

“Design and Comparison of Hysteresis Margin and Width in Schmitt Trigger Oscillators Implemented with Logic Gates in 28 nm CMOS”

V.Manasa¹, S.Sajida², S.Salma³,

¹PG Scholar, ²Assistant Professor, ³Assistant Professor, Dept of ECE, Anantha Lakshmi institute of technology & sciences, Anantapuramu.

Abstract— This study compares two Schmitt trigger circuits with different parameters of the circuits like higher threshold and lower threshold. This configuration utilizes the properties of NAND gates to create a hysteresis effect, allowing for noise filtering and reliable threshold-based switching. The Schmitt trigger is commonly used in digital circuits, such as in the design of oscillators, waveform generators, and pulse generators. The 28 nm CMOS technology's Cadence and model parameters are employed to evaluate the recommended circuits' performance.

Keywords—Schmitt trigger, Hysteresis, NAND Gate, CMOS.

I. INTRODUCTION

An electrical circuit known as a Schmitt trigger is used to transform an erratic or noisy input signal into a clear and distinct output signal. An alternative name for it is a regenerative comparator circuit. Two distinct threshold voltage levels are built into the Schmitt trigger design: one for the input signal's rising edge and another for its falling edge. Only when one of these threshold levels is crossed by the input signal does the Schmitt trigger's output change states. Because of this, the Schmitt trigger circuit is highly beneficial for applications involving signal conditioning and noise filtering. It is frequently utilized in voltage level detectors, oscillators, and digital circuits. The circuit's resistor and feedback voltage divider settings define the hysteresis width. The amplitude of the threshold voltage difference between the upper and lower increases with the hysteresis window and the circuit's resilience to noise and fluctuations in the input signal. Due to its ease of usage and minimal component count, the Schmitt trigger solution with a NAND gate is widely adopted. It is also incredibly adaptable and has a broad range of uses [2].

The ability of a Schmitt trigger to produce hysteresis—a circuit's output changing state only when the input voltage is beyond a predetermined threshold—is one of its primary benefits. By doing this, the circuit becomes more resistant to noise and changes in the input signal. It is advantageous to use a NAND gate for the Schmitt trigger implementation because they are readily available and reasonably priced. The NAND gate can be used in high-impedance circuits because of its extremely high input impedance.

The Schmitt trigger's ability to be readily cascaded with additional logic gates to create more intricate circuits is another benefit of utilizing it with a NAND gate. Because of this, it's a helpful component for oscillators, voltage level detectors, and digital circuits [3].

II. METHODOLOGY

A. WORKING OF CONVENTIONAL CIRCUIT

The circuit diagram of conventional Schmitt trigger is shown in Fig. 1 [11]. A type of comparator circuit that guarantees a smooth output transition is called a Schmitt trigger between two stable states by producing hysteresis through positive feedback. An operational amplifier with a feedback loop that incorporates a voltage divider, and a diode makes up the circuit. The diode supplies the positive feedback required for hysteresis, while the voltage divider establishes the circuit's threshold voltages.

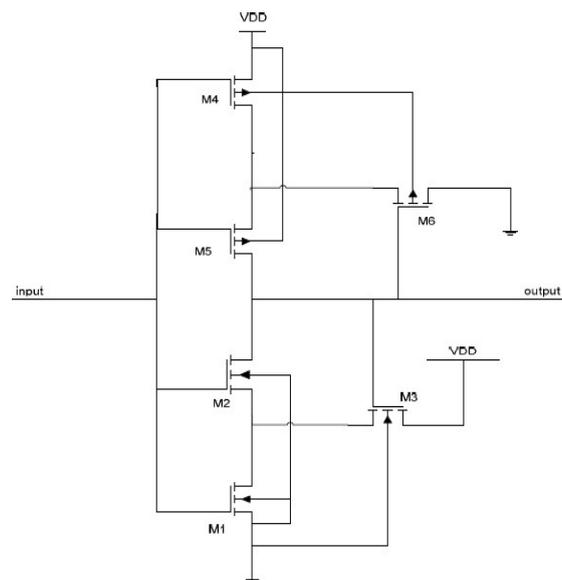


Fig. 1: Circuit diagram of Conventional Schmitt trigger

In the cut off mode, both MOSFETs M1 and M2 work and are turned off when the input voltage applied to their pins is zero volts, or a logic low level. Furthermore, the output voltage is raised to a high logic level since MOSFETs M4 and M5 are active. When the input reaches the M1's threshold voltage, it activates, while M2 stays closed. When the output is high, the M3 turns on and electricity begins to flow through it. [4] While MOSFET

pulls the same node up to $V_{DD}-V_T$ (switched on as the output is high), MOSFET M1 pulls down the node between M1 & M2. At the M2 output, a high logic is maintained. The output shifts from high to low logic when the input exceeds the M2 threshold.

Because M3 is pushing up the node between M1 and M2, a greater voltage is needed to draw it down. This is known as the upper switching threshold V_{IH} , and it causes the upper switching point to transition to a higher voltage. Moreover, PMOSs oversee moving the switching point to V_{IL} (lower voltage level) when input shifts from high to low logic. HYSTERESIS is the name given to the void that exists between V_{IH} and V_{IL} .

The transfer characteristics of conventional Schmitt trigger is shown in Fig. 2

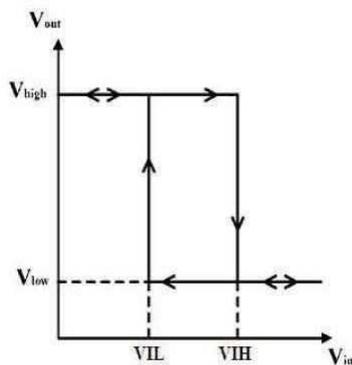


Fig. 2: Transfer characteristic of Schmitt trigger

Schmitt trigger circuits are helpful for a variety of signal processing and electronics applications because of their ability to produce steady and dependable switching behavior, as shown by simulation findings.

B. WORKING OF NAND GATE FUNCTION USING AN INVERTING SCHMITT TRIGGER

The Schmitt trigger circuit, a kind of comparator that employs positive feedback to produce hysteresis, receives the input signals A and B. [5] The output state of the Schmitt trigger is determined by the two threshold voltages, V_{th+} and V_{th-} . The Schmitt trigger has a low output when both inputs A and B are high. The Schmitt trigger's output rises as either A or B becomes low.

When inputs A and B are both low, the result stays high. After that, a NAND gate—a digital logic gate that generates a logical NAND function—is fed the Schmitt trigger's output and a second input that is linked to a constant voltage level are the NAND gate's two inputs.

Regardless of the second input, the NAND gate's output is low if the Schmitt trigger's output is high. If the second input is likewise low and the Schmitt trigger output is low, the NAND gate's output will be high. The NAND gate's output stays low if the second input is high.

Nand gate based using inverting Schmitt trigger is shown in Fig. 3. The input of circuit is pulse wave and output is showing in fig.6. these are the input and output of the circuit.



Fig. 3: Nand gate based using inverting Schmitt trigger

All things considered, the NAND gate, which is based on an inverting Schmitt trigger, offers a straightforward and trustworthy method of implementing a logical NAND function with digital logic circuits.

III. SIMULATION RESULTS

Schmitt trigger circuits are helpful for a variety of signal processing and electronics applications because of their ability to produce steady and dependable switching behavior, as shown by simulation findings.

The transient Input-output waveform of conventional Schmitt trigger is shown below in Fig. 4

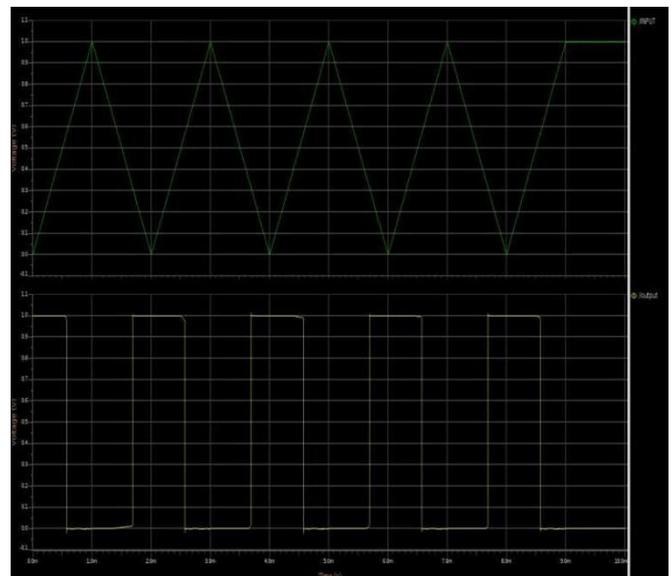


Fig. 4. Schmitt Trigger's Conventional Input-Output Waveform

Simulation is the process of creating a model of a real-world system or process and using that model to understand and analyze how the system or process behaves under different conditions.

The transient Input-output waveform of Nand gate based using inverting Schmitt trigger is shown below in Fig. 5

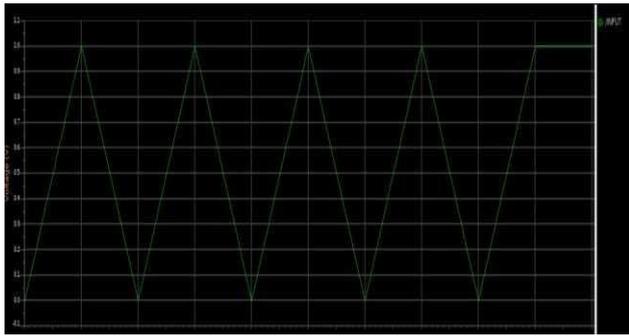


Fig. 5 Nand gate based input waveform employing an inverted Schmitt trigger

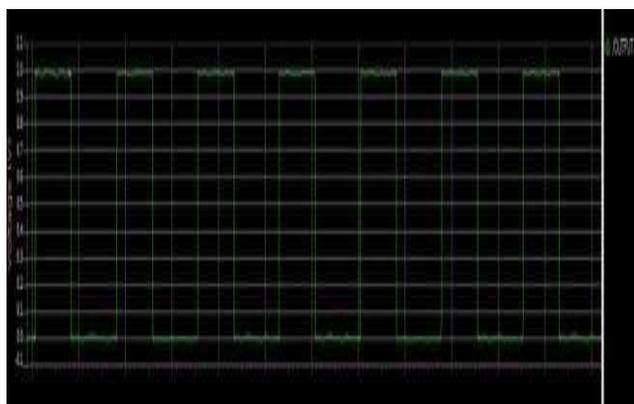


Fig. 6. Schmitt trigger inversion-based Nand gate output waveform

IV. COMPARATIVE ANALYSIS

A. Hysteresis width

The difference between VLH and VHL, which represent the Schmitt trigger's threshold voltages from high to low and from low to high, is known as the hysteresis width. In terms of math, it can be expressed as

$$HW = VLH - VHL$$

Where HW denoted as Hysteresis width

In Schmitt triggers, VLH normally refers to the voltage level at which the output changes from low to high (positive threshold), whereas VHL refers to the voltage level at which the output transitions from high to low (negative threshold). These voltage levels contribute to noise immunity and the definition of the Schmitt trigger's hysteresis by impeding fast switching in the vicinity of the threshold.

Hysteresis width in electronics refers to the variation in input voltage needed to turn a digital circuit on and off. Schmitt triggers, circuits that generate a clean digital output signal from a noisy input signal, frequently employ this. In this instance, the circuit's immunity to noise is determined by the hysteresis width.

B. Hysteresis Margin

The difference between a system's upper and lower set points is referred to as the hysteresis margin in control

system design. It is sometimes referred to as the dead band or hysteresis band.

Hysteresis margin is employed in control systems to prevent abrupt changes between the system's upper and lower set points. This can happen when the output quickly oscillates around the set point due to little variations in the input signal while the system is getting close to the set point. The system is made to settle inside a range of values The hysteresis margin, for instance, in a thermostat control. System would be the variation in temperature between the heating System's on and off temperatures. The heating system may switch on and off quickly if the hysteresis margin is too tiny, which would wear it out and waste energy. The room's temperature may change significantly before the heating system goes on or off if the hysteresis margin is too great [7].

The properties of the system and the intended control system performance dictate the hysteresis margin. It may be altered by adding more feedback loops or filters to the system, or by altering the set points.

TABLE I

EXAMINATION OF THE PROPOSED AND CONVENTIONAL CIRCUIT'S PERFORMANCE PARAMETERS

Parameter	Schmitt trigger (Conventional)	Schmitt trigger oscillator (using NAND gate)
Hysteresis Width(mv)	263	531
Hysteresis Margin(mv)	162	632

V. PERFORMANCE ANALYSIS

This section compares the suggested Schmidt trigger's performance to earlier research. Table II presents a performance comparison, with the dominating hysteresis width and hysteresis margin voltage are the parameters.

TABLE II

PERFORMANCE COMPARISON WITH PRIOR WORKS

References	Technology	Supply(v)	Hysteresis width(mv)	Hysteresis margin(mv)
[4]	180nm	0.5	162.951	-
[9]	180nm	0.8	170.270	-
[10]	130nm	0.4	76	-
S.T (Con.) This paper	28nm	1	263	162
S.T(using Nand gate) This paper	28nm	1	531	632

VI. CONCLUSION AND FUTURE SCOPE

Finally, subtle trade-offs are shown by contrasting Schmitt Triggers and Schmitt Triggers constructed utilizing logic gates in 28nm CMOS technology. Although the two concepts show promise in terms of Hysteresis width and Hysteresis margin, the use of logic gates in 28nm CMOS technology has prospective benefits in terms of lower power consumption and better integration with contemporary semiconductor processes. Nevertheless, the final decision between these designs is contingent upon application requirements, underscoring the need of considering variables like power efficiency, spatial limitations, and comprehensive system integration throughout the decision- making process [9].

Schmitt triggers are still useful in many electrical applications. Its continuous application in digital circuits for threshold detection, noise immunity, and signal conditioning represents its future potential. Schmitt triggers' energy-efficient qualities may also find uses in automation, low-power electronics, smart gadgets, and the Internet of Things as sensor and IoT technologies evolve. The Schmitt trigger's function in preserving signal stability and integrity is probably going to continue as technology advances. In digital circuit design, the Schmitt trigger used with NAND gates still has a bright future. Its uses include noise tolerance, square wave production, and signal conditioning. Schmitt trigger integration utilizing NAND gates may become useful in digital communication systems, low- power devices, and Internet of Things sensors as technology develops. NAND-based Schmitt triggers' intrinsic simplicity and adaptability make them important in the rapidly changing world of digital electronics.

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