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Realization of MIN-MAX Circuit using 0.18um CMOS Technology for Fuzzy Applications

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Abstract. This document proposes the achievement of a CMOS MIN -MAX circuitfor the Rule-Base block of Fuzzy Logic Temperature controller based on bounded difference circuit, using 0.18um CMOS technology. Here, we principally agreement with the analog implementation of VLSI circuit and we compare the digital implementation along with the analog implementation and also show the advantages of the analog one in this case. Now, analog implementing is popular primary since of their continuous-time-processing and high frequency and low power implementation.

Keywords: Digital implementation, Analog implementing, MIN-MAX circuit.

1. Introduction

Fuzzy logic is a branch of artificial intelligence that deals with reasoning algorithms used to emulate human thinking and decision making in machines. In contrast to binary logic, fuzzy logic can be thought of as gray logic, which creates a way to express in-between data values. Fuzzy logic associates a grade, or level, with a data range, giving it a value of 1 at its maximum and 0 at its minimum. Fuzzy Logic was originally developed in the early 1960's by Professor Lotfi Zadeh, who claimed for a new kind of computational paradigm capable of modeling the own uncertainness of human reasoning. In 1965, Zadeh published the first ideas on fuzzy sets, the key concept in Fuzzy Logic (FL). Here, we used Takagi-Sugenos type controller. Now, in this controller we are mostly concern about the Rule Base block, where, a set of rules indicating the combining of input membership values are saved. The controllers here for employed by the inference mechanism, can thus be applied to multi-input-multi-output problems and single- input- single-output problems.
The block diagram of Fuzzy control (see Fig.1).

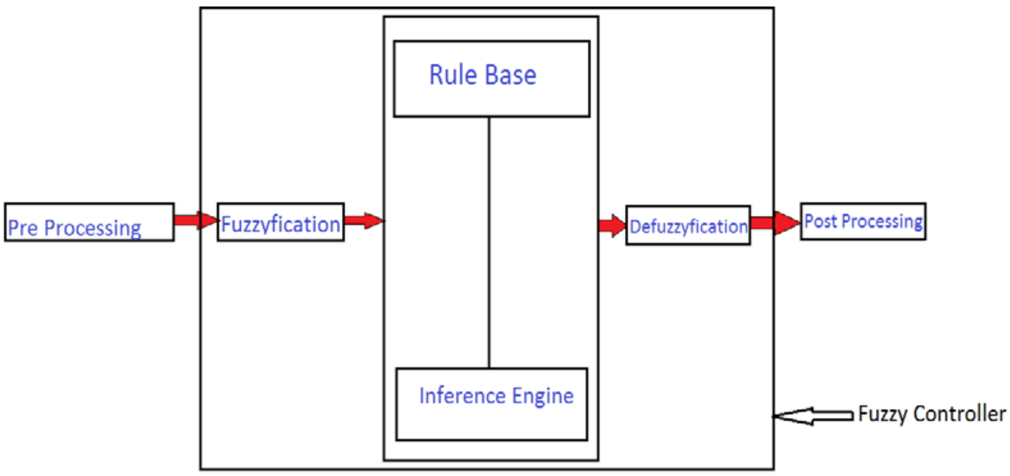

Fig.1. Block diagram of Fuzzy logic controller.

For designing the Rule base block we consider the analog realization of CMOS over digital implementation.

2. Digital Implementation of fuzzy logic

The digital implementation of fuzzy logic systems offers several advantages issued from the sound knowledge of digital circuit design and technology. Digital fuzzy processors are generally designed for multipurpose applications in order to interest a maximum of potential customers. They should thus implement a great and various number of fuzzy operators, membership functions and inference rules. On the other hand, there are some disadvantage for digital realization. Complex representation of fuzzy vectors and parallel structures are however required to obtain accurate and fast processing. Digital implementations of common fuzzy operations unfortunately rapidly to complicated, enormous very large scale integration (VLSI) circuits.

Now, combined with an appropriate programming environment, linguistic rules derived from a human expert can be directly translated into an implementation on a chip.

Digital implementation is used in control, expert systems, robots, image recognitions, diagnosis etc.

3. Analog implementation of fuzzy logic

As the advantages of the analog approach, they can perform continuous-time processing and have the particularity to be well compatible with sensors, actuators and all other analog signals. Therefore, they are obviously indicated to deal with fuzzy values, which are analog, by nature. In many cases, analog circuits can supplant digital controllers for some applications requiring low power consumption, compact and high-speed stand-alone chips.

On the contrary, analog circuits are much less flexible and adaptable than digital ones that are programmable, and they must be designed and implemented according to the structure of specific application.

Clearly, analog signals are represented either by voltages or by currents. Since voltage mode approach makes it easier to distribute a signal in various parts of a circuit, it is more attractive.

As a drawback, voltage-mode fuzzy circuit implies a large stored energy into the node parasitic capacitances and speed is limited by charge delays of various capacitors. They are moreover penalized by a certain lack of precision because signals are sensitive to changes of supply voltages. Voltage-mode approach needs resistors to achieve additions and to convert voltages into currents. Integrated resistors are unfortunately inaccurate, cumbersome and involve significant parasitic capacitances. Unlike the voltage-mode approach, current-mode circuits do not need resistors and can achieve summation and subtraction in very simple way, just by wire connections. This leads to simple and intuitive configurations, which exhibits high speed and great functional density. Current-mode circuits can also exhibit advantages as low power dissipation and low supply voltage, as good insensitivity to the fluctuation of the latter. As a disadvantage, current-mode circuits are restricted to single fan-out; therefore, current repeatability is of prime importance and the distribution of signals requires
multiple current mirrors to share out signal among several operational blocks. Additionally, matching of transistors is worse than matching of capacitors or resistors.

3.1. Voltage Mode

It is attractive since it makes easy to deliver a signal in diverse parts of a circuit. Non-linear operators including the MIN, MAX and truncation ones are fairly easy to apply in voltage mode. Multiple-input MIN & MAX circuits are manufactured with bipolar transistors and these circuits are known as Emitter coupled fuzzy logic gates. These basic non-linear gates present right characteristics and robustness. Such circuits are not practical with MOS transistors which cause an acceptable error associated with the transition region in which multiple devices are active. CMOS multiple-input minimum (MIN) & maximum (MAX) circuits using gain-improved voltage followers based on differential amplifiers. They are more involved but have frequency and accurate performance.

But, voltage-mode fuzzy circuit require a large stored energy into the parasitic capacitances and speed is limited by charge delays of different capacitors. They are further punished by a certain lack of precision because signals are susceptible to changes of supply voltages. The problems principally lie in the sizing of some components and also many functions are very hard to construct in voltage-mode. Now, this type of implementation requirements resistors to receive additions and to convert voltages into currents. But, the integrated resistors are imprecise, cumbersome and cause significant parasitic capacitances. The truncation of consequent and the defuzzification pose a major problem as far as the parallelism of the Inference engine (particularly when the number and size of output sets is large). This approach implies high-power dissipation and large chip area and leads to high cost. These problems can be retracted by the Current mode operation.

3.2. Current Mode

These circuits don't need resistors and can achieve summation and subtraction in the easiest way, just by wire connections. This result to simple and intuitive configurations, which offer high speed and big functional density. They are mainly used for systems needing a high level of interconnectivity.

The main advantages of the current mode circuits are:

(i) Low power dissipation

(ii) Low supply voltage

(iii) Good insensitivity to the supply voltage fluctuation.

like, current mode circuits have a single fan-out, current repeatability is of prime importance and the distribution of signals requires multiple-output current mirrors.

Current Mirror

It is a circuit achieved to circuit designed to replica a current across one active device by control the current in other active device of a circuit, maintain the output current invariable independent of charging.

An ideal current mirror is simply an ideal current amplifier.

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We have 3 major requirements that characterize a current mirror

(a) The current level it generates.

(b) Its ac output resistance which fixed how much the output current vary with the voltage followed to the mirror.

(c) The minimum voltage chute the mirror required to ensure that it work properly.

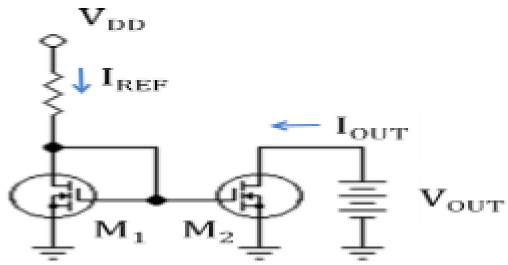

Fig.2. An n-channel MOSFET Current Mirror

Already the transistors are employed to grow the current mirror but now a day, the transistors are replaced by the MOSFET as the speed of MOSFET is much greater and the power dissipation is low. The n-channel MOSFET current mirror with a resistor to set the reference current **I**REF (see Fig.2).
A basic realization of multiple-output CMOS current mirror is shown below (see Fig.3).

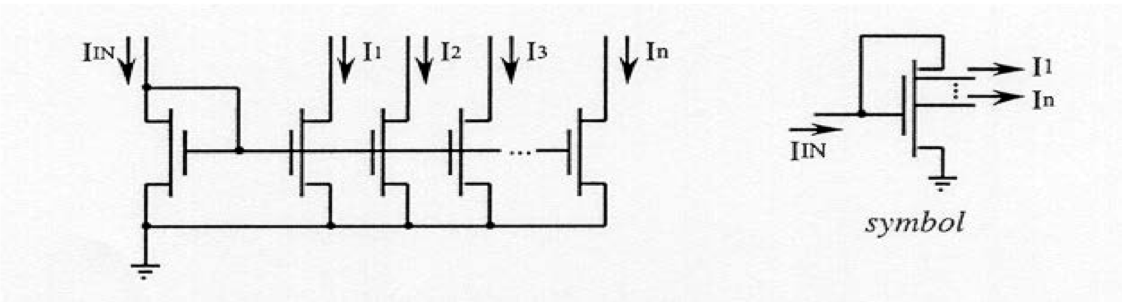

Fig.3. Basic n-output CMOS current mirror and symbolic represemtation

The circuit nevertheless not adapted for synthesizing accurate functions considering all output current is lightly adjusted through output voltage around the Early conductance. The output current should be separate of the output voltage, which is received via decreasing the conductance as with the 3 common mirrors illustrated in fig.3. The drain voltage of the transistor which require the current is then independent of the output voltage of the circuit. Multiple-output cascade mirrors are frequently used just Wilson ones are better than for low power applications because they involve a single polarization voltage in the place of two superposed voltages. The Mod-Wilson mirror is achieved by adding a transistor to the Wilson mirror to enhance its symmetry. This mirror offers good accuracy and input

current is well replicate with well paired identical transistors. The precision of all these mirrors depends on their output resistance and on the matching of their transistors.
Current mirror may be utilized as building block to synthesize fuzzy logic operation and pertinent processing. In this manner, nine basic fuzzy operations can be easily applied on the monolithic ICs with standard CMOS technologies. This current mode basic logic cells exhibit good linearity which cannot be readily obtained in voltage mode and result to fuzzy integrated systems which are generally less than in voltage mode.

MIN-MAX circuit

The most popular fuzzy logic operators used to compute the inference of a rule are logical “AND” and logical “OR”. MIN and MAX modules can be used to implement the AND and OR operations respectively. We have used current mode MIN circuits to implement the rule base. One MIN is required for calculating the inference of each rule.

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Minimum (MIN) and Maximum (MAX) operators are normally used to define the decision connecters in any type of fuzzy controller. In MAMDANI controller they also specify the fuzzy implication and aggregation mechanism. They are also used in the fuzzification operation using membership functions. The building block of these circuits is called as bounded difference circuit, which is defined as

$$X \ominus Y = \begin{cases} x-y; & \text{if } x \geq y \\ 0; & \text{if } x < y \end{cases} \quad \text{[where, x, y are two variables]} \qquad (1)$$

The bounded difference circuit can be provided by the combination of a current mirror and a diode. Now, the diode can be readily made in the CMOS circuit or by a single FET in which gate and drain is connected together

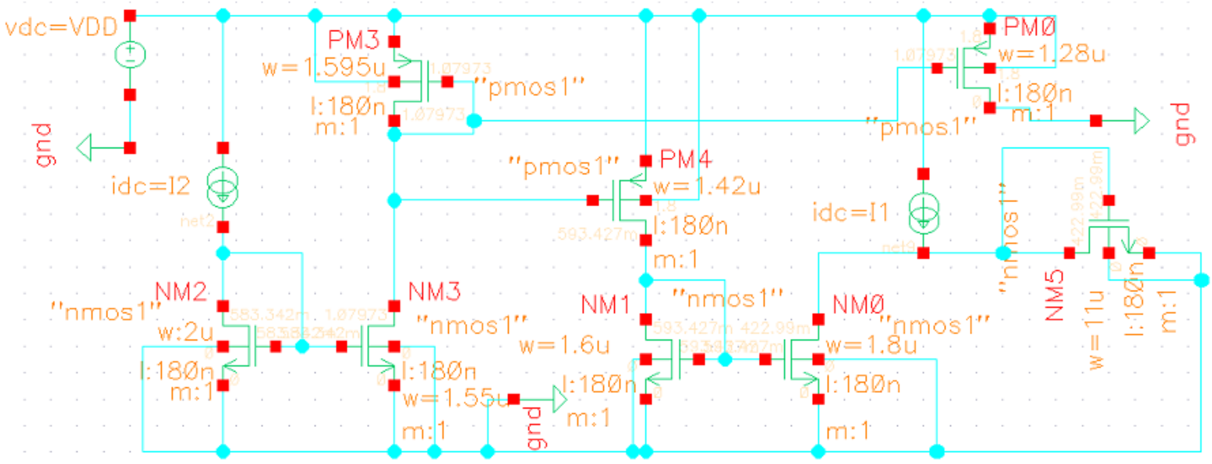

Fig.4. A Bounded Difference Circuit

Input and output of Bounded difference circuit is provided below (see Fig.5).

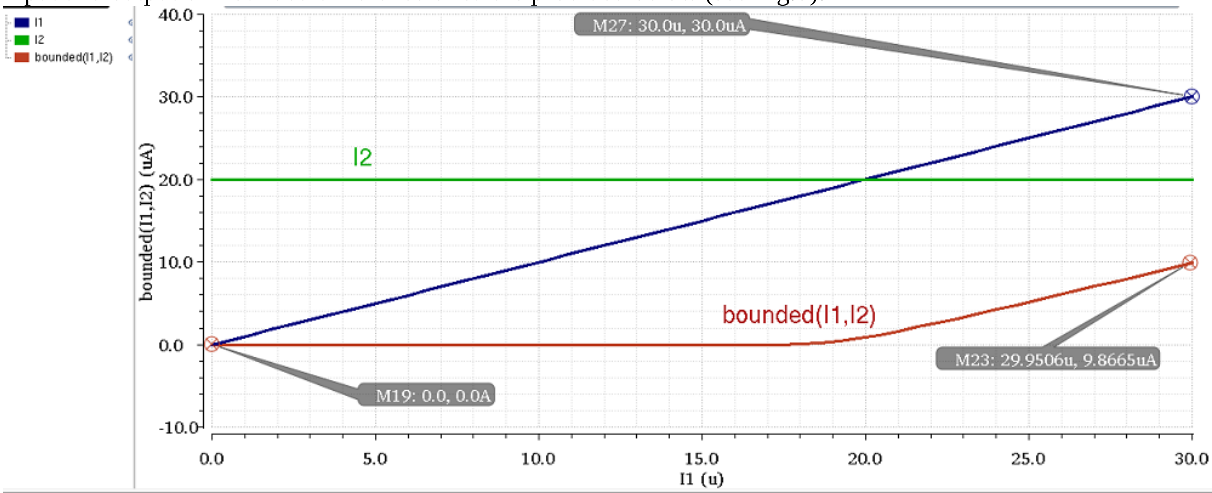

Fig.5. DC response of Bounded difference circuit

Today, as bounded difference and algebraic sum are adequate to realize any fuzzy functions, fuzzy circuits may be designed only by specifying connections between difference sub-circuits.
MIN function of two inputs x and y can be obtained using bounded difference operator following:

$$\text{MIN}(x, y) = x \ominus (x \ominus y) \qquad (2)$$

And the circuit is illustrated in (Fig.6).

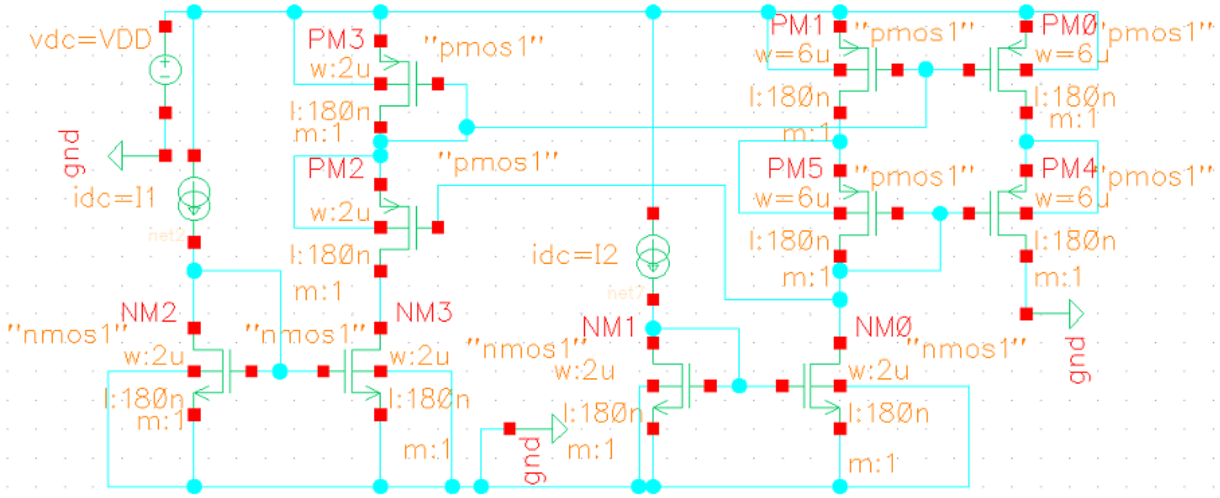

Fig.6. A two input MIN circuit

The simulation of MIN circuit is given below.

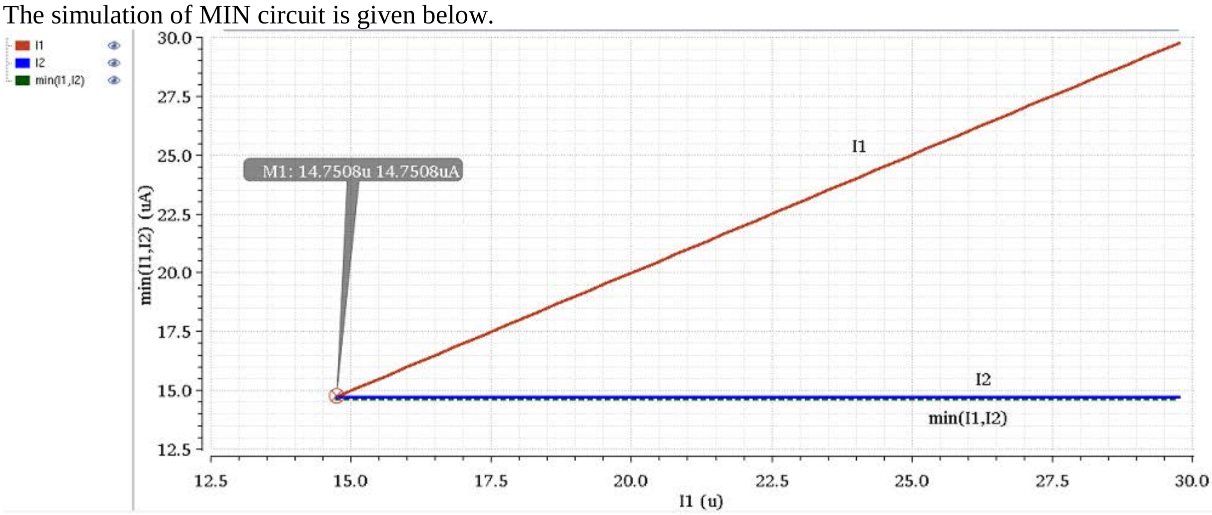

Fig.7. Input and output of minimum (MIN) circuit

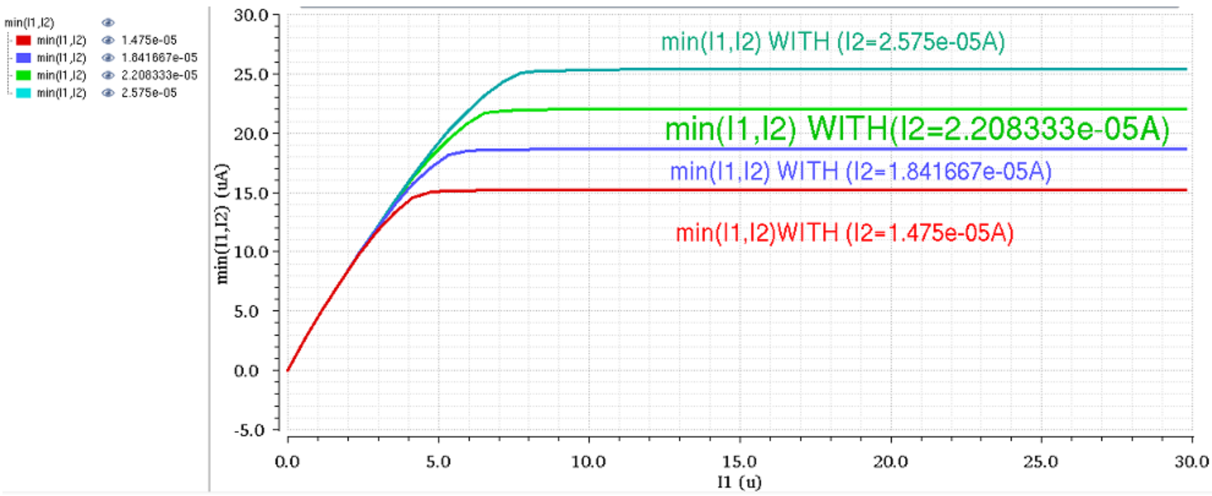

Fig.8. DC response of Min circuit of two inputs (i1, i2).

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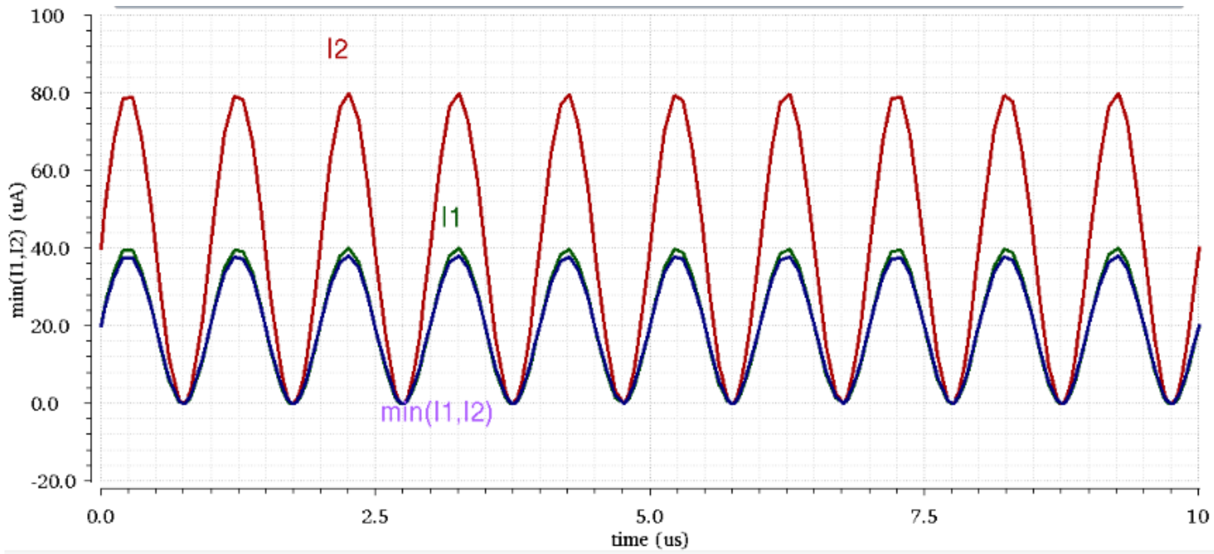

Fig.9. Transient response of two input minimum (MIN) circuit.

Maximum (MAX) function of two inputs x and y can be obtained using bounded difference operator and Add (+) operator as follows:

$$MAX\ (x, y) = (x \ominus y) + y \quad (3)$$

And the circuit is given in (Fig.10).

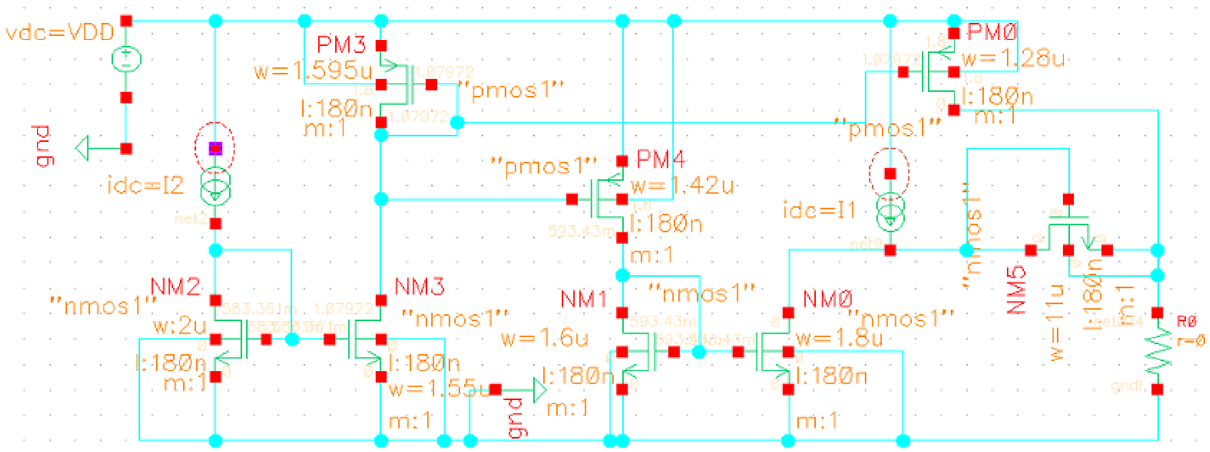

Fig.10. A two input MAX circuit

The input and output of Maximum (MAX) circuit is given below.

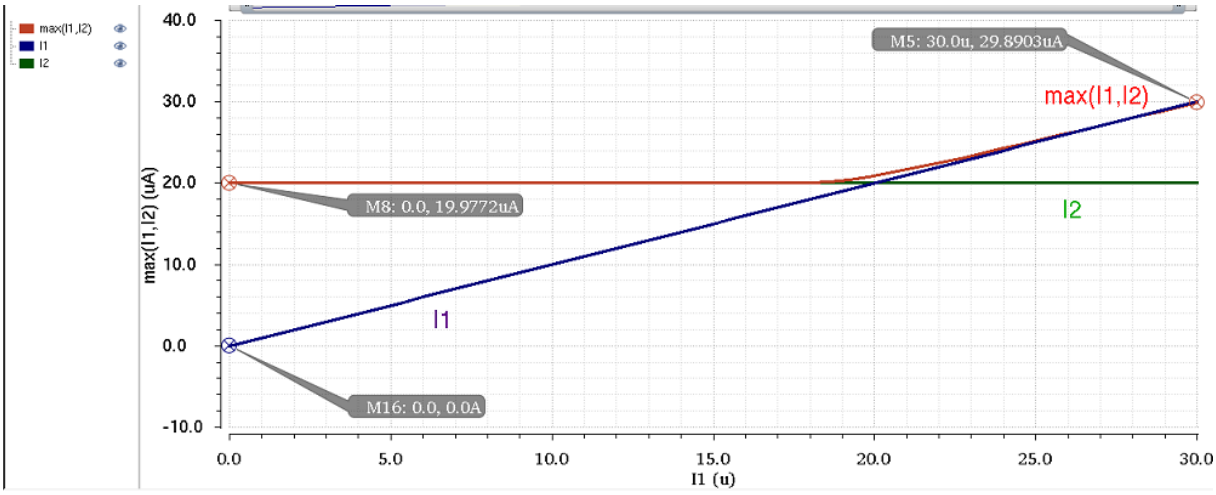

Fig.11. Input and output of MAX circuit

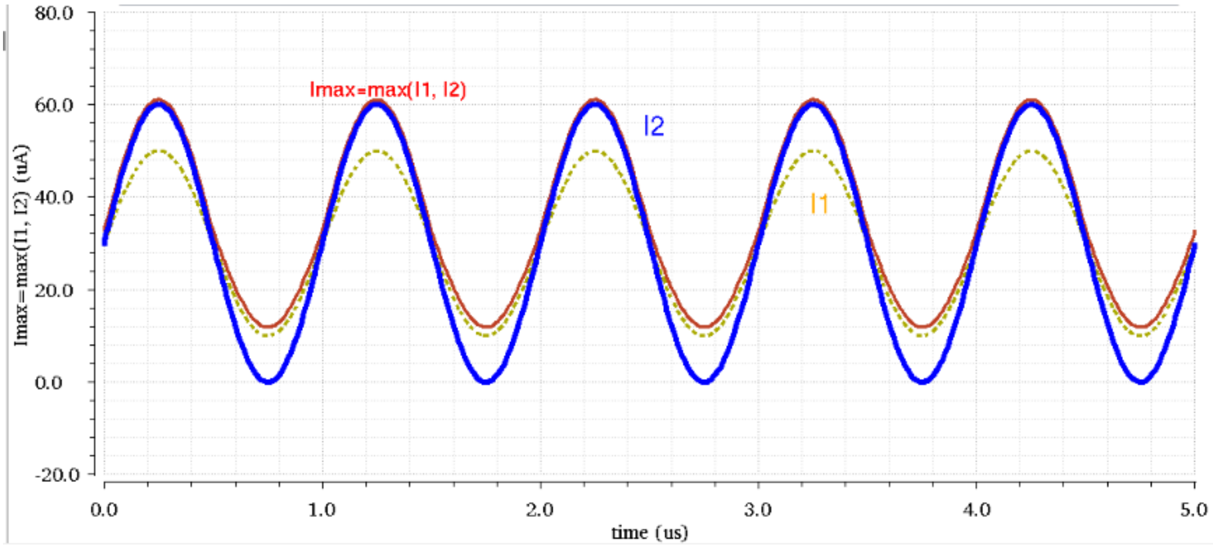

Fig.12. Transient response of two input MAX circuit.

4. Conclusion

In this paper, an attempt has been made here to initiate work on analog realization of fuzzy circuits using 0.18um CMOS technology, the different information least circuits are one-arranging circuit with high precision and have a vast powerful range. These structures are straightforward and secluded, so it very well may be effectively extended to meet the necessity of multi-input signals MIN and MAX circuits. Based on the reenactment results, it is apparent that the proposed circuit has the right capacity and sensible level of accuracy.

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