

## Fuzzy Controller Design of Lighting Control System By Using VI Package

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### ABSTRACT

This paper describes how we design a lighting control system including hardware and software. The control circuit applies reed relay in digital control way to adjust the variable resistor value of the traditional dimmer. Software incorporates LABVIEW graphical programming language and MATLAB Fuzzy Logic Toolbox to design the light fuzzy controller. The rule-base of the fuzzy logic controller either for the single input single output (SISO) system or the double inputs single output (DISO) system is developed and compared based on the operation of the bulb and the light sensor. The control system can dim the bulb automatically according to the environmental light. It can be applied to many fields such as control of streetlights and lighting control of car's headlights and it is possible to save energy by dimming the bulb. Experimental results show that the fuzzy controller with the DISO system can make bulb response faster than with the SISO system under sudden change of environmental light.

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## 1. INTRODUCTION

After Lotfi Zadeh had introduced the fuzzy logic in 1965, the fuzzy control method is extensively used since it has the advantage of being model-free without any a priori information required. It is easy to design a fuzzy control system with requisite knowledge and the experience of a skilled operator. Many issues focus on determining fuzzy control rules, membership functions, and structures of fuzzy controllers [2, 4, 6]. Various ways of fuzzy logic used to improve industrial control [5] and methodology to reduce the number of variables.

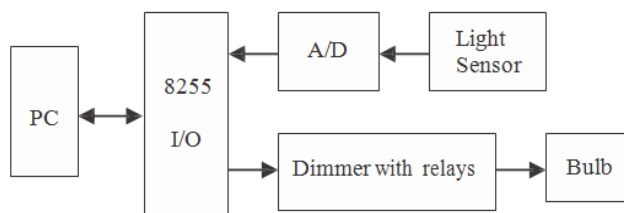


Figure 1. The block diagram of the proposed lighting control system

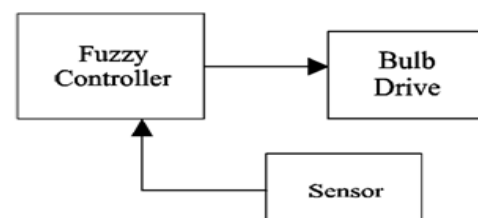


Figure 2. The fuzzy control scheme.

The application of fuzzy logic in lighting control has been presented in a number of papers. For example, it is possible to save energy by dimming the bulb or the fluorescent lamp. Dimming of the

fluorescent lamp can be done by changing the input frequency of the electronic ballast [1]. A microprocessor-based intelligent control device for streetlight control applying fuzzy decision theory to distinguish various interferences accurately and to make it operate reliably, which can turn on or off the transformer automatically according to environmental light [7].

Section II introduces the proposed lighting control system including hardware design. One of the important problems involved with the design of fuzzy logic controllers is the development of fuzzy if-then rules for fuzzy controllers. Section III presents the design method of fuzzy logic controllers. The experimental results and discussions are shown in Section IV.

**2. SYSTEM DESCRIPTION**

The block diagram of the proposed lighting control system is shown in Figure 1, which can be represented by a simple form like Figure 2. The 8255 I/O shown in Figure 1 is the expanding I/O circuit of a PC printer port. Originally, only 8-bit I/O in PC printer port can be used. After the 8255 expanding I/O circuit shown in Figure 3 had been established, we have 24-bit I/O available now. The bulb drive shown in Figure 2 is basically composed of a dimmer with 6 reed relays, and its corresponding hardware circuit is shown in Figure 4. The reed relays in the bulb drive are regarded to as digital outputs of the light control system, thus the D/A converter is unnecessary for our case. One more thing need to be done is to design a parallel set of resistor circuit work as the function of the variable resistor in the dimmer.

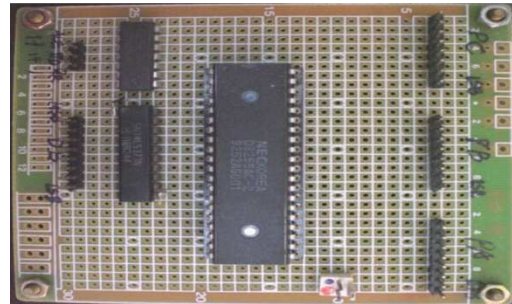
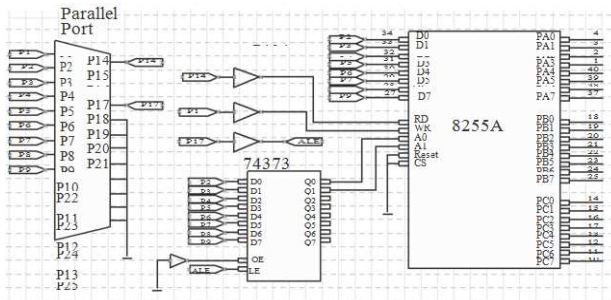


Figure 3. The 8255 expanding I/O circuit connected with a PC printer port

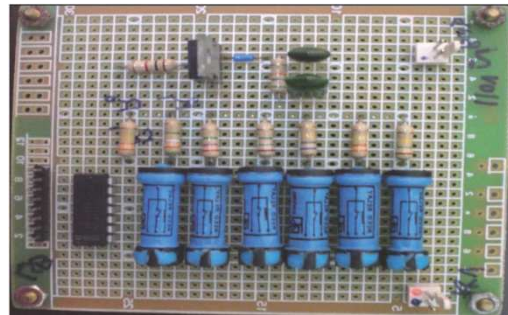
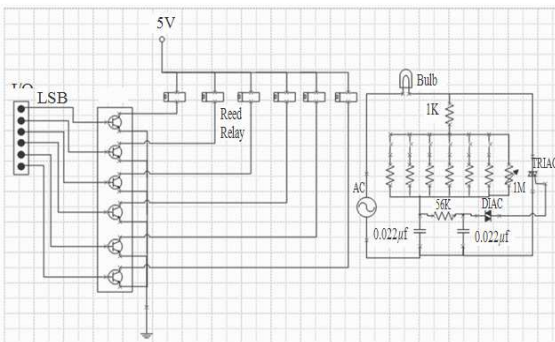


Figure 4. The control circuit of the system

The main objective of designing a parallel-resistor circuit is to make the total resistance decreases homogeneously with the increase of the DN value of the control output. Figure 5 shows the hardware layout of the parallel-resistor circuit, and it stands for one of the many possible solutions as long as the above requirement (homogeneously decreasing) can be met. The simulation result of the total resistance versus control output is shown in Figure 6. The sensor block in Figure 2 corresponds to the combination of A/D block and the Light sensor block, its hardware circuit is shown in Figure 7, which contains photo-resistor CdS sensor and an 8-bit A/D converter and LED displaying circuit. Consequently, the hardware layout of the lighting control system is shown in Figure 8. After all the hardware works had been done, subsequently, our goal is to design a FLC used to dim the bulb according to the environmental light.

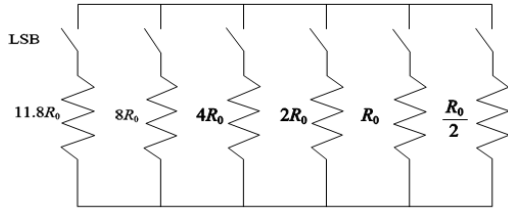


Figure 5. The hardware layout of the parallel-resistor circuit ( $R_0 = 330\text{ K}\Omega$ )

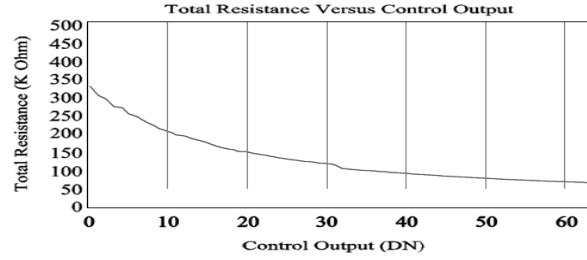


Figure 6. Total resistance versus control output (DN: 0~63)

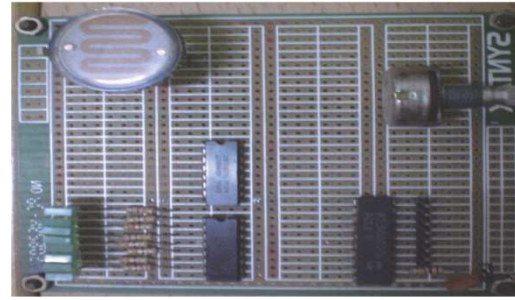
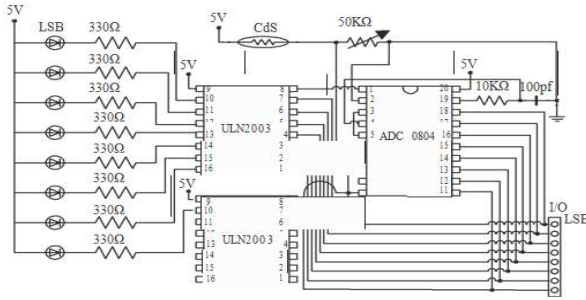


Figure 7. The sensing circuit of the system

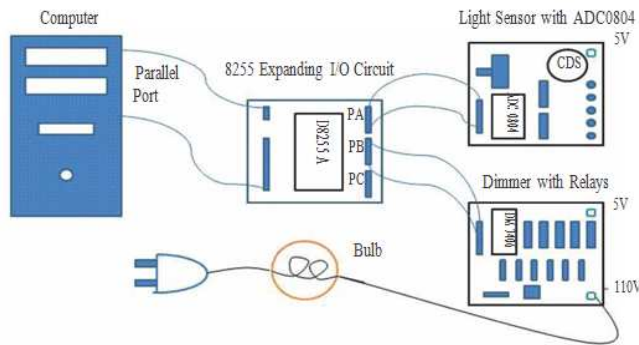


Figure 8. The hardware layout of the lighting control system

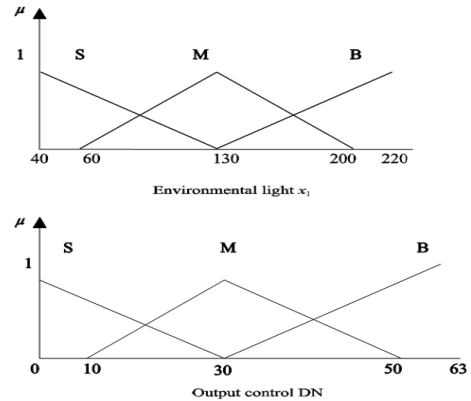


Figure 9. Fuzzy sets showing the input and the output of the SISO system

### 3. FUZZY LOGIC CONTROLLER

In this paper, the single input single output (SISO) system and the double inputs single output (DISO) system are discussed. The environmental light is used as input variable  $x_1$  for the SISO system; while another input variable  $x_2$  (the changing rate of the environmental light) is considered for the DISO system. The output variable is the numerical value DN to the output circuit. The input variables are fuzzified by assigning them a singleton fuzzy set, i.e. a set with membership function  $\mu$  and zero elsewhere. The fuzzy set of the output variable is inferred by the max-min composition and the fuzzy relation describes the desired control action. The fuzzy set of the output variable is defuzzified to deliver a crisp numerical value by the center-of-gravity method. The fuzzy rule base consists of a collection of fuzzy IF-THEN rules of the form.

$$R^{(k)}: \text{IF } x_1 \text{ is } F^k \text{ and } x_2 \text{ is } G^k, \text{ THEN } y \text{ is } G^k, \text{ for } k = 1, 2, \dots, n \tag{1}$$

Where  $x_1, x_2 \in U$ , and  $y \in R$  are the input and output of the fuzzy sets in  $U_1, U_2$  and  $R$  representing the  $k^{th}$  antecedent pairs and consequent pair respectively and  $n$  is the number of rules.

The SISO system and the DISO system will be discussed and analyzed by using MATLAB Fuzzy Logic Toolbox in the followings.

### 3.1. SISO

We assume that the input to the system is the environmental light  $x_1$ . We further assume that the environmental light can be Big, Medium, and Small. The output DN can range between 0 and 63 and is divided into Small, Medium, and Big. Figure 9 shows the fuzzy sets describing the above. Labels for the membership functions are given in Table 1. The rules base, with its 3 rules, is shown in Table 2.

Table 1. Labels for the membership functions in the SISO system

Label	Membership
S	Small
M	Medium
B	Big

Table 2. Rule base of the SISO system

$x_1$	S	M	B
	B	M	S

Table 3. Labels for the membership functions in the DISO system

Label	Membership	Label	Membership
VS	Very Small	VB	Very Big
S	Small	NS	Negative Small
SB	Small Big	ZE	Zero
MB	Medium Big	PS	Positive Small
B	Big		

Table 4. Rule base of the DISO system

$x_1/x_2$	S	M	B
PS	MB	S	VS
ZE	V	SB	S
NZ	VB	MB	SB

Figure 10 shows the results of the simulation of the rule base by fuzzy inference development environment (MATLAB Fuzzy Logic Toolbox) software for the input value of the environmental light  $x_1 = 164$ . The output is 24.22. Here only two rules are needed to calculate the output. The inferred output solved by the center-of-gravity method can also be checked by hand calculation as follows:

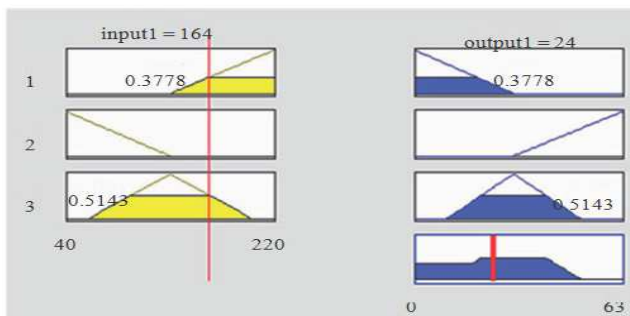


Figure 10. The inferred output of the SISO system.

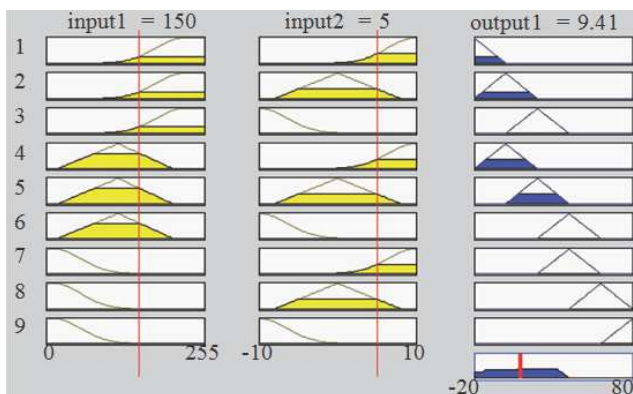


Figure 12. The inferred output of the DISO system.

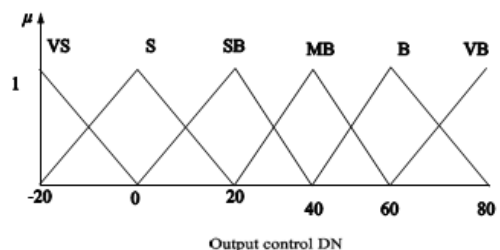
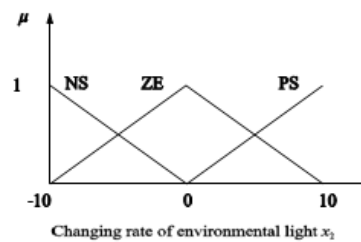
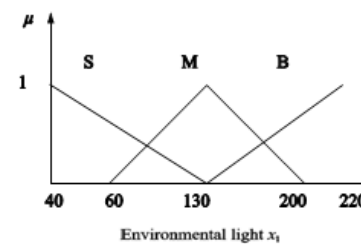


Figure 11. Fuzzy sets showing the inputs and the output of the DISO system

### 3.2. DISO

We assume that the inputs to the system are the environmental light  $x_1$  and the changing rate of the environmental light  $x_2$ . Where the changing rate of the environmental light ranges between -10 and +10 and is divided into Negative-Small, Zero, and Positive-Small. We further assume that the

environmental light can be Small, Medium, and Big. To make the inferred output value homogeneously distribute on all regions (especially, for dark region), the output DN ranges between -20 and 80 and is divided into VS, S, SB, MB, B, and VB. Figure 11 shows the fuzzy sets describing the above. Labels for the membership functions are given in Table 3. The rules base, with its 9 rules, is shown in Table 4. Figure 12 shows the results of the simulation of the rule base by fuzzy inference development environment (MATLAB Fuzzy Logic Toolbox) software for the input values of the environmental light  $x_1=150$  and the changing rate of the environmental light  $x_2 = 5$ . The output is about 9.41. Here only six rules are needed to calculate the output. The surface shown in Figure 13 is the control surface. It means that for every possible value of the two inputs, there is a corresponding output based on the rules. For example, if the environmental light  $x_1$  and the changing rate of the environmental light  $x_2$  are given, the control output DN of the system can be obtained immediately.

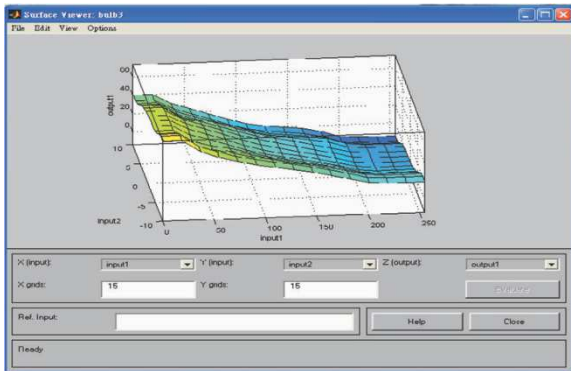


Figure 13. The result of the simulation of the DISO system using surface viewer of MATLAB fuzzy logic toolbox



Figure 14. Bulb responses for control value DN = 5, 15, 25

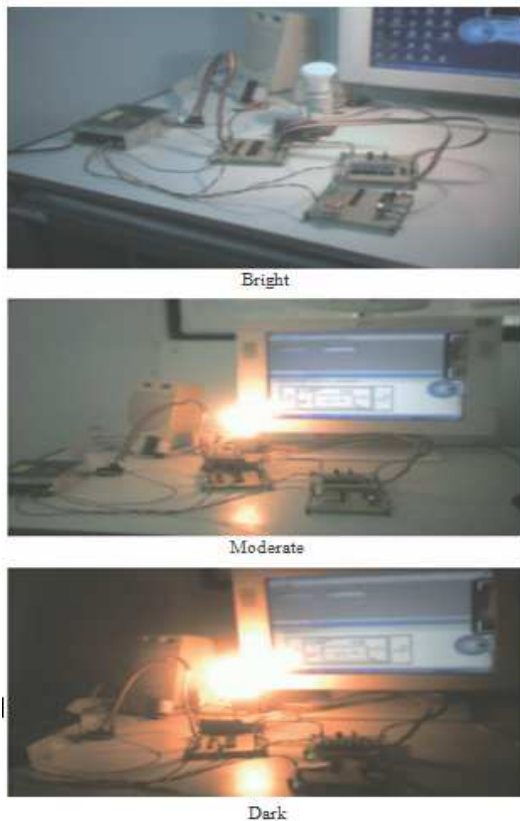


Figure 15. Bulb output response against different environmental light.

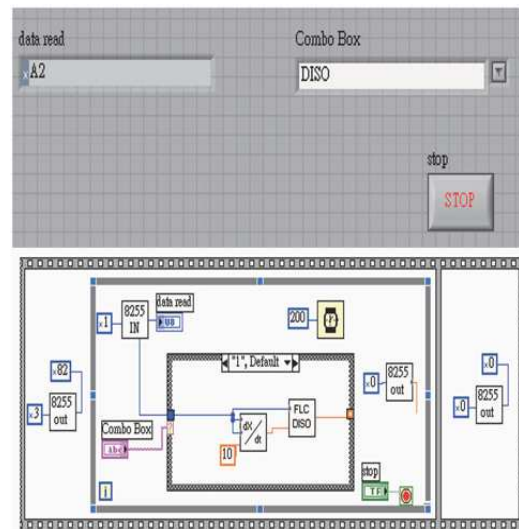


Figure 16. Front panel and block diagram in LabVIEW.

#### 4. RESULTS AND DISCUSSION

The light control system is constructed in a PC base using the 8255 expanding I/O circuit instead of a DAQ card. The 8255 I/O expanding circuit, sensing circuit, and the output control circuit become the requisite components in the design of a light control system. The resolution of A/D device is 8-bit and the digital outputs used only 6-bit. The tasks of acquiring the input signal, process of the input data, and output of the DN are commanded by using LabVIEW, which is a graphical programming language to accommodate the light control system.

Figure 14 shows the corresponding bulb responses for the control value DN = 5, 15, 25 respectively. Figure 15 shows the change of the lightness of the bulb against the variations of the environment lightness. The front panel and the block diagram of the LabVIEW program are shown in Figure 16. At begin, we create a combo box with two items (SISO and DISO) in the front panel of LabVIEW, shown in the upper part of Figure 16. To simplify the whole program, we make two sub-vi's icons denoted as FLC SISO and FLC DISO to do the corresponding job of the FLC, shown in the lower part of Figure 16. After that, we can easily run the LabVIEW program and choose the item in the combo box and even switch the item to another one during the execution of the LabVIEW program.

The main features in the design of the light control system using the LabVIEW are: low cost, easy implemented in a PC without any DAQ card, and incorporate MATLAB Fuzzy Logic Toolbox with LabVIEW program.

Javidbakht [1] used fuzzy controller with the SISO system to dim the fluorescent lamp based on the availability of the outside light. And Zhang [7] adopted fuzzy controller with the DISO system to distinguish environmental interferences, avoiding the fault action and jittery and improving the reliability. In this paper, both the SISO system and the DISO system are discussed respectively in the fuzzy controller. The experimental results show, due to the light signal and the changing rate are considered, the DISO system responses faster than the SISO system when environmental light changes suddenly. It has also verified the effectiveness and robustness of the proposed fuzzy controller.

#### 5. CONCLUSIONS

Important hardware such as the light sensing circuit and the dimmer with relays (like parallel-resistor circuit) were designed and proved work well. The control device can be used to adjust the light level of the bulb, making relays engaged or disengaged and saving the power. The device is reliable and convenient for maintenance.

The control of the bulb light system using a fuzzy logic controller is presented. Both the SISO system and the DISO system are discussed in the fuzzy logic controller and the LabVIEW program incorporated with MATLAB Fuzzy Logic Toolbox for the FLC is carried out. The experimental results have shown the satisfactory response of the bulb system against sudden change of the environmental light. This intelligent dimming device can also be applied to dim the bulb of the streetlights or car's headlights automatically according to environmental light, which worked reliably and had obtained good effect of energy saving.

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