Title of the experiment:

Circuit-Level Simulation Of A Smart Industrial Gas Leak Detection System With Auto-Ventilation And Latching Alarm.

Theory:

Operation & Working Principle

This industrial gas leak detection system utilizes mixed-signal hardware logic to provide a zero-latency, fail-safe response without relying on microcontrollers. The architecture is divided into 3 functional stages:

- **A. Sensing Stage (Wheatstone Bridge):** To simulate an MQ-series gas sensor's variable resistance, a Wheatstone bridge is utilized alongside a Piece-Wise Linear (PWL) voltage source. As simulated gas concentrations fluctuate, the bridge unbalances, generating a proportional analog millivolt signal.
- **B. Decision Logic (LM393 Comparators):** The analog signal feeds into an LM393 Dual Differential Comparator. It is evaluated against two DC reference thresholds:
    - **Moderate Leak (2.0V):** Triggers the primary exhaust ventilation.
    - **Critical Leak (3.5V):** Triggers the evacuation alarm.
- **C. Hardware Memory (SR Latch):** To comply with industrial safety standards, a critical alarm must not automatically deactivate if gas levels temporarily dip. The critical comparator's output passes through an ADC bridge into a hardware **Set-Reset (SR) Latch** (constructed from cross-coupled digital NOR gates). Once triggered, the internal feedback loop locks the alarm in a continuous logic '1' (5V) state. It remains latched until an operator manually triggers a 5V reset pulse to clear the memory.

Schematic Diagram:

The circuit schematic of Circuit-Level Simulation Of A Smart Industrial Gas Leak Detection System With Auto-Ventilation And Latching Alarm in eSim is shown below.

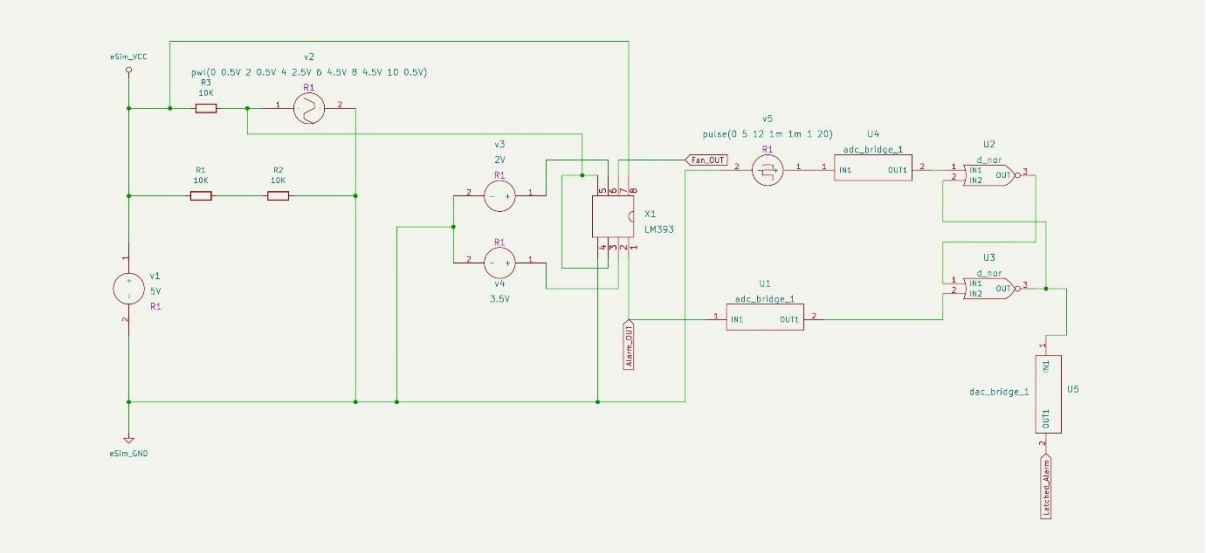

Figure 1: Mixed-Signal SR Latch Configuration

Simulation Results:

1. Ngspice Plots

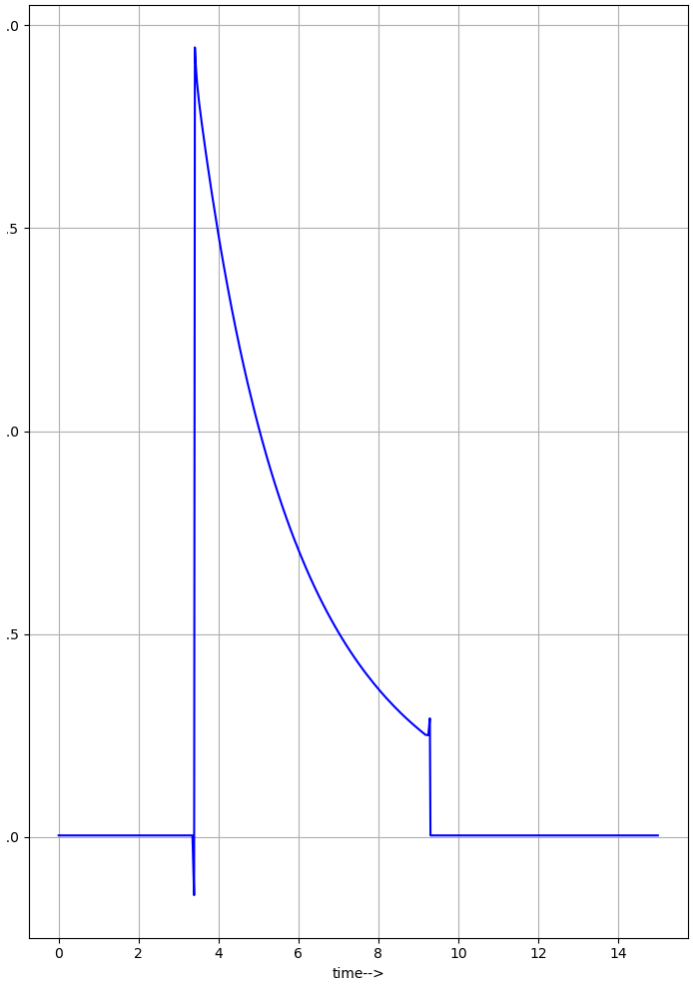

Figure 2: Output response of Fan node.

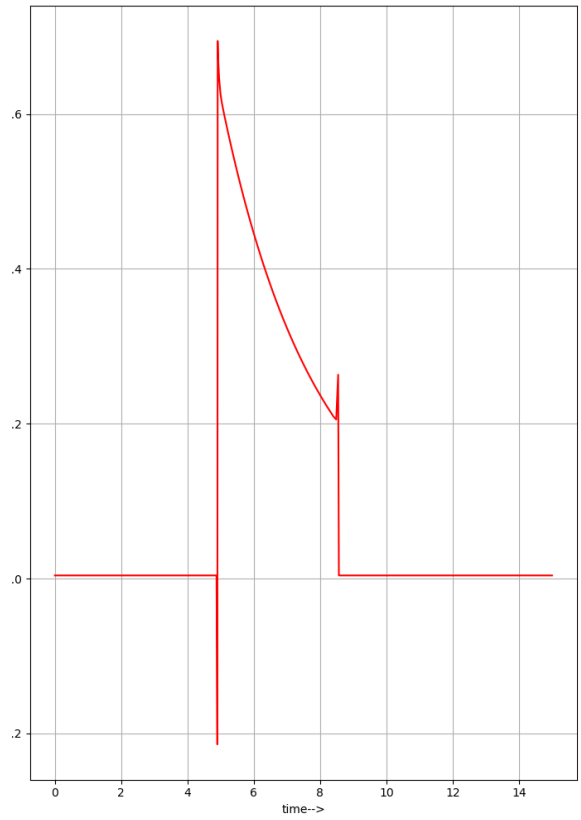

Figure 3: Output response of Alarm node.

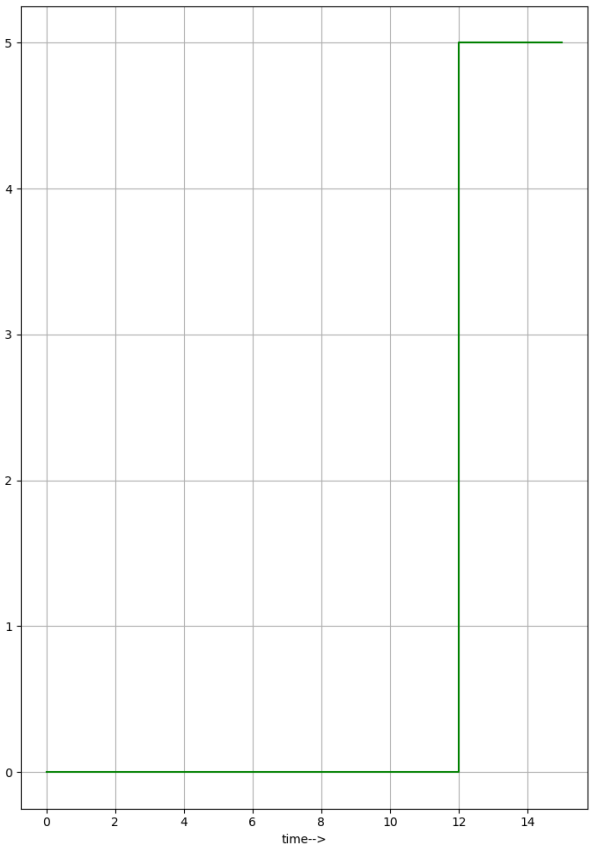

Figure 4: Output response of Latched_Alarm node.

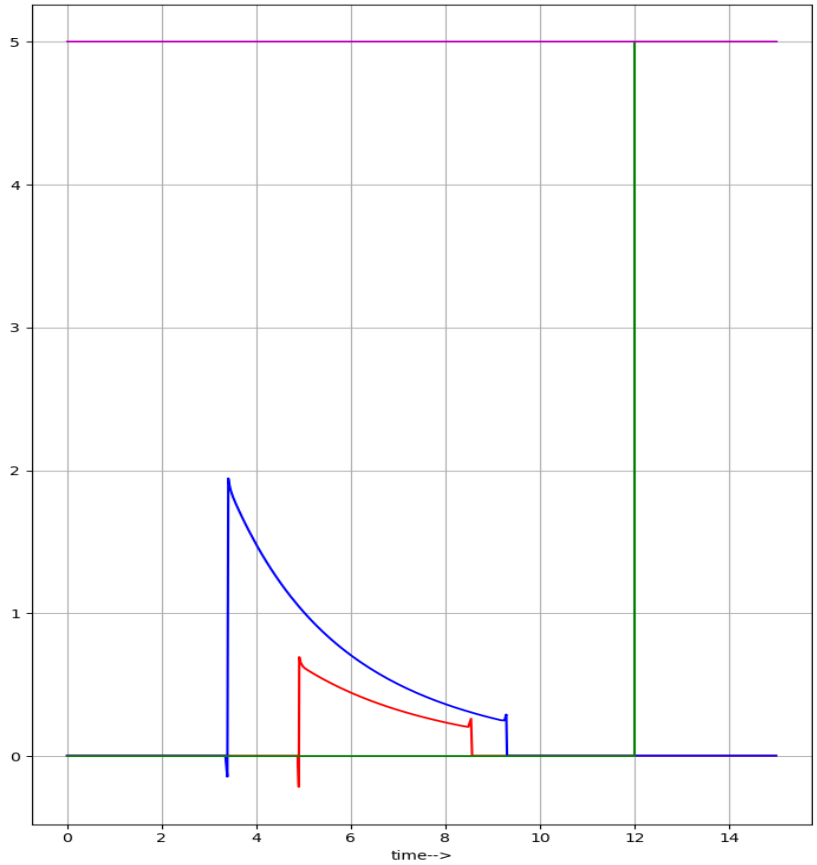

Figure 5: Output response.

Conclusion:

The project successfully demonstrated the design and simulation of a fail-safe, mixed-signal industrial gas leak detection system. By utilizing an LM393 dual differential comparator and cross-coupled NOR gates for hardware memory, the system effectively differentiated between moderate and critical gas concentrations without the reliance on a microcontroller. The Ngspice simulation verified the core safety objectives: automated actuation of exhaust ventilation during moderate leaks, and the permanent latching of a critical evacuation alarm that safely remained active until manually reset by an operator. This purely hardware-driven architecture ensures zero-latency signal processing and eliminates the risk of software crashes, proving its high reliability and suitability for hazardous industrial environments.

References:

1. https://ieeexplore.ieee.org/abstract/document/10060907?utm_source=copilot.com
2. https://www.scribd.com/document/960119611/l00-sv