🡨 warmR

Rule4🡨 brightR

yes

no

Cs5

warmR<normR

Rule5🡨 warmtR

Rule5🡨 normR

yes

no

Cs6

warmR<dimR

Rule6🡨 warmR

Rule6🡨 dimR

yes

no

Cs7

coldR<brightR

Rule7🡨 coldR

Rule7🡨 brightR

yes

no

Cs8

coldR<normR

Rule8🡨 coldR

Rule8🡨 normR

yes

no

Cs9

coldR<dimR

Rule9🡨 coldR

Rule9🡨 dimR

yes

no

hotR<brightR

Rule1🡨 hotR

Rule1🡨 brightR

hotR<normR

Rule2🡨 hotR

Rule2🡨 normR

hotR<dimR

Rule3🡨 hotR

Rule3🡨 dimR

medium 🡨 Rule5

Cs10

Rule1>Rule2

blast 🡨 rule1

blast🡨 Rule2

yes

no

Cs11

Rule3>Rule4

fast 🡨 Rule3

fast 🡨 Rule4

yes

no

Cs12

Rule6>Rule7

slow 🡨 Rule6

slow 🡨 Rule7

yes

no

Cs13

Rule8>Rule9

stop 🡨 Rule8

stop 🡨 Rule9

yes

no

Den 🡨 stop+slow+medium+fast+blast  
Num 🡨 stop+(slow<<6)+(medium<<7)+(fast<<6)+(fast<<7)+(blast<<8)-blast  
pwt 🡨 0, TSC 🡨 HSEC

Cs14

Cs15

Num < Den

Cs16

0

1

TSC > 0

1

0

TSC > 0

TSC > 0

**PreLab:**

1. Write the Verilog code of the Fuzzy Logic Controller
2. Write the necessary Test Fixture code to simulate this subsystem

**Lab:**

1. Complete the system Verilog code.
2. Implement your design
3. Test your system using variable voltage sources for VT and VL.
4. Plot the measured control surface

**Step 5:** Closed Response

1. Design the two transducer signals conditioning circuits.
2. Implement the two conditioning circuit and feed them into the system.
3. Test your system.
4. Demonstrate your project.