以運算放大器實現模糊歸屬函數之類比電路
OPA Based Analog Circuit for Fuzzy Membership Functions

侯俊禮* 陳世翔 洪君維
Chun-Li Hou*, Shih-Hsiang Chen, Jiun-Wei Horng

摘要

本文利用兩個運算放大器和一個超級二極體來實現模糊理論中的歸屬函數電路合成。藉由運算放大器適當的偏壓製造出片段線性曲線。調整電路內部大量的電阻來獲得所需片段線性曲線的斜率。運算放大器使用一般的UA741 而超級二極體則由運算放大器和一個二極體組成。超級二極體連接在輸出端。而商業用運算放大器有著非常廣大的用途。

關鍵詞：模糊歸屬函數，運算放大器，類比電路

Abstract

In this paper, two OPAs and a superdiode are used to realize the circuit of a fuzzy membership function. It allows the piecewise linear curve to be generated by biasing the OPAs properly. A lot of variable resistors are adjusted to obtain the required slope of the piecewise linear curve. The OPAs adopts the common UA741 ICs and the superdiode composed of an OPA and a diode. The superdiode is connected in the output end. The commercially available operational amplifiers are widely used in practical applications.

Keywords: fuzzy membership function, operational amplifier, analog circuit

I. INTRODUCTION

Fuzzy theory has been developed for decades in [1]. It has been extensively applied to various fields in [2-5]. For example, machinery controls, electronics, chemistry, civil engineering, automobiles, and electric machine, etc. The most important application is the fuzzy controlling. This circuit can be applied as the next stage of the detecting devices. The circuit corresponds to the tenuity signals as temperature or pressure received by sensors to the location on the fuzzy distribution curve. There are few research to realize fuzzy membership function with discrete circuit in the past [6]. So the circuit mentioned here is very important for the extensively using OPAs in industry.

II. FUZZY MEMBERSHIP FUNCTION

The fuzzy membership function is used to show fuzzy degree in [7-8]. According to the figure, a common fuzzy membership function can be divided into three big classes: Triangular, Trapezoidal and Bell-shaped. The triangular membership function is such as Equation (1) and Fig. 1.

$$A(x)=\begin{cases} b\left(1-\dfrac{|x-a|}{s}\right) & \text{when } a-s \leqq x \leqq a+s \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

The trapezoidal membership function is such as Equation (2) and Fig. 2.

$$A(x)=\begin{cases} \dfrac{(a-x)e}{a-b} & \text{when } a \leqq x \leqq b \\ e & \text{when } b \leqq x \leqq c \\ \dfrac{(d-x)e}{d-c} & \text{when } c \leqq x \leqq d \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

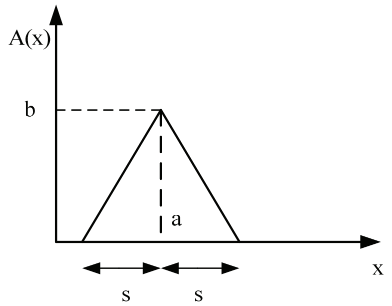

Fig. 1 The triangular membership function

中原大學電子工程學系
*Corresponding author. E-mail: clhou@cycu.edu.tw
Department of Electronic Engineering, Chung-Yuan Christian University, Chung-Li, Taiwan, R.O.C
Manuscript received 8 December 2008; revised 19 February 2009; accepted 31 March 2009

The bell-shaped membership function is such as Equation (3) and Fig. 3.

$$A(x) = ce^{-\frac{(x-a)^2}{b}} \tag{3}$$

The function represents the fuzzy degree of observed object. The object is absolute match our subjective definition if the value is maximum. The minimum is opposite.

III. CIRCUIT CONFIGURATION

1. Inverting operational amplifier

Fig. 4 shows an inverting amplifier. The voltage of the noninverting terminal is obtained from Vcc and -Vee. According to the superposition theorem and amplifier theory, if Vee=Vcc we can get:

$$V_{o1} = -\frac{R_2}{R_1}V_i + \left(\frac{R_1+R_2}{R_1}\right)\left(\frac{R_4-R_3}{R_4+R_3}\right)V_{CC} \tag{4}$$

if $V_{o1} = 0$ we find the horizontal intercept in Figure 5:

$$Vi' = \left(\frac{R_1+R_2}{R_2}\right)\left(\frac{R_4-R_3}{R_4+R_3}\right)Vcc \tag{5}$$

Fig. 5 shows the transfer curve of the inverting amplifier. We can adjust R_1 and R_2 to control the slope of the curve. And from Equation (5), the horizontal intercept is tunable by resistors R_3 and R_4 and Vcc.

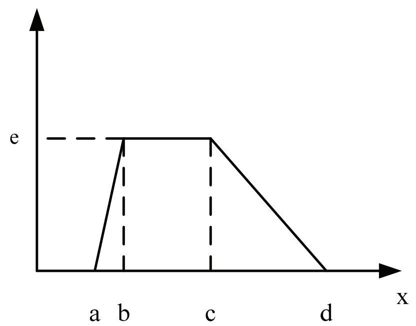

Fig. 2 The trapezoidal membership function

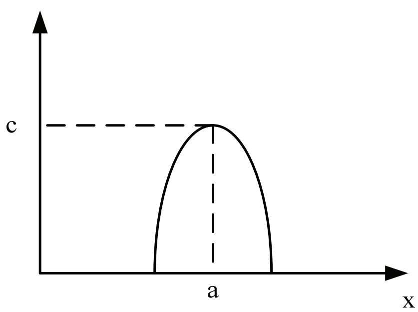

Fig. 3 The bell-shaped membership function

2. Noninverting operational amplifier

Fig. 6 shows a noninverting amplifier. The voltage of the noninverting terminal of the amplifier is obtained from Vcc and -Vee. According to the surperposition theorem and the amplifier theory, if Vee=Vcc we can find

$$V_{o2} = \left(\frac{R_8+R_9}{R_8}\right)\left\{\frac{R_5R_6V_i + [R_6R_7 - R_5R_7]Vcc}{R_5R_6 + R_5R_7 + R_6R_7}\right\} \tag{6}$$

if $Vo_2 = 0$ the horizontal intercept

$$V_i{*} = \frac{R_5R_7 - R_6R_7}{R_5R_6}V_{CC} \tag{7}$$

Fig. 7 shows the transfer curve of the noninverting amplifier. From Equation (6), it is obvious that R_5, R_6, R_7,

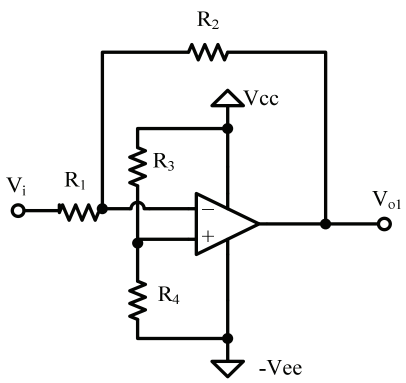

Fig. 4 The inverting amplifier

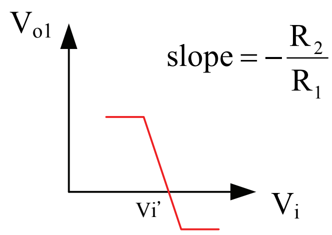

Fig. 5 The transfer curve of the circuit in Fig.4

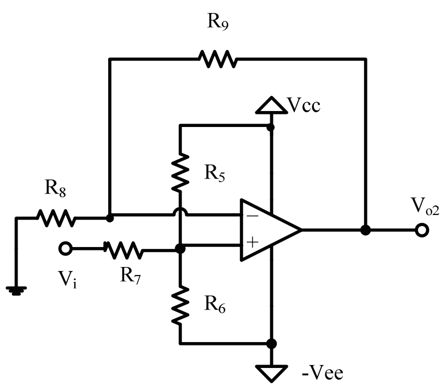

Fig. 6 The noninverting amplifier

R_8, and R_9, control the slope. While from Equation (7), the horizontal intercept is controlled by resistors R_5, R_6, and R_7 and Vcc.

3. The operational amplifier-based fuzzy membership function

A fuzzy membership function circuit employing OPAs is proposed in Fig. 8. The circuit consists of an inverting amplifier, a noninverting amplifier and a superdiode. The greatest advantage of the circuit which constructed the membership function is with few components and two power supplies. The circuit has the advantages of low cost and high efficiency. In Fig. 8, the noninverting amplifier and the inverting amplifier have the same input V_i.

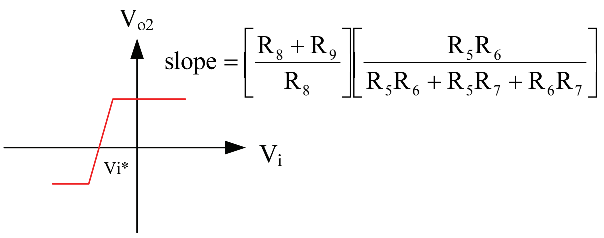

Fig. 7 The transfer curve of the circuit in Fig. 6

The output of the above mentioned two amplifiers are combined to be the input of the superdiode. In Fig. 8, if $R_9 = R_{10}$=R, then the combination of the transfer curve form a function Vo (V_i) with the input V_i by using superposition theorem

$$V_0^*(V_i) = \frac{1}{2}\left(V_{o1}(V_i) + V_{o2}(V_i)\right)$$

$$V_o(V_i) = \begin{cases} V_0^*(V_i) & \text{if } V_0^*(V_i) \ge 0 \\ 0 & \text{if } V_0^*(V_i) \le 0 \end{cases} \tag{8}$$

where $0 \le V_o(V_i) \le V_{o\max}$. $V_{o\max}$ is the maximal value of $V_o(V_i)$. The membership function $F(V_i)$ can be defined by $F(V_i) = [V_o(V_i)]/V_{o\max}$ with $0 \le F(V_i) \le 1$.

V. SIMULATION RESULT

HSPICE is used to simulate the circuit shown in Fig. 8. The simulation result is shown in Fig. 9. From the proceeding narration, the slope of the different parts of the membership function curve can be controlled independently and are equal to halves of the single OPA output ends. The whole output curve crosses over the positive region and the negative region. The two kinds of characteristics keep this circuit more flexible for industrious applications.

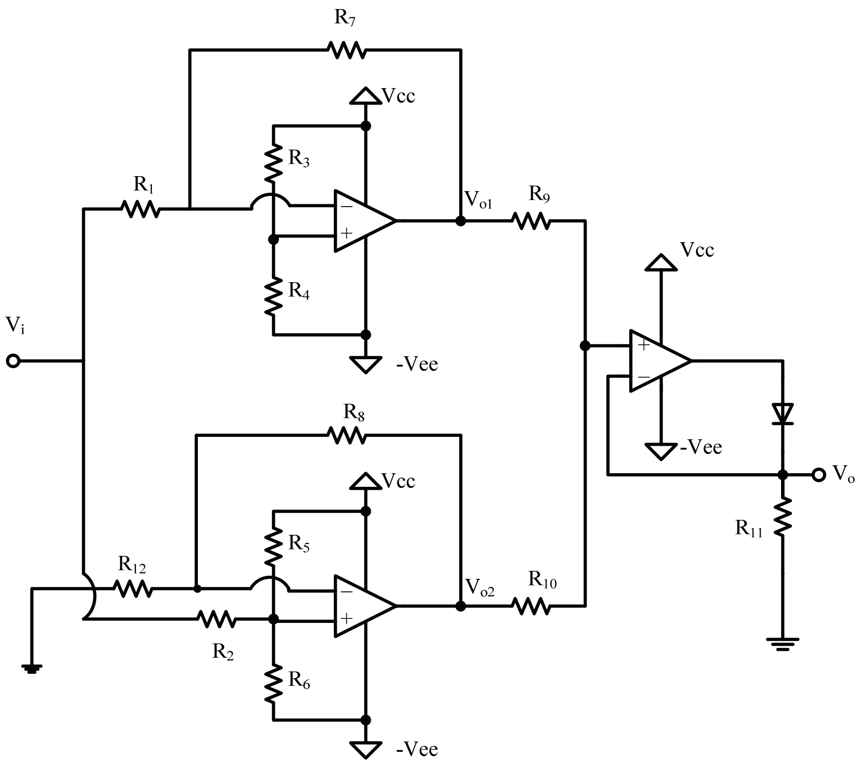

Fig. 8 The operational amplifier-based fuzzy membership function

V. CONCLUSION

The proposed circuit achieves fuzzy membership functions with few components of OPAs, superdiode and power supplies in discrete circuit compared with [9]. And so the cost reduced . Fuzzy membership function can be controlled easily by variable resistors and power supplies. Because OPAs are very popular in industry and Fuzzy membership function is very important in many fields as [10-14], the proposed circuit is very important to construct a fuzzy analog circuit.

ACKNOWLEDGEMENTS

We appreciate the assistance of CHUN-MING CHANG, CHEN-CHUAN HUANG and YUNG-CHANG YIN. They give us many suggestions and make some simulations for the research.

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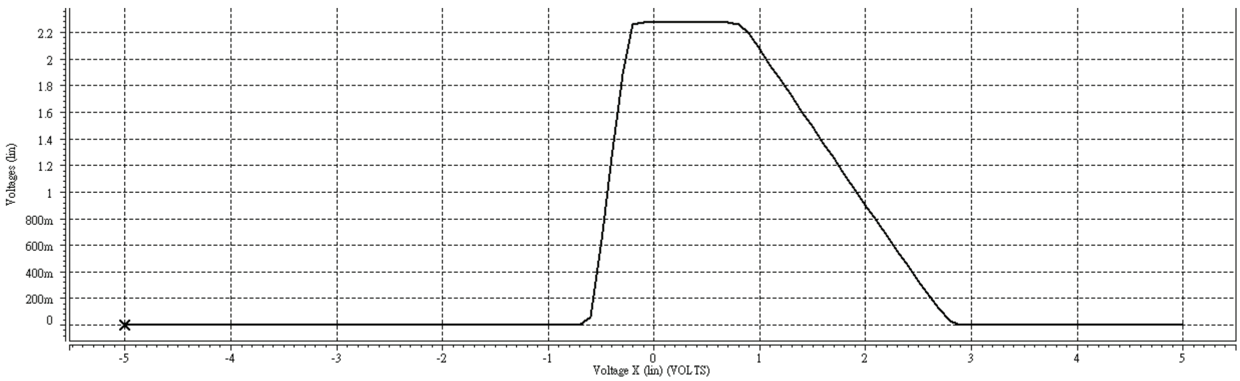

Fig. 9 The simulation result