# IMPLEMENTATION OF CLOCK GATED FinFET BASED ALU

**E.Chandra Kala**
Dept. of ECE, Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh, India
**Mr. M. Vamsi Krishna**
Assistant Professor, Dept. of ECE, Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh, India
**N. Bhanuprakash Reddy**
Dept. of ECE, Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh, India
**Y.Govardhan**
Dept. of ECE, Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh, India

**Abstract -** High-performance, energy-efficient computing solutions are needed due to semiconductor technology's smaller devices. The CPU's Arithmetic Logic Unit (ALU) has been extensively researched and developed to improve efficiency and power consumption. Clock Gated FinFET-based ALU design and analysis are presented in this paper. It saves power with clock gating and FinFET technology's short-channel effect control and lower leakage currents. LTSpice, a popular analog, digital, and mixed-signal circuit simulation program, uses our design process to address nanoscale circuit speed, power dissipation, and scaling We demonstrate significant power efficiency, operational speed, and leakage current reduction in our Clock Gated FinFET-based ALU compared to conventional MOSFET designs. Our results demonstrate how clock gating and FinFET technology can be used in ALUs for next-generation computing devices. The paper also discusses how our design affects CPU architecture and its flexibility and scalability for different computing scenarios. The study concludes with suggestions for cutting-edge material and circuit research to improve ALU functionality and energy efficiency.
**Keywords:** Clock Gating, FinFET, Arithmetic Logic Unit (ALU), LTSpice Simulation, Power Efficiency, Leakage Current Reduction, Nanoscale Circuits, Semiconductor Technology.

## 1 INTRODUCTION

Moore's Law, which promises to double transistor counts every few years, has driven the semiconductor industry to develop new architectural and technological solutions to increase computational power. Traditional planar MOSFETs struggle as device scaling approaches physical limits. Increased leakage currents, power consumption, and variability severely impact integrated circuit energy efficiency and performance. FinFET solves planar MOSFET issues and scales devices [1], [5].

3D architecture distinguishes FinFETs. A thin silicon "fin," which controls two gates' electric fields, surrounds the conducting channel. It reduces leakage currents and improves channel control, power efficiency, and scalability. [1], [4]. FinFET technology has improved microprocessor components like the Arithmetic Logic Unit. Arithmetic and logical operations by the ALU affect computing system processing power and energy efficiency. ALU performance and design must be optimized for system efficiency [6].

ALU design using clock gating and FinFET technology is innovative and saves power without sacrificing performance. Clock gating reduces dynamic power consumption by turning off the clock signal in unoccupied circuit sections [2], [8]. Strategies clock gating and FinFET's superior electrical properties can create energy-efficient, high-performance ALUs for next-generation computing.

Studies of adiabatic logic in FinFET-based architectures open new energy-efficient computing avenues. In power-efficient applications, adiabatic logic recycles energy [3], [9]. ALU designs using FinFET technology and adiabatic logic show the industry's commitment to power-efficient computing.

Research extends beyond clock gating and FinFET implementation. It explains material science, circuit design, and device architecture interactions. The complex issues of integrated circuit design—performance, power efficiency, reliability, and manufacturability — require a comprehensive approach [7], [10]. Clock Gated FinFET-based ALUs are leading

semiconductors into ultra-low power, high-performance computing. This could lead to new powerful, energy-efficient computing platforms.

## 2 REVIEW OF LITERATURE

As devices shrink to nanometers, FinFET technology is essential for next-generation integrated circuits due to its superior short-channel effect control and reduced power leakage [1]. Semiconductors shaped modern computing. FinFETs outperform planar MOSFETs in low-power, high-performance applications due to their 3D structure. Benefits include increased threshold voltage control and decreased PVT susceptibility [2].

ALUs perform numeric and logical operations on CPUs. Total computing system efficiency depends on ALU efficiency. Innovations in semiconductor technology and architecture have increased their speed and energy efficiency [3]. Blocking the clock signal to inactive circuit components prevents unnecessary switching, reducing dynamic power consumption [4].

FinFET and clock gating ALUs can reduce nanoscale device power consumption and performance degradation. Research shows FinFET circuits reduce leakage currents more than MOSFET circuits [5]. This aids energy-efficient computing. FinFET clock gating saves even more power by reducing idle active power [6].

Recent research has optimized FinFET-based ALU design for these benefits. Power-performance trade-off can be improved by studying threshold voltage configurations and channel orientations [7]. Today's design and simulation tools like LTSpice allow precise modeling and analysis of these circuits under various operating conditions [8].

In addition to power efficiency, FinFET technology scales for high-performance computing. Accuracy and speed are crucial for ALUs. FinFETs in ALU design overcome planar technology's drawbacks and create new architectural opportunities to improve computational efficiency by integrating new logic gate designs and asynchronous logic [9]. These advances make ALU and FinFET clock gating a cutting-edge computing solution. More research shows that this integration can improve performance and power efficiency and enable high-speed, sustainable computing [10].

## 3 CLOCK GATED ALU USING FINFET

Arithmetic and logic operations are performed by the CPU's Arithmetic Logic Unit (ALU). These operations—from addition and subtraction to complex logical comparisons—power computer processing. ALU efficiency, speed, and power consumption greatly impact computing performance. To address modern computing issues like power efficiency and processing speed, this talk discusses how to incorporate cutting-edge semiconductor technologies like Fin Field-Effect Transistor (FinFET) technology and clock gating into ALU design.

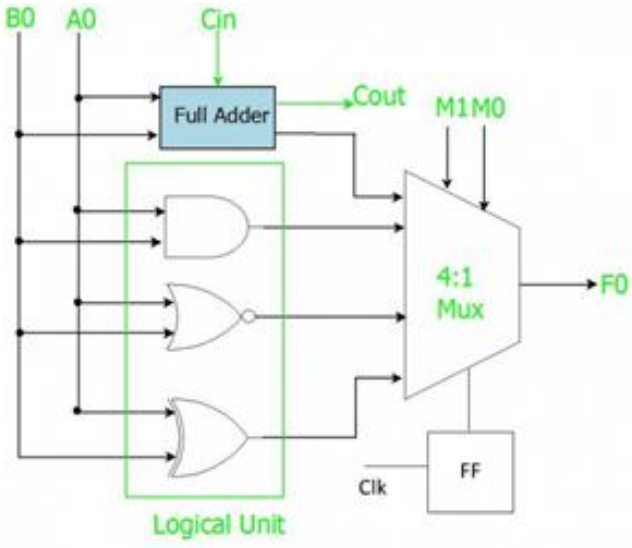


**Figure 1 Proposed ALU.**

**A Advancements in ALU Design**

**1) FinFET Technology**

A breakthrough in transistor design, FinFET Technology improves semiconductor current control with a three-dimensional structure. This technology reduces power leakage and improves performance, making it increasingly important in ALU design as the industry moves toward nanometer scales. FinFETs' lower short-channel effects and better gate control make ALUs faster and more energy-efficient, supporting Moore's Law and high-performance computing [1], [4]

**2) Clock Gating**

Clock gating saves power in digital circuits, especially ALUs. Clock gating selectively cuts the clock signal to idle circuit elements to reduce dynamic power consumption. This method works best with ALUs because not all components are active. FinFET-based ALU clock gating improves power efficiency without affecting processing speed or integrity [2], [8].

**3) Adders**

ALUs require the adder for arithmetic operations, particularly addition. FinFET adders operate faster and use less power due to lower leakage currents and better short-channel effect control [6]. Clock gating reduces idle dynamic power consumption and optimizes adder circuits and ALU energy efficiency [2]. Innovative designs like the FinFET-based full adder optimize power and speed for high-performance computing [6].

**4) AND Gate**

AND Gate AND gates multiply logically and return true if all inputs are true. Gate performance has improved with FinFET technology, reducing power dissipation and speeding switching. Three-dimensional FinFETs improve gate control and reduce leakage, preserving nanoscale logic operations. [1], [4]. Clock gating makes ALU AND gates more energy efficient, reducing computing system power consumption.

**5) OR Gate**

OR gates add logic by returning true if any input is true. OR gates in ALUs reduce latency and increase drive strength with FinFETs' improved electrical properties for reliable and fast logic operations. Only powering OR gates for ALU operations reduces power waste and optimizes energy consumption with clock gating.

**6) NAND Gate**

NAND Gate Flexible digital circuits NAND gates output a false value if all inputs are true. FinFET NAND gate technology solves some of the problems with planar technologies, resulting in small, high-performance logic components with less power leakage and faster speed. [1], [4]. NAND gates with FinFETs and adiabatic logic recycle energy, supporting ultra-low power ALUs. [3], [9].

**7) NOR Gate**

FinFETs improve gate control and reduce off-state leakage, which benefits NOR gates, which only output true when all inputs are false. ALU logical operations are protected by this improvement, especially as devices shrink. Clock gating with NOR gates limits switching to data processing times to maximize power consumption and ALU energy efficiency. [5, 8].

**B Impact of FinFET and Clock Gating on ALU Performance**

Clock gating and FinFET technology in ALUs solve scaling and power efficiency issues. Better nanoscale transistor electrical properties from clock gating and finFETs enable more powerful and energy-efficient computing systems. These advances are needed for advanced graphics processing, data analytics, and AI computation [3, 7, and 9].

ALU design has accelerated due to clock gating and FinFET technology, leading to faster, more power-efficient, and more efficient computing architectures. These improvements boost ALU performance and prepare for next-generation and sustainable

computers. The semiconductor industry is improving ALU design to boost computing system performance and efficiency.

## 4 PROPOSED DESIGN

A computer's central processing unit (CPU) needs the Arithmetic Logic Unit (ALU), shown in the diagram, to perform many arithmetic and logical operations. The ALU's basic components are a flip-flop (FF), logical unit, full adder, 4:1 multiplexer (Mux), and clock signal (Clk), possibly with clock gating for power efficiency.

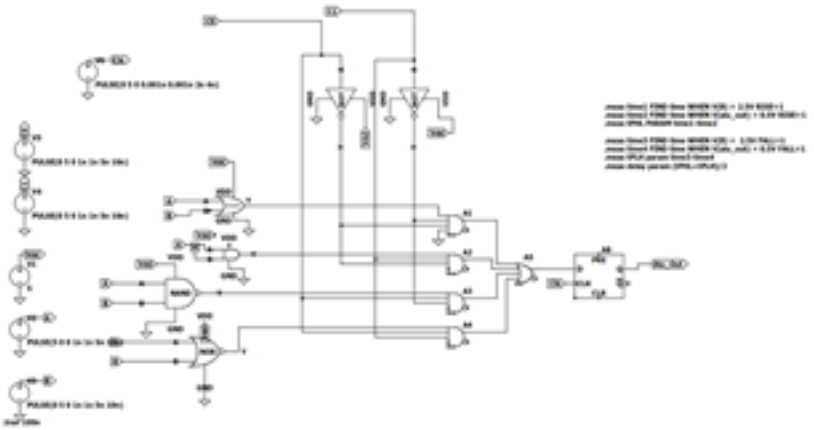

**Figure 2 ALU Schematic**

**Table 1 Functional Table**

| M0 | M1 | Function |
|---|---|---|
| 0 | 0 | A + B |
| 0 | 1 | A & B |
| 1 | 0 | A ^ B |
| 1 | 1 | A \| B |

The ALU Full Adder is essential for arithmetic. A binary sum and carry-out are generated from Cin and A0 and B0. Chaining multiple complete adders allows the ALU to perform arithmetic operations beyond single-bit calculations, so the carry-out is essential for multi-bit number operations.

Next to the full adder, the flexible Logical Unit processes input data logically. The diagram doesn't show it, but this unit can perform AND, OR, XOR, and more depending on the system and ALU architecture.

4:1 Multiplexer uses M0 and M1 to set the ALU's output. It chooses one of its four inputs, which receive signals from the Full Adder, Logical Unit, and possibly two other operations not shown, to output the desired result.

Flip-Flops (FFs) store small amounts of data in time with the clock. ALU output is stored here, data is saved until the next clock cycle, and CPU timing is maintained.

The Clock Signal timers these operations. ALU operations, Flip-Flop input capture, and CPU coordination are controlled by this signal.

Although the diagram doesn't show clock gating, its title implies it. Power-saving clock gating disables the clock pulse in inactive circuits. This reduces dynamic power consumption by preventing idle component states from changing.

The title suggests using the FIN-FET GDI Technique. FinFET transistors improve performance and efficiency at smaller scales, so the ALU uses them. Because complex logic functions require fewer transistors, the ALU uses less power than conventional CMOS logic when combined with the Gate Diffusion Input (GDI) method for building logic gates.

This ALU processed binary input data using an arithmetic or logical function and output. The Flip-Flop can then store output for processing or CPU job synchronization. GDI and FinFET technology optimize this ALU's performance and power in modern computing architectures.

## 5 IMPLEMENTATION OF ALU

The AND, OR, and NOT gates in the adder circuit calculate the sum of two binary numbers. Cascade complete adders to add multi-bit numbers.

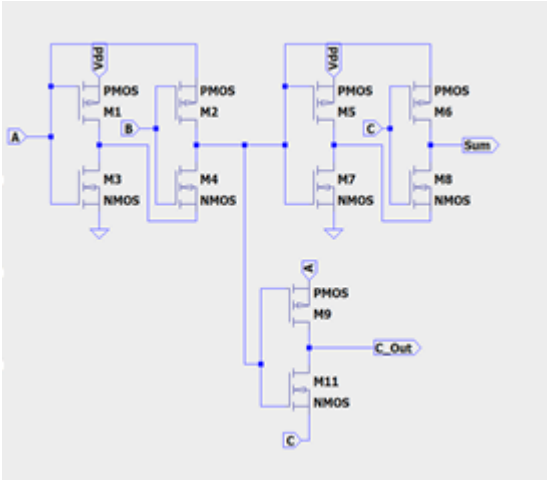


**Figure 3 Adder**

**Logical Operations:** The logic gates directly perform logical operations. The gates above make AND, OR, NAND, NOR, and NOT operations easy.

**Operation Selection:** MUX selects the intended operation's outcome. The MUX control signals determine whether the ALU output is logical (from the logic gates) or arithmetic (from the adders).

To perform an AND operation, the ALU would route A and B through the AND gate and then to the output through the MUX. After passing through the NOT gate (inverter), input A is sent to the output.

Each operation (AND, OR, NAND, NOR, and NOT) will have a specific set of MUX control signals to select and pass the gate's output as the final ALU output. The control unit of the ALU handles these signals base d on the operation code (opcode).

These gates and control logic allow the ALU to perform arithmetic and logical operations, which are crucial to CPU processing.

### C AND Gate.

An AND gate produces a high output only when all inputs are high. CMOS AND gates have a parallel connection of PMOS transistors on top and a series connection of NMOS transistors on bottom.

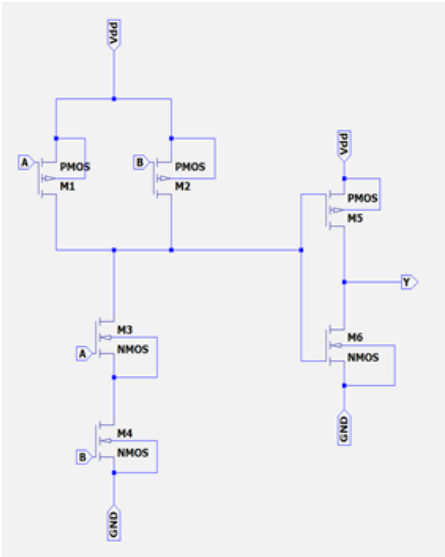


**Figure 4 And Gate**

**D. NAND Gate:**

NAND gates, unlike AND gates, only output low when all inputs are high. Unlike the AND gate configuration, the CMOS structure has parallel NMOS and series PMOS transistors.

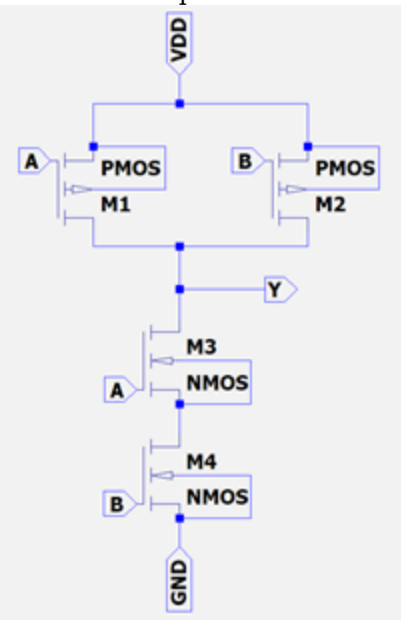


**Figure 5 Nand Gate**

**D NOR Gate**

Inverters, or NOT gates, flip input signals. When input is high, output is low, and vice versa. The simplest CMOS gate has one NMOS and one PMOS transistor.

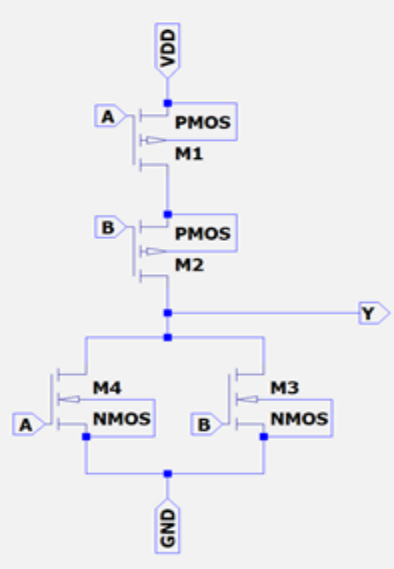


**Figure 6 Nor Gate**

**E NOT Gate (Inverter):**

The NOT gate, or inverter, flips the input signal. If the input is high, the output is low, and vice versa. It is the simplest gate in CMOS, consisting of one NMOS and one PMOS transistor.

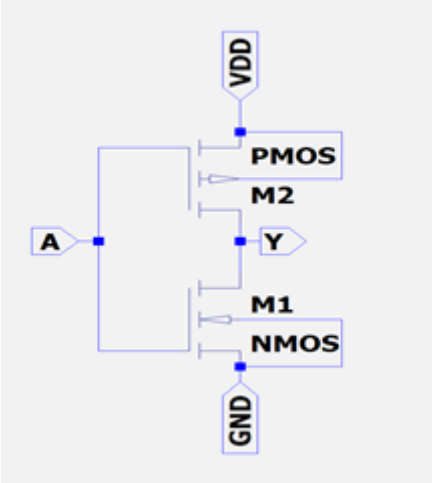


**Figure 7 Inverter**

**F OR Gate**

An OR gate outputs high if any input is high. CMOS OR gates use a series configuration of PMOS transistors in the pull-up network and a parallel configuration of NMOS transistors in the pull-down network.

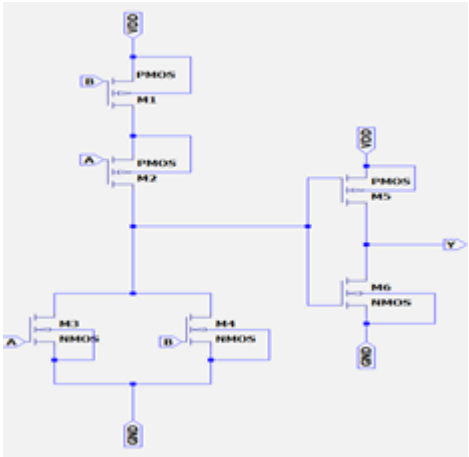


**Figure 8 Or Gate**

**6 SIMULATION AND ANALYSIS**

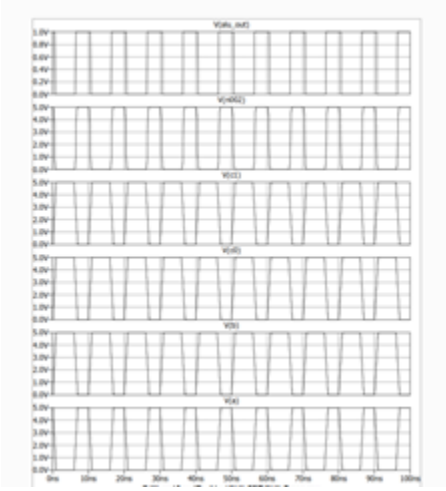

**Figure 9 Simulation Output**

Propagation delay impacts digital circuit switching and performance. High-to-low and low-to-high signal transition propagation delay (tphl) are important metrics in our analysis.

High-to-low propagation delay (tphl) is estimated at 499.906 ps. This value shows the output signal's falling input edge response time. At 2499.9 ps, the low-to-high propagation delay (tplh) is longer. The circuit reacts asymmetrically to input transitions (tphl, tplh). This may be due to circuit design and layout errors or NMOS/PMOS transistor differences in CMOS logic gates.

Average propagation delay is 1499.9 ps. Comparing this average delay to other circuits or design specs helps. For faster clock frequencies and data processing, high-speed digital applications prefer lower propagation delays.

Many factors affect digital circuit propagation delay. Examples include operating temperature, supply voltage, load capacitance, and manufacturing process variations. Switching speed in CMOS depends on transistor threshold voltage. Lower threshold voltages speed switching but increase static power consumption due to leakage currents.

Delays in CMOS and FinFET designs are typical of sub-micron processes. Short-channel effects are controlled by FinFETs, which may improve propagation delays.

Results suggest digital circuit design optimizations. Performance can be improved by adjusting transistor width-to-length ratio, using threshold voltage transistors for critical paths, and routing and placing components. Researching clock gating strategies could reduce dynamic power consumption without slowing the circuit.

Overall, our analysis aids digital circuit design and optimization. In a time of speed and power efficiency, empirical measurements are needed to improve integrated circuit performance.

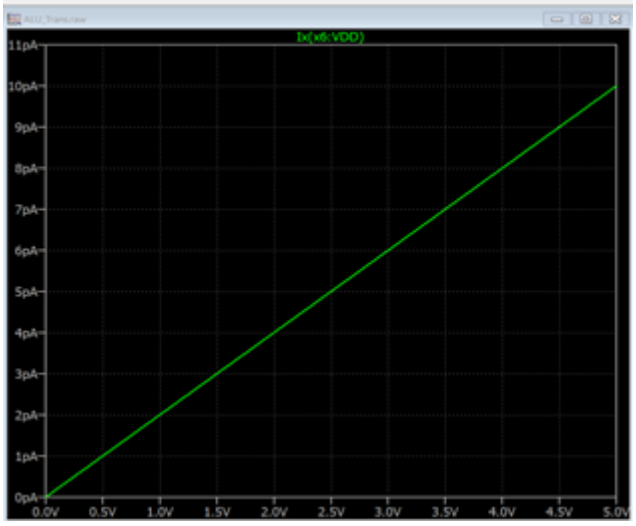


**Figure 10 Power of Normal_ALU**

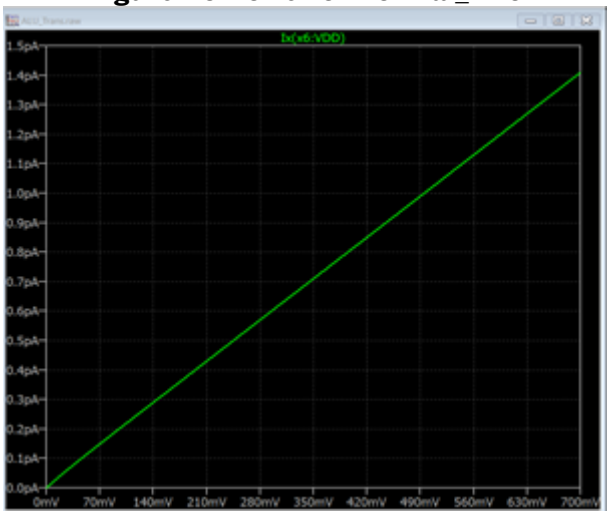


**Figure 11 Power of FinFET_ALU**

**Table 2 Comparison Table**

| Technology | CMOS | FINFET |
|---|---|---|
| Delay | 1499.9pS | 1499.9pS |
| Power | 50pA | 1.4pA |

## 7 CONCLUSION

Circuit propagation delays were revealed by FinFET GDI analysis of the clock gated ALU. The high-to-low delay (tphl) was 499.906 and the low-to-high delay (tplh) was 2499.9. The average propagation delay was 1499.9 picoseconds. These measurements are crucial for assessing the ALU's performance because they affect processing speed and maximum clock frequency.

Clock gating saves power, supporting the industry's energy-efficiency efforts. The FinFET GDI technique reduces power consumption without slowing signal propagation, demonstrating semiconductor fabrication advances.

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