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Design and Simulation of Gaussian Membership Function

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Abstract: This paper presents the proposed circuit for the designing of the Gaussian membership function using electronic devices like metal oxide semiconductor field effect transistor (MOSFET), operational amplifier (OPAMP) in ORCAD. Proposed circuit includes concepts of current mirror and current sink. In the proposed circuit we can also have S and Z membership functions by varying various voltages.

Keywords: Metal oxide Semiconductor Field Effect Transistor, Operational Amplifier, Fuzzy System, Membership Functions, Current Mirror, Current Sink.

I. INTRODUCTION

Fuzzy membership functions are used to determine the degree to which they belong to each of the appropriate fuzzy sets [1-4]. We always provide the crisp value as an input and the output is a fuzzy degree of membership in the qualifying linguistic variable. The proposed circuit in this paper is made using the several electronic devices like operational amplifier, metal oxide semiconductor field effect transistor, current sink, and current mirror circuit [5-7].

An operational amplifier (OP-AMP) is used to amplify and invert a signal. It can be used to amplify both dc as well as ac signal. Mainly it was proposed for performing mathematical operations like addition, subtraction etc. It is a direct coupled high gain amplifier [8-10].

Two stage CMOS operational amplifier is most widely used op-amp in VLSI designs. This amplifier is divided into two stages which are Input stage or First stage and Output stage or Second stage [11-12]. The first stage include differential amplifier which convert differential voltage into differential current and current mirror which convert current to voltage and gives the single ended output this entire first stage can be termed as CMOS differential amplifier and another stage includes the common source mosfet and current sink. This entire second stage can be relate to current sink load. The differential amplifier and common source mosfet provides the transconductance stage and the remaining two current mirror and current provides the load stage [13-14].

Metal oxide semiconductor field effect transistor (MOSFET) is a voltage controlled field effect transistor. MOSFET is having a very fine layer of insulating silicon dioxide known as glass which insulates it from the main semiconductor n-channel and p-channel [15].

The current mirror uses the principle that if gate - source potentials of two identical MOS transistors are equal, channel currents should be mirror. The conditions for the circuit to be mirror circuit are as follows [12]:

- $V_{gs(M1)} = V_{gs(M2)}$
- The gate terminal of both PMOS are to be connected
- The source terminals are to be connected
- Drain current of both the PMOS are to be equal ($I_{D1} = I_{D2}$)

Current Sink is a two terminal device whose current is always independent of the voltage across its terminals. Current flows from positive node, through sink, to the negative node. Typically negative node is at V_{ss}. Gate voltage is applied to create the desired value of current accordingly. There is a threshold voltage V_{min} which is required for the current sink to start. In it we connected the drain of M_3 to V_1 and source to the circuit of current mirror.

We are already having S, Z, and triangular, trapezoidal membership functions [6]. But to obtain Gaussian membership function along with S, Z membership functions further a circuit is proposed in this paper.

II. METHODOLOGY

The circuit diagram for S and Z membership functions have been already implemented using op-amps [6] & two stage op-amps. After studying those circuits we have indigenously designed Gaussian function along with S and Z membership functions.

We have divided the Gaussian membership function circuit into 3 parts as shown in figure 1

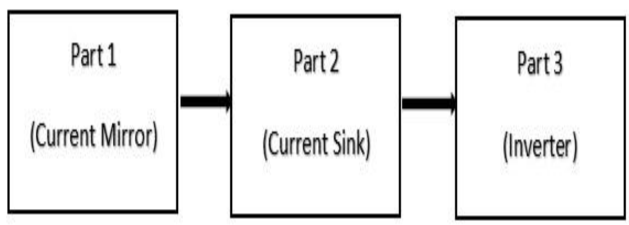

FIGURE 1: Block diagram of Gaussian membership function

Figure 2 shows the proposed circuit to form Gaussian as well as S and Z membership function.

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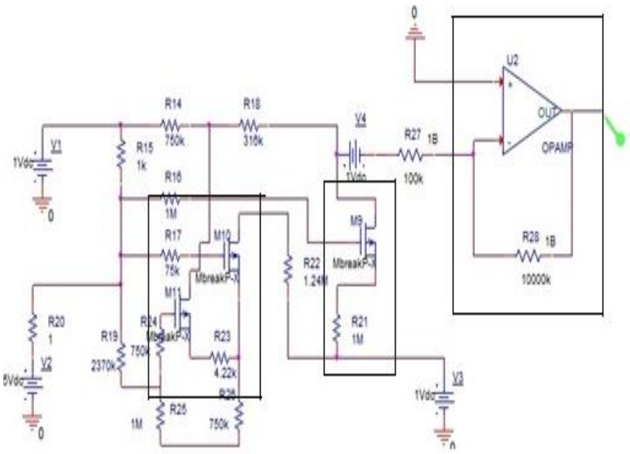


FIGURE 2: Proposed Circuit of Gaussian membership function

Figure 3 shows the output corresponding to the proposed circuit to form the Gaussian function.

Table 1 shows the slew rate and power dissipation of the proposed circuit.

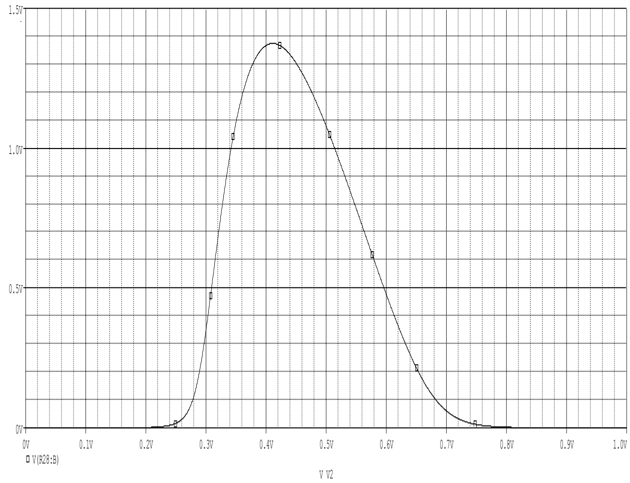


FIGURE 3: Output corresponding to the proposed circuit

TABLE 1: Electrical parameters of the proposed circuit

Electrical Parameter	Value
Power Dissipation	-70.46493m
Slew Rate (Fall)	-2.58573m

<u>*S-membership function*</u>: To achieve S-membership function from the proposed circuit we have following conditions-

- $V_3 > V_4$
- $V_3 = V_4 > V_1$

Table 2 shows the output of S-membership function for various cases obtained from proposed circuit satisfying the above condition and further Table 5 shows the electrical parameters for S-membership function circuit from proposed circuit.

TABLE 2: S-membership function cases from proposed circuit varying V_1, V_3, and V_4 in circuit

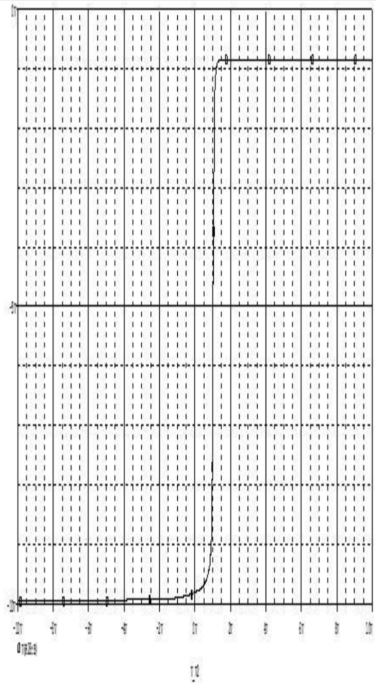
CASES	OUTPUT	EXPLANATION
$V_1=V_3>V_4$		Output voltage start decreasing from V_3 to V_4 or V_1 and then further it is inverted and amplified using op-amp inverter circuit in order to achieve s membership function.
$V_1=V_4<V_3$		
$V_4=V_3>V_1$		
$V_3=V_1>V_4$		
$V_3>V_4>V_1$		
$V_3>V_1>V_4$		
$V_1>V_3>V_4$		
$V_1<V_3>V_4$		
$V_3>V_4<V_1$		
$V_4>V_1<V_3$ and $V_3>V_4$		

TABLE 3: Electrical parameters for cases of Table 2

Cases	Slew Rate (SR-Rise)	Power Dissipation
$V_1=V_3>V_4$	52.43366	-644.37891u
$V_1=V_4<V_3$	53.68333	-770.47230u
$V_4=V_3>V_1$	55.75744	-7.04819m
$V_3=V_1>V_4$	52.43360	-644.37891u
$V_3>V_4>V_1$	50.57349	-769.29451u
$V_3>V_1>V_4$	51.84653	-709.83200u
$V_1>V_3>V_4$	52.36998	-713.58430u
$V_1<V_3>V_4$	55.76450	-729.47230u
$V_3>V_4<V_1$	50.24681	-6.76477m

Z-membership function: To achieve Z-membership function from the proposed circuit we have following conditions-

- $V_4 > V_3$
- $V_3 = V_4 < V_1$

Table 4 shows the output of Z-membership function for various cases obtained from proposed circuit satisfying the above condition and further Table 5 shows the electrical parameters for Z-membership function circuit from proposed circuit.

TABLE 4: Z-membership function cases from proposed circuit varying V_1, V_3, and V_4 in circuit

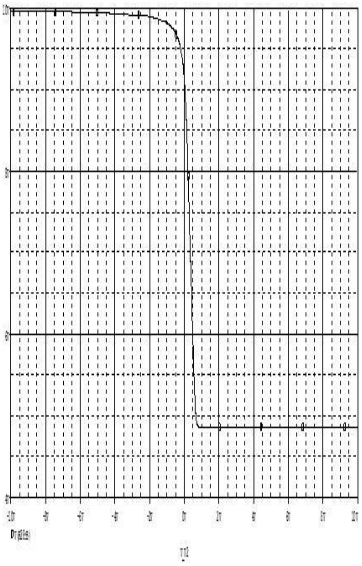
CASES	OUTPUT	EXPLANATION
$V_1=V_3<V_4$		Output voltage start increasing from V_3 to V_4 or V_1 and then further it is inverted and amplified using op-amp inverter circuit in order to achieve z-membership function.
$V_1=V_4>V_3$		
$V_4=V_3<V_1$		
$V_3=V_1<V_4$		
$V_4>V_3>V_1$		
$V_4>V_1>V_3$		
$V_1>V_4>V_3$		
$V_4<V_1>V_3$		
$V_3<V_4>V_1$		
$V_4>V_1<V_3$ and $V_3<V_4$		

TABLE 5: Electrical parameters for cases of Table 4

Cases	Slew Rate (SR-Fall)	Power Dissipation
$V_1=V_3>V_4$	-8.97746	-7.04819m
$V_1=V_4<V_3$	-7.59133	-7.70472m
$V_4=V_3>V_1$	-8.77746	-7.04819m
$V_3=V_1>V_4$	-7.81590	-6.44378m
$V_3>V_4>V_1$	-7.57537	-7.69251m
$V_3>V_1>V_4$	-6.14632	-7.09823m
$V_1>V_3>V_4$	-6.14369	-7.15847m
$V_1<V_3>V_4$	-8.57196	-7.29220m
$V_3>V_4<V_1$	-7.29341	-6.76591m

The Tables above showing the electrical parameters like slew rate and power dissipation, here we have obtained the slew rate positive when it is taken slew rate(rise) and negative when it is taken slew rate(fall). One surprising result we have come across is negative power. Basically there is two type of loads that is passive and active passive loads. Just like resistance which is a passive element which leads to the positive power dissipation because in this case charges flow takes place from high potential to low potential (Holes) which means work is done by the charges but in the case of active elements like mosfet, battery etc., charges flow takes place from low potential to high potential which means work is done on the charges, which leads to negative power. The electrical parameters are measured at the end side of the circuit means at the op-amp in the end which is used as inverter.

Hence we can conclude that the op-amp which is the active passive load causes the charges flow from the low potential to high potential which causes work is done on the charges and hence we get the negative power dissipation.

III.CONCLUSION

In this paper, we had made an attempt to design the fuzzy membership functions and its electronic implementation. We have successfully designed and implemented the Gaussian membership function, through that circuit we have made S and Z membership function. We have also calculated its various electrical parameters like Slew Rate and power dissipation.

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