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MOS Based Fuzzy Logic Multiplexer Design and Simulation

[1] Nadeem Tariq Beigh, [2] Mir Mohammad Burhan, [3] Faizan Tariq Beigh

[1]Department of Electronics and Communication, Sharda University, Greater Noida, India
[2]Department of Electronics and Communication, Sharda University, Greater Noida, India
[3]Department of Electronics and Communication, Islamic University Of Science & Technology, Awantipora, India

Abstract: **In this paper we present a fuzzy logic hardware implementation of a 2:1 multiplexer using MOSFETs. We propose the design of fuzzy multiplexer using more sophisticated CMOS technology with a low power design. The fuzzy multiplexer acts as a switch to determine the relation of a fuzzy input 's' with the two fuzzy sets 'input1' and 'input2' to obtain an output fuzzy set 'output'. The fuzzy multiplexer forms the main building modules in fuzzy systems. All designs and simulations were done using NI Multisim 13.0.**

Keywords: **Fuzzy logic, Fuzzy Gates, Fuzzy Multiplexer, Fuzzification, Membership Functions, Fuzzy Sets.**

1. INTRODUCTION

Fuzzy logic was first proposed by Lofti.A.Zadeh in his 1965 paper entitled none other than Fuzzy set, explored and validated by Mamdani, fuzzy logic has been used successfully in numerous control systems. Most applications rely on conventional digital computers or microprocessors programmed with a sequential calculation of the fuzzy logic quantities to perform the logic inferences [1]. Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets, where variables may take on true or false values, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.

Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. The main characteristic of the fuzzy logic is the use of continuous, rather than discrete, waveforms [2]. The research on analog fuzzy systems started with the pioneering work of Yamakawa, and was followed by many researchers [4][2][[6][7][8]. With the nonlinear characteristics of the active devices in analog circuit, the fuzzy elements can be implemented in very simple structures. This brings a reduction in the circuit complexity which implies better speed performance, reduced chip area and reduced power consumption. Until now the main drawback of the analog approaches has been their poor flexibility. To overcome these drawbacks, we propose a novel architecture for the hardware implementation of fuzzy logic multiplexer using MOS logic rather than Op-amps.

2. BASIC FUZZY GATE DESIGN

Consider two fuzzy sets X and Y in the universe of discourse U will have values in the closed interval {0, 1}. To design the fuzzy logic gates we can follow various inference strategies. The T and S norm, Madami approach and others [5].

The T-norm operation is defines as [bench]: $U_{X \wedge Y}(u) = MIN(\mu_X(u), \mu_Y(u))$ *for all* $u \in U$.

S-norm is defined as: $U_{X \vee Y}(u) = MAX(\mu_X(u), \mu_Y(u))$ *for all* $u \in U$.

Fuzzy negation is defined as: $U\text{-}_X(u) = 1\text{-}\mu_X(u)$ *for all* $u \in U$.

The T-norm operation represents the fuzzy and, the S-norm represents fuzzy.

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A. Fuzzy And Gate:

The fuzzy and gate is represented using the T-norm or the minimum operation function. The fuzzy and (F-AND) is implemented in [2], however the resulting circuit as shown in figure 1. Is difficult to implement. The researcher has tried to implement it using the op-amp technology but the results produced are not completely fuzzy. The design we have shown is implemented from [1] and does not need additional diodes to obtain the true fuzzy operation. The designed and gate is small in area and power dissipation. The modified fuzzy gate has been shown in figure 2.This modification may reflect the special needs in the use of discrete components and does not reflect any fault in the design.

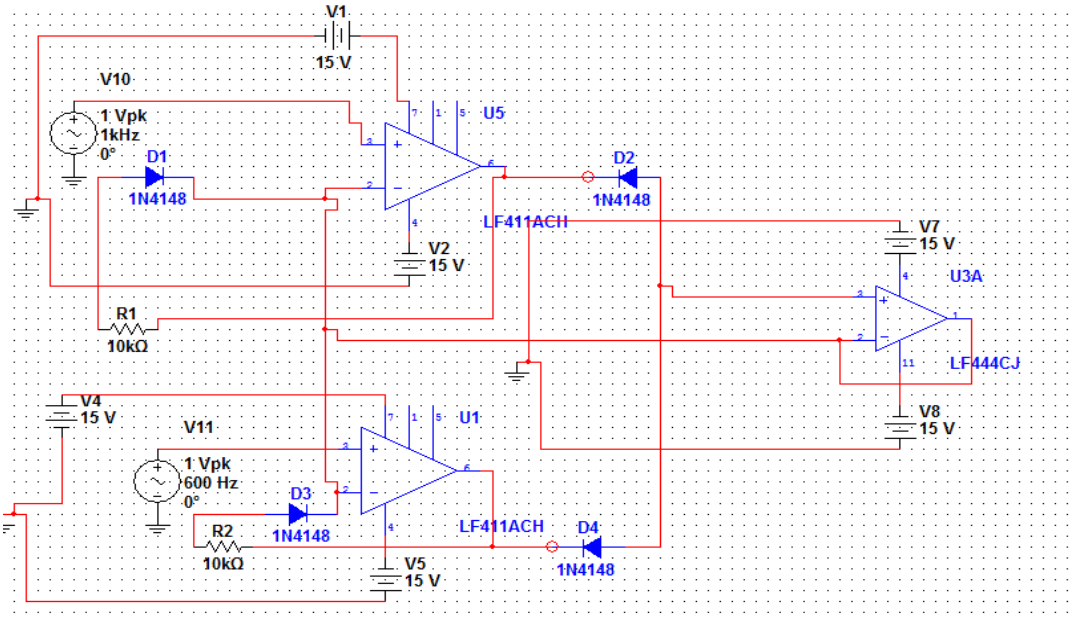

Figure 1: Generalized Fuzzy And.

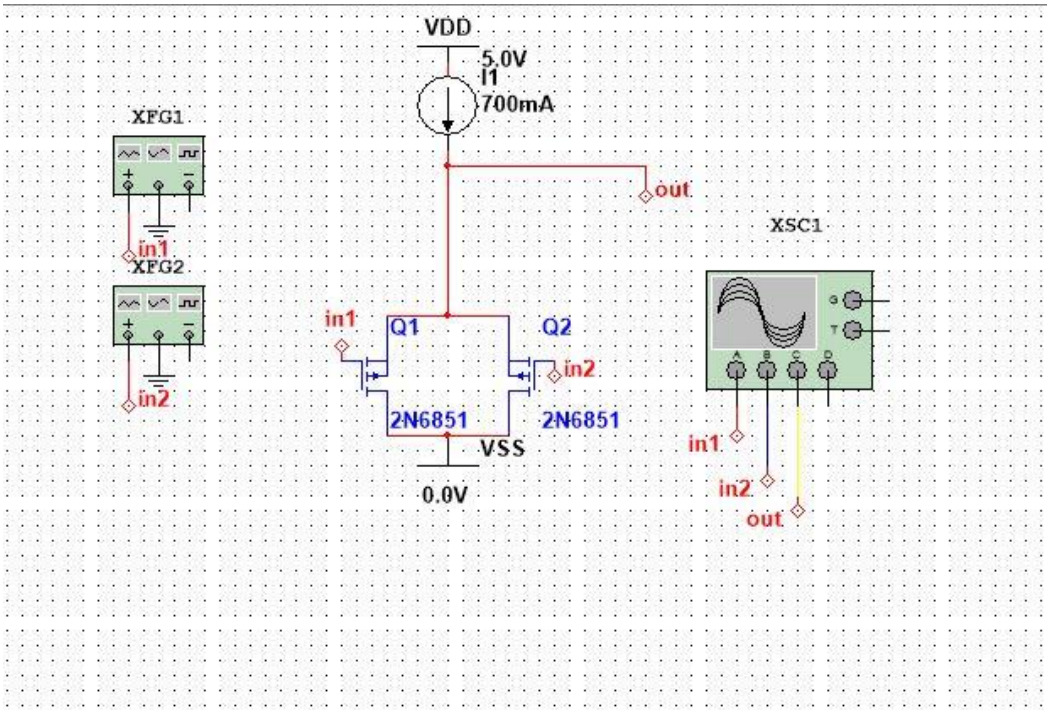

Figure 2: Modified Fuzzy And.

The inputs to the fuzzy And are sine waves of frequency 1 kHz and 2 kHz and the output waveform are shown in figure 3.The output voltage = MIN(X,Y) + offset voltage.

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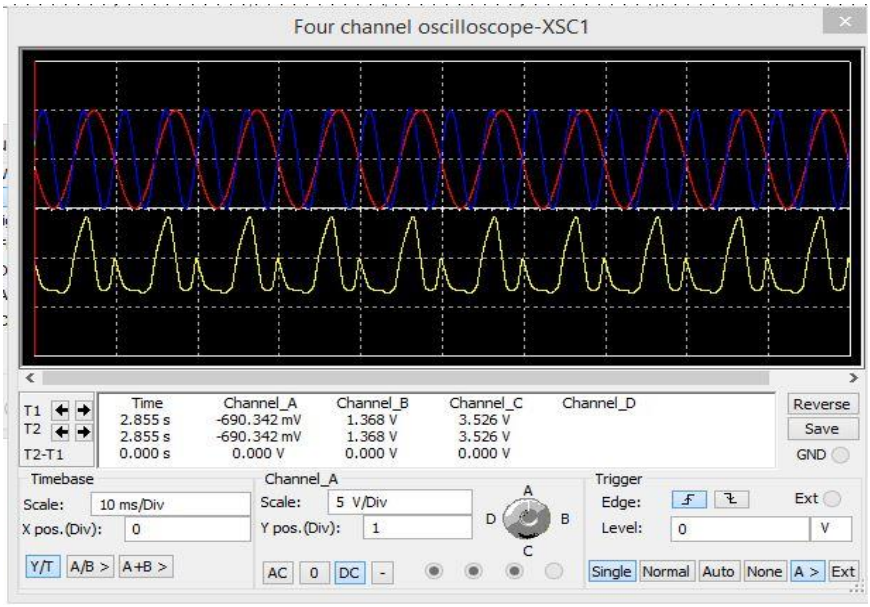

Figure 3: Input output waveform of fuzzy And. (output =Yellow).

B. Fuzzy Or Gate:

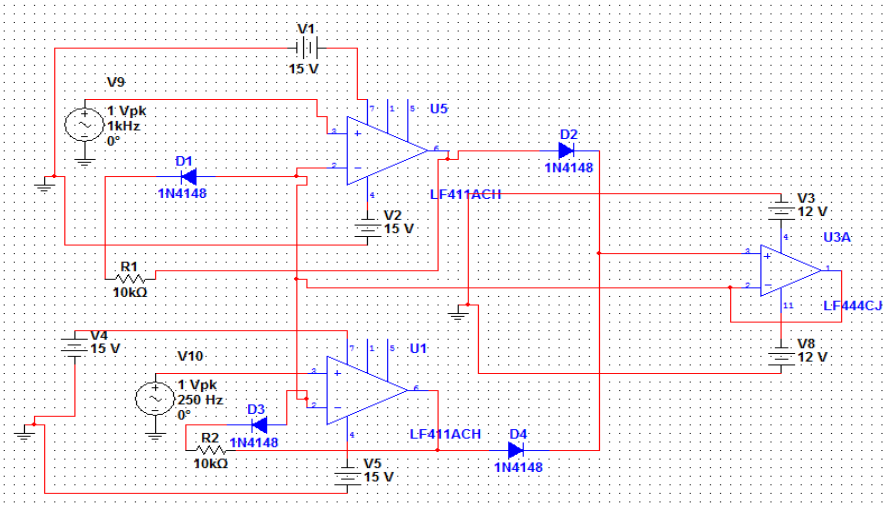

Figure 4: Fuzzy or gate.

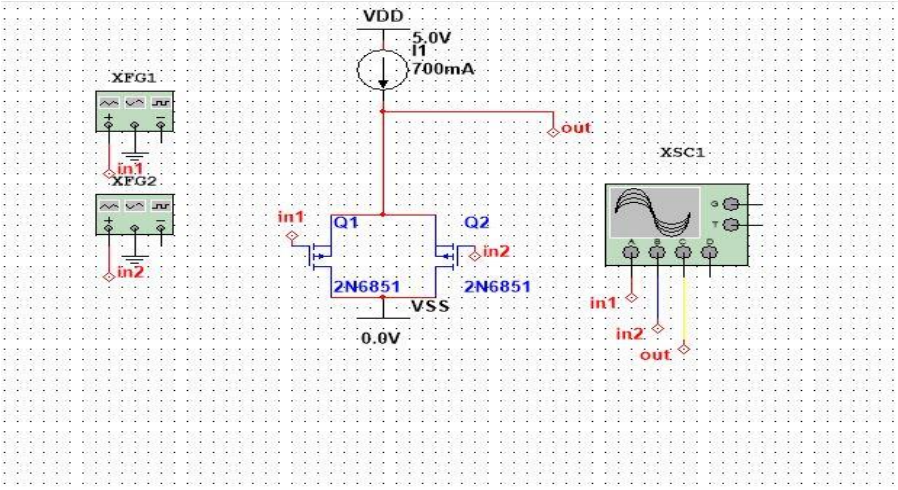

Figure 5: Modified Fuzzy or.

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The fuzzy and gate is represented using the S-norm or the maximum operation function. The fuzzy and (F-AND) is implemented in [2]. The inputs to the fuzzy And are sine waves of frequency 1 kHz and 2 kHz and the output waveform are shown in figure 6.

The output voltage = MAX(X, Y) – offset voltage.

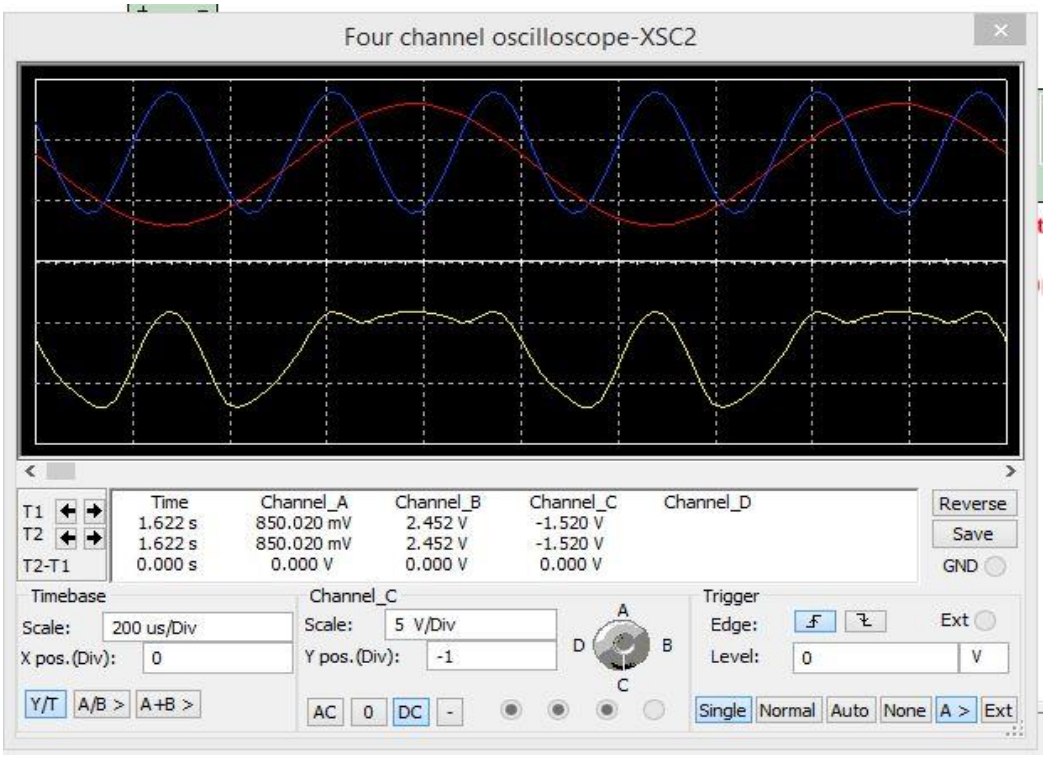

Figure 6: Input output waveform of fuzzy or (output =Yellow)

C. Fuzzy Not Gate:

Fuzzy not has been implemented as implemented by [2], as an inverting difference amplifier with a fixed voltage at the non-inverting terminal and the fuzzy input at the other. The output is the continuous difference of the input with the fixed voltage to obtain the fuzzy not operation as, $\boldsymbol{U\text{-}_X(u) = 1\text{-}\mu_X(u)}$ ***for all u ϵ U.***

[1] Output **s_bar = + R4/R2 (VDD – s); where R3/R1 = R4/R2 =1; Thus s_bar = (VDD – s).**

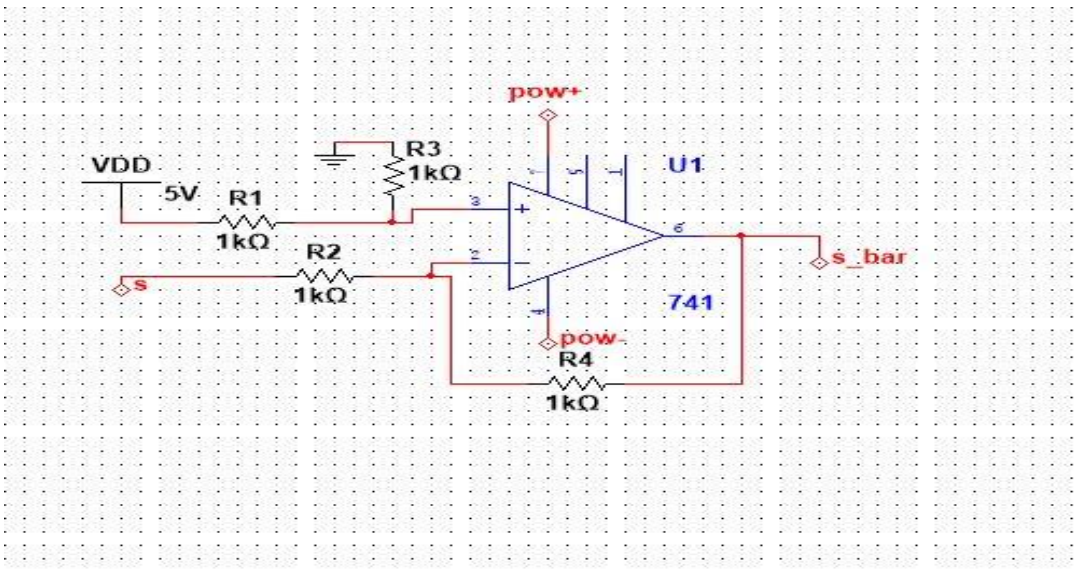

Figure 7: Fuzzy Not Gate.

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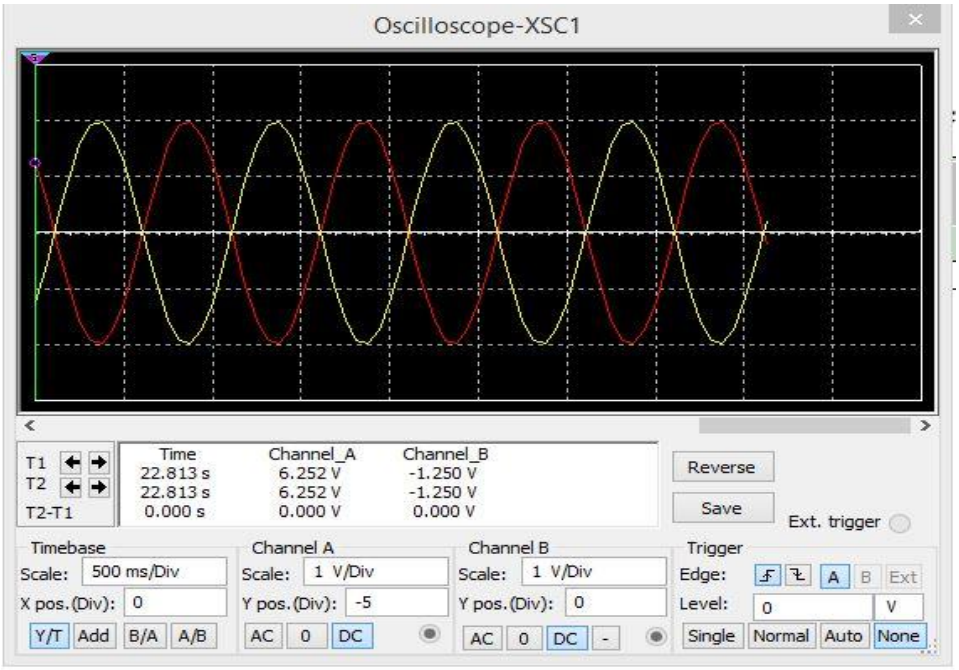

Figure 8: input output waveforms of fuzzy Not (output = Yellow).

D. Gate Visualizations:

Traditional *Bivalent fuzzy* logic uses the Boolean operators AND, OR, and NOT to perform the intersect, union and complement operations. These operators work well for bivalent sets and can be essentially defined using the following truth table [3]:

Table 1: Truth table for AND, OR, NOT.

X	Y	X and Y	X or Y	Not X
0	0	0	0	1
0	1	0	1	1
1	0	0	1	0
1	1	1	1	0

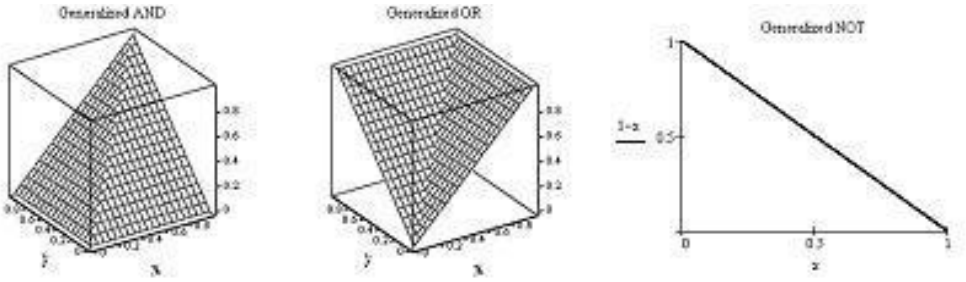

Figure 9: Generalized AND, OR, NOT gate.

The truth table above works fine for bivalent logic but fuzzy logic does not have a finite set of possibilities for each input; this makes for an infinitely large truth table. The operators need to be defined as functions for all possible fuzzy values, that is, all real numbers from 0 to 1 inclusive. Fuzzy logic is actually a superset of bivalent logic since it includes the bivalent options (0,1) as well as all real's in between, so a generalized form of these operators will be use full. The generalized form for these three operators are given in the table 2.

Table 2: Fuzzy Logic Gates and their generalized forms

X and Y	Min(X,Y)
X or Y	MAX(X,Y)
Not X	1 – X

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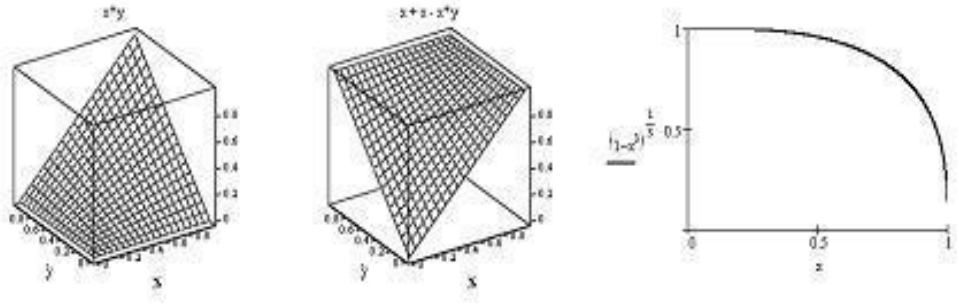

Figure 10: t-norms, t-norms & negation Visualization for fuzzy logic.

3. FUZZY MULTIPLEXER DESIGN

In essence, a fuzzy multiplexer acts as a fuzzy switch whose output is determined on a basis of the logic values of the information inputs being switched (selected) by the select input. Multiplexers are generic building modules in digital systems. Using fuzzy multiplexers, we can easily form cascade structures (networks) as commonly encountered in the two-valued logic constructs (digital systems).The output of a fuzzy multiplexer is a fuzzy combination of the two fuzzy sets 'X' and 'Y' based on the membership function of the select set 'S'. The membership function defines the relation of the Fuzzy sets.

The logical equation of a multiplexer is given as: ***Output = (input1 * S_bar) + (input2 * S)***;

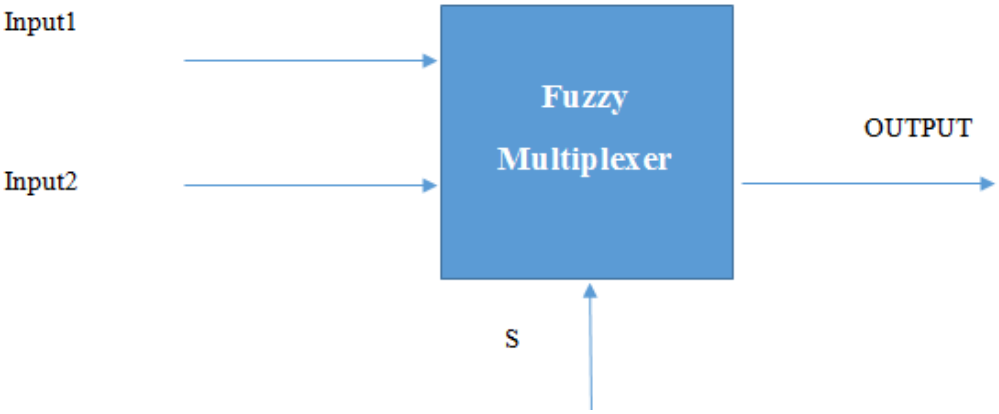

Figure 11: Block diagram of a fuzzy multiplexer.

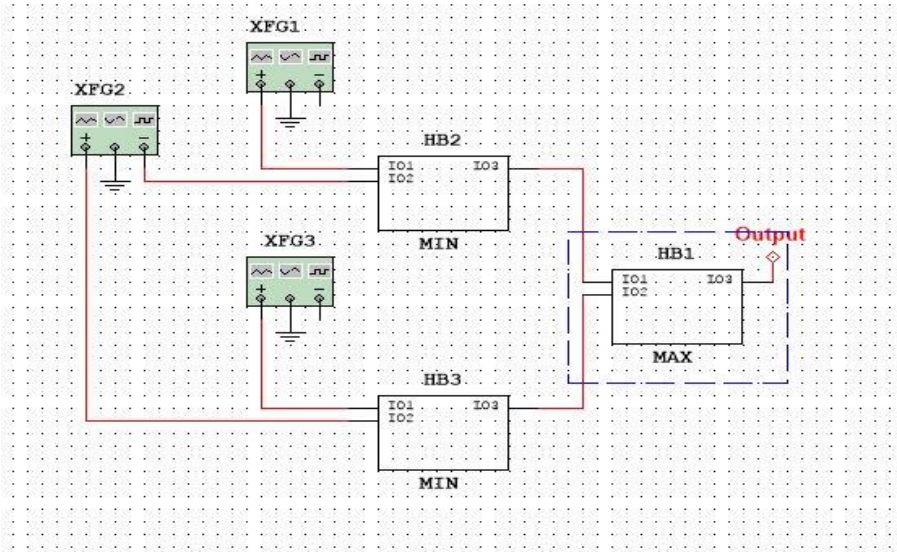

Figure 12: General Fuzzy multiplexer setup.

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The above equation can be re-written as:

= > Output = input1 ^ S_bar V input2 ^ S,

= > Output = MAX {MIN (input1, S), MIN (input2, S_bar)};

= > Output = MAX {MIN (input1, S), MIN (input2, (1 – S))};

So the multiplexer is implemented using a MAX, MIN and negation blocks. The general setup of a 2:1 multiplexer is given in figure 12.The setup comprises of 2 MIN function blocks as an input to a MAX function block with the select input provided in inversion to the two MIN blocks. Each separate block has been discussed.

The setup includes the waveform generators used provide a sine wave input of 1 KHz, 5 volt Vp for input 1, 2 KHz, 5 volt Vp for input2 and 3 KHz, 5 volt Vp for select input, the logical not gate here represents the fuzzy not discussed earlier. The waveform are observed using a 4 input oscilloscope. The simulation for fuzzy multiplexer was done using Mutisim and the results were as follows in time base of 1ms/Div and voltage scale of 10V/Div. The inputs, input1 and input2 represent the fuzzy sets defined by one of the standard membership function and the input s define the changing parameters that demand some control action to occur upon this change, e.g. the temperature variation of the engine demands the change in ventilation control and valve position. The figure14 shows the I/O waveform of the 2 input fuzzy multiplexer for digital and analog input.

The simulation setup of a 2:1 multiplexer is given as:

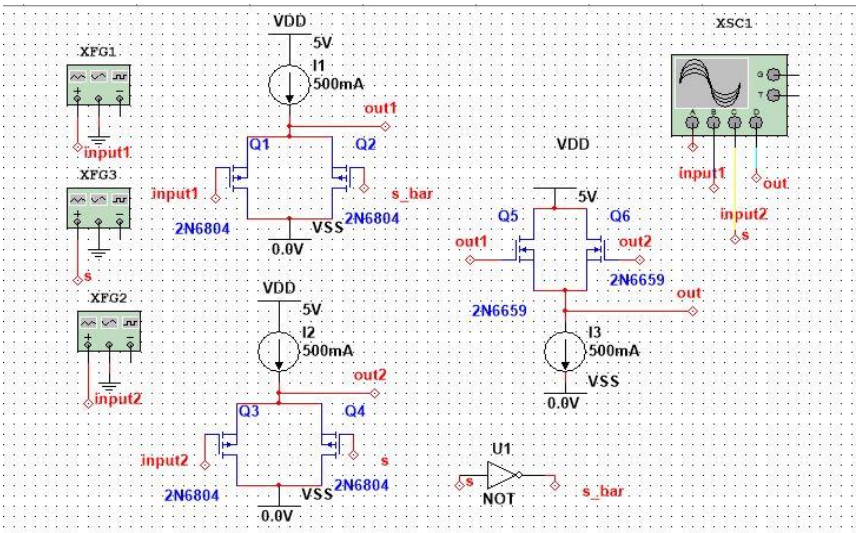

Figure 13: MOS Based Fuzzy multiplexer.

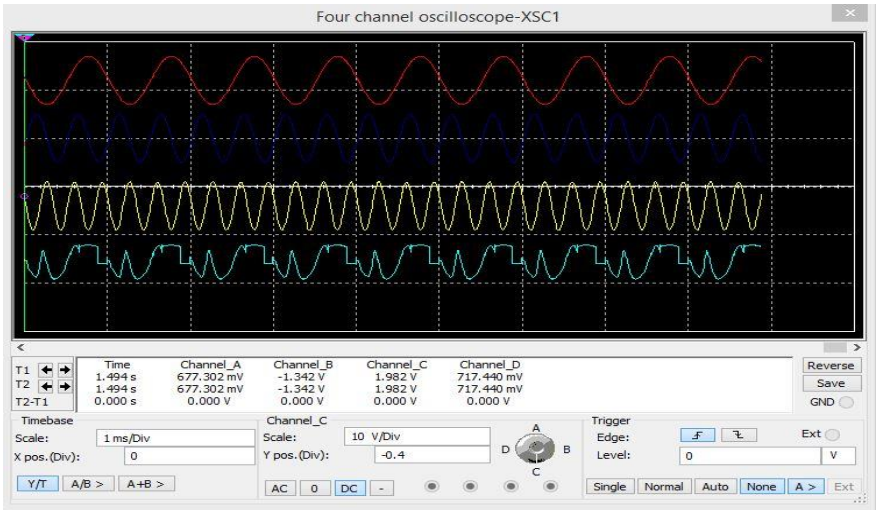

Figure 14: The analog I/O waveforms. (Output = light blue)

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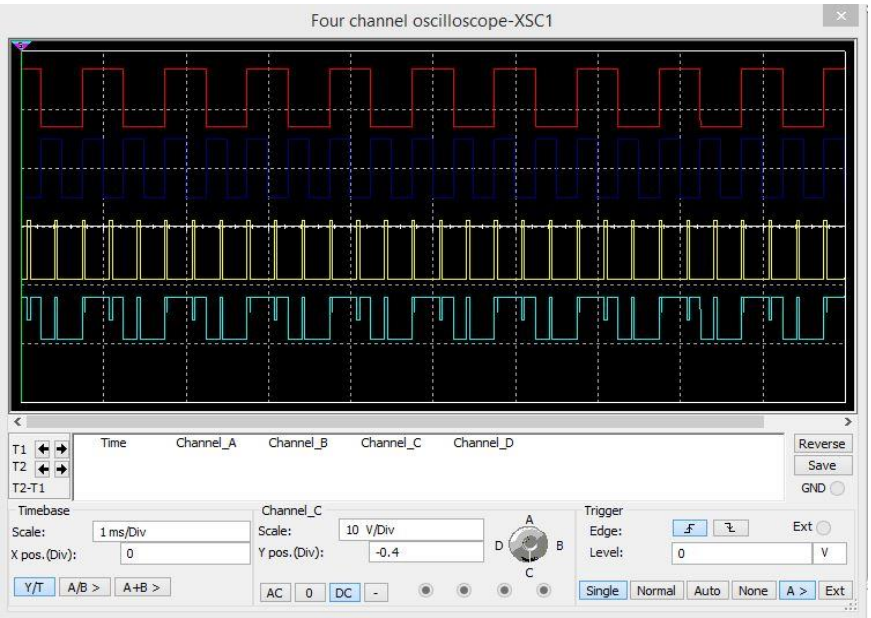

Figure 15: The digital I/O waveform (output = light blue)

4. CONCLUSION

In this paper we presented a design and simulation of MOS based Fuzzy Multiplexer along with the generalization to classical logic using simulations. In this paper we the already existing op-amp based fuzzy logic gates. These fuzzy gates were used to design fuzzy multiplexer to perform multiplexing of two fuzzy signals with the logic of selection line and the corresponding simulations were shown. The fuzzy multiplexer was also tested for general binary signals and was found to be performing to desired standards. The overall floor area and power consumption of the fuzzy multiplexer was reduced by using such a design. fuzzy multiplexer are direct generalizations of fundamental building blocks encountered in two-valued (digital) logic and being used in a design process therein. The design of the fuzzy multiplexer networks has been carried in the framework of genetic optimization.

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