Design and Implementation of a CMOS Schmitt Trigger using Skywater 130nm

Shravana H S

Department of Electronics and Communication Engineering, Dayananda Sagar Academy of Technology & Management
Bengaluru, Karnataka, India
Email: shravanahs97@gmail.com

Abstract

This paper focuses on the design and implementation of a CMOS Schmitt Trigger using Skywater 130nm PDK technology. The Schmitt Trigger is a widely used electronic circuit designed to filter out noise and improve signal stability by introducing hysteresis. This hysteresis creates two distinct threshold voltage levels—one for switching on and the other for switching off—ensuring smooth transitions and preventing rapid output fluctuations when the input signal is near the threshold. The dual-threshold mechanism makes the Schmitt Trigger essential for signal conditioning, noise reduction, and waveform shaping. The study examines various CMOS-based configurations, discussing their strengths, limitations, and applications. Simulations performed using eSim, along with comparisons to LTSpice, NGSPICE, and XSCHEM, provide a practical understanding of the circuit's behavior and performance. Overall, this work highlights the importance of Schmitt Triggers in digital systems, showcasing their ability to enhance signal integrity and improve noise immunity in modern electronic designs.

Keywords: Schmitt Trigger, CMOS

I. INTRODUCTION

The CMOS Schmitt trigger is an essential element in digital circuit design, known for its ability to provide stable output signals in the presence of noisy or slow-changing inputs. Its unique hysteresis property enables the circuit to produce well-defined transitions between high and low states, making it ideal for applications in signal conditioning, waveform shaping, and pulse generation. This paper will explore the implementation considerations and the practical realization of the circuit using CMOS technology. Additionally, we will discuss its significance in enhancing the performance and reliability of digital systems.

II. FUNCTION OF SCHMITT TRIGGER

The Schmitt Trigger is a crucial component in digital systems, serving multiple purposes to improve signal quality. Its primary function is to enhance **noise immunity**, as its hysteresis property ensures that small fluctuations in the input signal do not lead to spurious switching. This makes Schmitt Triggers essential for generating stable digital signals from noisy or analog inputs. Additionally, Schmitt Triggers excel in **signal conditioning** by defining distinct upper and lower threshold levels, which allows them to convert slow, noisy, or analog signals into clean, fast-transitions digital signals, thereby improving overall signal integrity. Furthermore, Schmitt Triggers play a key role in **waveform shaping**, transforming irregular or analog waveforms into well-defined digital pulses. This is especially beneficial in applications such as pulse generation, clock signal creation, and timing circuits, where precise, stable signals are necessary. Overall, Schmitt Triggers significantly enhance the reliability and performance of digital systems by stabilizing signals, improving noise immunity, and shaping waveforms.

III. WORKING PRINCIPLE

The working principle of a CMOS-based Schmitt Trigger relies on hysteresis and positive feedback to ensure stable and reliable digital output from noisy or fluctuating input signals. The circuit typically uses an operational amplifier (op-amp) configured as a comparator, with two distinct threshold voltages: an upper threshold (+Vth) and a lower threshold (-Vth).

When the input voltage exceeds the upper threshold, the output switches to a high state (logic 1). This transition is reinforced by positive feedback, which maintains the high output state even if the input signal fluctuates near the threshold. Similarly, when the input voltage drops below the lower threshold, the output switches to a low state (logic 0), with feedback ensuring the output remains stable.

The hysteresis effect, created by the difference between the upper and lower threshold voltages, prevents the output from toggling due to small fluctuations or noise in the input signal. This ensures reliable and clean transitions between the high and low states.

This mechanism makes the CMOS Schmitt Trigger essential for noise immunity, signal conditioning, and waveform shaping. It effectively converts noisy, slow-changing, or analog signals into sharp, clean digital transitions, playing a critical role in enhancing signal integrity in digital systems.

IV. CIRCUIT DIAGRAM

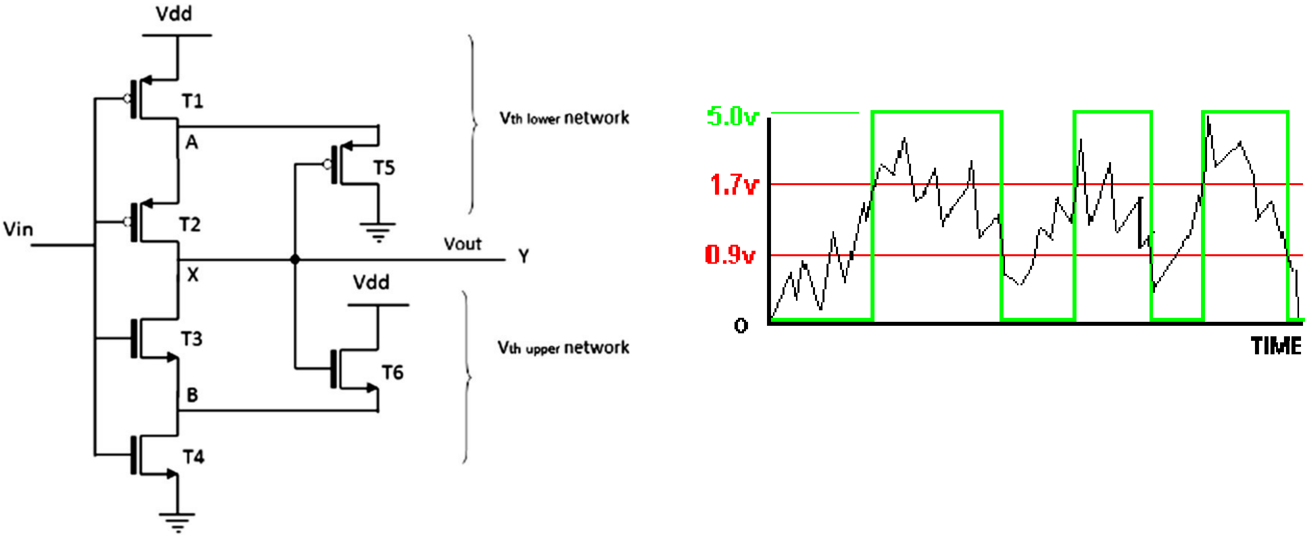

Fig. 1:CMOS based Schmitt Trigger with waveforms

The CMOS Schmitt Trigger circuit consists of two output stages that provide a stable high output when the input voltage exceeds the upper threshold voltage (+Vth) and a stable low output (0) when the input voltage falls below the lower threshold voltage (-Vth). This behavior introduces hysteresis, which helps maintain the output state even in the presence of input noise, ensuring reliable signal transitions.

The circuit features a **pull-up network** comprising PMOS transistors (T1 and T2) and a **pull-down network** comprising NMOS transistors (T3 and T4). The pull-up network drives the output high when the input voltage surpasses the upper threshold, while the pull-down network drives the output low when the input voltage drops below the lower threshold. This dual-threshold mechanism establishes the hysteresis characteristic.

Additional NMOS and PMOS transistors are incorporated to ensure precise switching behavior. These transistors work together to generate a high output voltage (+Vcc) when the input is high and 0V when the input is low. This arrangement provides effective control over the switching thresholds, stabilizing transitions and ensuring the Schmitt Trigger's functionality in digital signal conditioning and noise suppression applications.

V. EXISTING SYSTEM

The existing system demonstrates the implementation of a Schmitt trigger circuit using LTspice software. This circuit is designed to function as both a signal conditioner and a waveform shaper, which are essential components in digital electronics. The Schmitt trigger's primary role is to enhance signal integrity by filtering out noise and shaping waveforms to ensure reliable digital output. This functionality is critical for numerous digital applications where noise immunity and signal stability are vital.

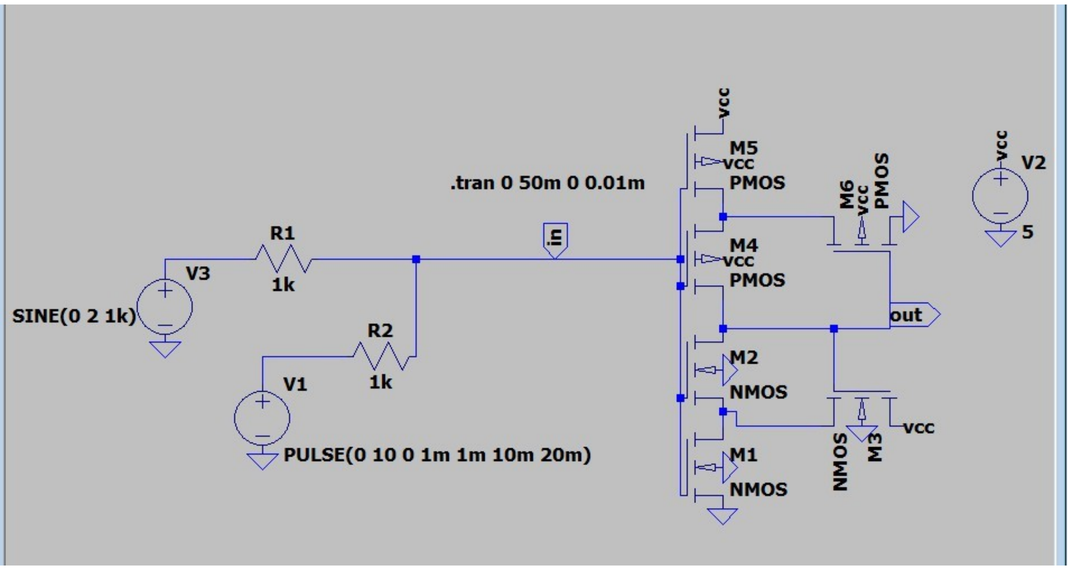

Fig. 2: Schmitt Trigger Circuit in LTspice

The Schmitt trigger circuit, designed in LTspice, incorporates a configuration of 3 NMOS and 3 PMOS transistors to establish hysteresis. This design enables the circuit to maintain two stable output states, determined by the input voltage's position relative to the upper and lower threshold levels. The hysteresis characteristic ensures robust operation, even in the presence of noisy or slow-changing input signals, making the Schmitt trigger a fundamental component in digital signal processing.

OUTPUT WAVEFORM

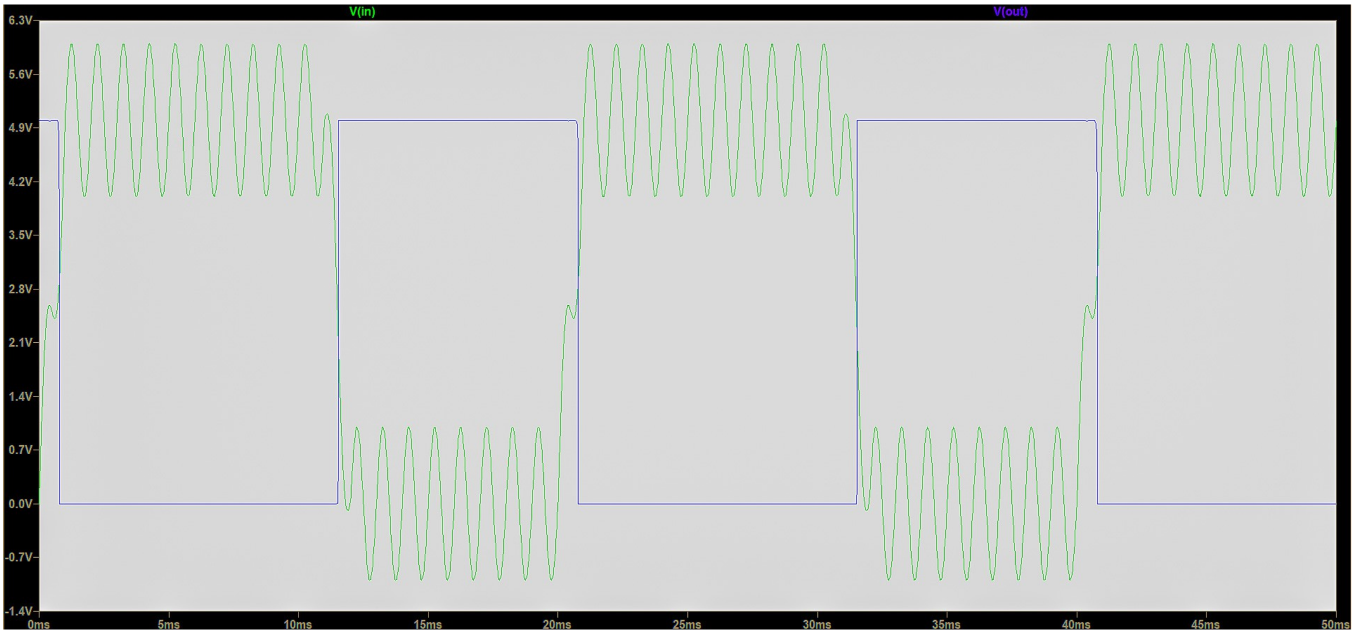

Fig. 3: Output Waveform of Schmitt Trigger Circuit in LTspice

Figure 3 illustrates the output waveform of the Schmitt trigger circuit simulated in LTspice. The **green** waveform represents the **input signal** applied to the circuit, while the **blue** waveform corresponds to the **output signal.** As the input signal crosses the upper and lower threshold voltages, the Schmitt trigger switches between its stable high and low output states This simulation demonstrates the Schmitt trigger's capability to filter noise and produce clean, well-defined digital transitions. The hysteresis effect ensures reliable operation by preventing unnecessary switching caused by minor input variations. This makes the circuit essential for applications requiring precise signal conditioning and noise immunity in digital systems.

VI. PROPOSED SYSTEM

The proposed system introduces a Schmitt Trigger circuit implemented using eSim software. This circuit aims to demonstrate the functionality of a noise remover and waveform shaper, which are essential in digital electronics. The schematic of the CMOS-based Schmitt Trigger is designed in eSim, and waveforms are analyzed using Ngspice.

(we are using normal mosfets for its model parameter we are using sky 130nm pdk file)

This circuit comprises:

- **3 PMOS and 3 NMOS transistors** configured to provide hysteresis through positive feedback.
- **Power supply:** +VDD is connected to the PMOS drains, and the NMOS sources are grounded.
- **Input signal:** Applied to the transistor gates.
- **Output signal:** Derived from the pull-up and pull-down network.
- **Noise injection Circuit:** consists of two 10k resistos which acts as a signal adder (noise+message signals)

1. NOISE INJECTION FOR ANALYSIS

To evaluate the robustness and noise immunity of the Schmitt Trigger, a **noise injection** was conducted as part of the simulation process. Noise was introduced to the input signal to observe the behavior of the circuit in handling external disturbances. To analyze the functionality of the Schmitt Trigger, a voltage divider network is used to merge a square wave digital input signal with a high-frequency sine wave noise signal. This creates a distorted message signal (Vin), simulating real-world noise conditions for testing.

- A sinusoidal noise signal with a controlled amplitude and frequency was superimposed on a slowly varying input signal (Square wave).
- The noise parameters used were:
  - **Amplitude:** Anoise=100mV(variable)
  - **Frequency:** fnoise=1MHz (adjustable based on noise testing scenarios).

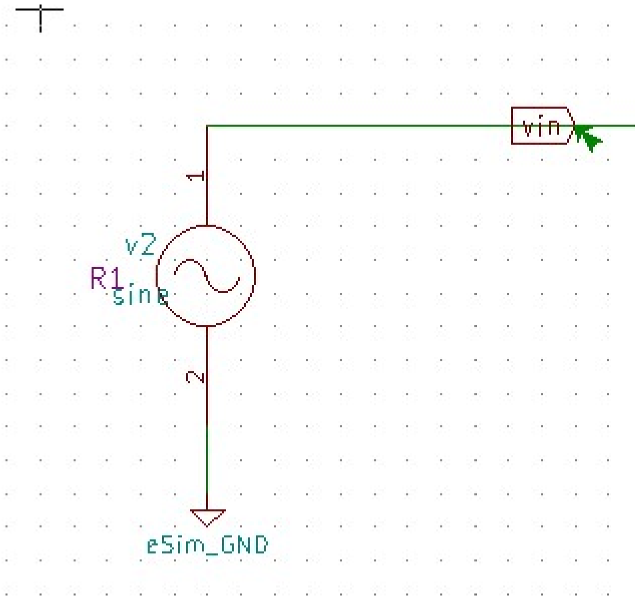

Fig. 5: Noise injection circuit for schemit - trigger in eSim

2. eSIM CIRCUIT

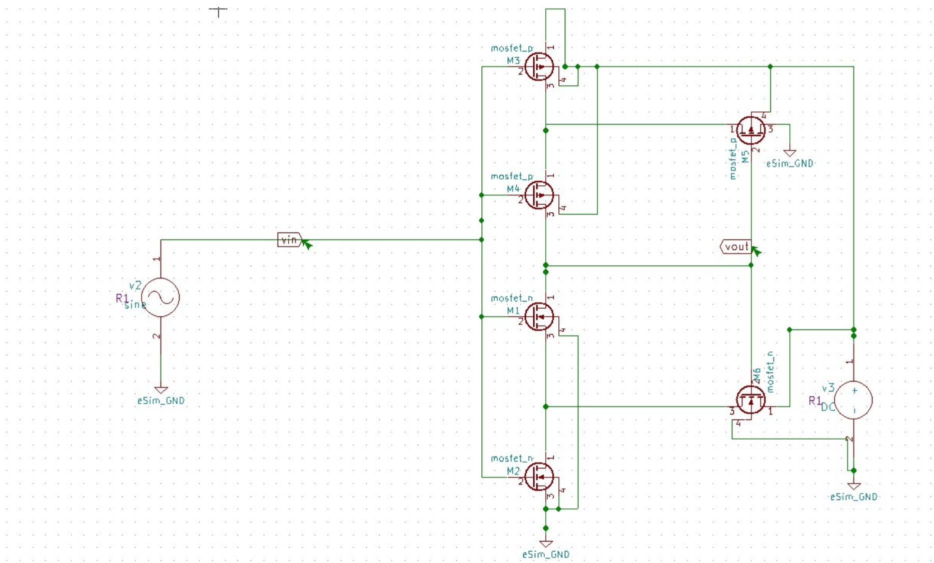

Fig. 6: Schematic of schemit - trigger in eSim

3. OUTPUT WAVEFORM

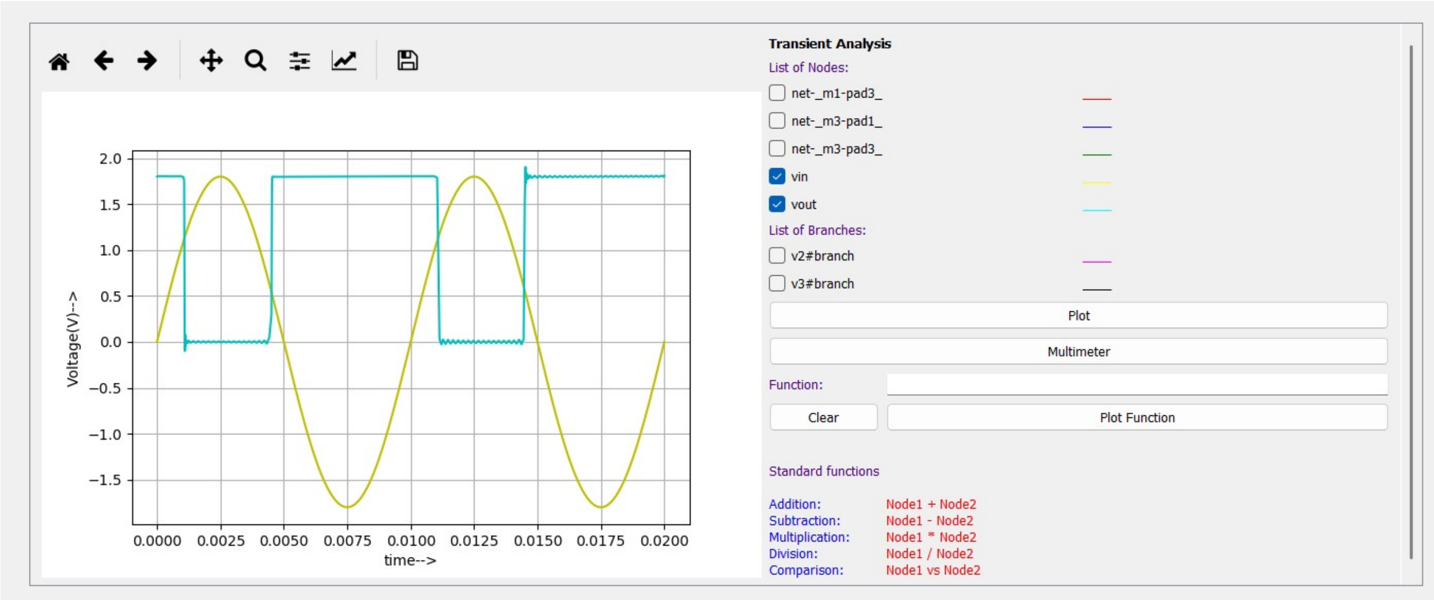

Fig. 7: Output Waveform of schemitt trigger Circuit in eSim

Figure 5 showcases the output waveform of the Schmitt Trigger circuit simulated using eSim software. The **red** waveform represents the **noisy input signal** applied to the circuit, while the **blue** waveform illustrates the corresponding **output response**. The input signal triggers transitions between the Schmitt Trigger's stable states as it crosses the upper and lower threshold levels. This process results in a clean and distinct output waveform, highlighting the Schmitt Trigger's capability to suppress noise and shape the waveform effectively. This demonstrates the circuit's utility in signal conditioning and digital electronics applications.

VII. CONCLUSION

The Schmitt Trigger circuit designed and simulated using eSim software effectively demonstrates its ability to perform noise removal and waveform shaping. By utilizing its hysteresis property, the circuit reliably transitions between stable states only when the input signal crosses predefined threshold levels, thereby suppressing noise and ensuring clean digital output transitions. The simulation results confirm the circuit's capability to condition noisy input signals into distinct and stable waveforms, making it a valuable component in digital electronics and signal processing applications. This study highlights the significance of Schmitt Triggers in improving signal integrity and enhancing the reliability of electronic systems.

REFERENCES

[1] GitHub - ShravanaHS/CMOS-Schemitt-Trigger-: CMOS based Schmitt Trigger using Sky water PDK 130nm Technology
[2] https://www.multisim.com/content/kFECPJyDZjNH5vqdz9xWWN/schmitt-trigger-using-op-amp/open/
[3] Microsoft PowerPoint - lect_19_CMOS_opamps.ppt
[4] https://spoken-tutorial.org/tutorial-search/?search_foss=eSim&search_language=English