Team 2

PROJECT REPORT

ELEG103 | Lab

Supervised by: Eng. Alaa Tarek

Team 2

Abdullah Gamil Mohammed - Abdelrahman Hassan Mohammed
Bassel Ahmed Mohammed - Kaream Mohamed Taha

Abstract

This project addresses the critical medical risk of air embolism and blood backflow caused by unnoticed empty Intravenous (IV) bags. We designed and implemented a **low-cost "IV Near-End Alarm System**" that automatically alerts medical staff when fluid runs out. The solution utilizes an **N-Channel MOSFET (2N7000)** as a logic inverter switch, leveraging the electrical conductivity difference between saline solution and air. The final prototype successfully triggers an immediate audio-visual alarm upon fluid depletion while ensuring patient safety through high-impedance sensing.

1. Introduction

Intravenous (IV) Therapy System: IV therapy is a standard medical procedure used to deliver fluids, medications, and nutrients directly into a patient's vein. It relies on a fluid bag suspended above the patient, using gravity or a pump to regulate flow.

Importance of Monitoring: Continuous monitoring of the IV fluid level is vital to ensure the patient receives the full prescribed dosage without interruption. It is also crucial for preventing complications that arise when the line runs dry.

Problems with Empty IV Bags:

1. **Air Embolism:** If air enters the vein, it can travel to the heart or lungs, potentially causing fatal blockages.
2. **Blood Backflow:** When pressure in the IV line drops, blood may flow back into the cannula, causing clotting and requiring painful re-insertion.
3. **Nurse Workload:** Medical staff must frequently check IV bags visually, which is inefficient and distracting in busy wards.

Project Objective: The objective is to design an automated electronic circuit using a MOSFET to detect the depletion of IV fluid and trigger an alarm, thereby enhancing patient safety and reducing the monitoring burden on nurses

2. Problem Statement

The Core Issue: critical need for affordable monitoring solutions in the medical field, specifically regarding IV (intravenous) therapy. While modern hospital-grade IV pumps utilize expensive ultrasonic or optical sensors to detect fluid levels, their high cost often limits accessibility in resource-constrained environments.

Limitations of Manual Monitoring:

- Human error and fatigue.
- Disturbance to resting patients during frequent checks.
- Delays in changing the bag, leading to treatment interruptions.

Need for a Solution: There is a strong need for a simple, low-cost, and reliable electronic device that can alert medical staff as soon as the IV fluid reaches a critical low level.

Inspiration & Literature Review: The design of this system is informed by a comparison between high-end medical patent literature and low-cost industrial sensing.

- **Industry Standards:** A review of existing medical technology, such as **US Patent 5,563,584A**, reveals that traditional IV monitoring relies on complex optoelectronic bubble detection or volumetric timers. While effective, the literature notes these systems are historically expensive **(costing ~$2,000)** and mechanically complex, making them inaccessible for resource-constrained environments.
- **Technical Adaptation:** To bridge this gap, this project adapts the **resistive soil-moisture sensing** principles commonly used in agriculture and industrial water-level indicators. By treating the saline solution as a conductive medium (similar to moist soil) we can use a **MOSFET** as a high-sensitivity electronic switch.

This hybrid approach takes the reliability of industrial "near-end" sensing and applies it to a medical context. The result is a system that provides the same life-saving alerts as expensive hospital-grade pumps but at a fraction of the cost, ensuring timely replacement of the IV bottle and preventing the risk of air embolism..

3. Project Objectives

1. **Automatic Detection:** Reliably detect when the IV fluid reaches a critical low level in the drip chamber or tube.
2. **Immediate Alert:** Trigger a loud audio and visual alarm before the bag becomes completely empty to allow time for replacement.
3. **Patient Safety:** Ensure the electrical sensing mechanism uses negligible current to prevent any harm or chemical reaction in the fluid.
4. **Simplicity & Cost:** Design a circuit that is easy to build, affordable, and uses standard electronic components (specifically a MOSFET).

4. System Overview

General Operation: The system operates on the principle of **electrical conductivity**. Saline solution is a conductor, whereas air is an insulator. Two probes are placed inside the fluid path. When fluid is present, it closes a circuit; when fluid is gone, the circuit opens. This change is processed by a MOSFET to switch an alarm ON.

Block Diagram:
[Conductivity Sensor] --> [Signal Conditioning (Resistor Network)] --> [Control Switch (MOSFET)] --> [Output Load (Buzzer & LED)]

Block Descriptions:

- **Sensor:** Two copper probes acting as a variable resistor R_fluid.
- **Signal Processing:** A voltage divider network that converts resistance changes into voltage levels (0V or 5V).

- **Control Switch:** A 2N7000 MOSFET that acts as a logical inverter.
- **Alarm:** An active buzzer for sound and a Red LED for visual indication.

5. Hardware Components

Component	Name/Type	Purpose	Why Chosen?
Transistor	**2N7000**	**Central Control Switch (MOSFET).**	???

Answer the Question: Why did we use the MOSFET for this circuit ????

1- First reason: Without the MOSFET the logic of the circuit will invert.

The buzzer will alarm when the two probes conduct (in water), and turn off when they don't conduct (in air).
So, **the MOSFET works as an inverter switch**

2- Second reason: we will need about a **100 V voltage source !!!**
The resistance of water is about 5 KΩ. This means with our source 5V, The current in circuit will be 5V / 5KΩ= 1 mA (can't operate the Buzzer which needs at **least 20mA**)

So, **MOSFET has High Input Impedance**, meaning it draws almost zero current from the sensor/fluid

3- Third reason: even if we use 100V to operate the buzzer, it is a clinical problem because this current will change the chemical properties of the medication

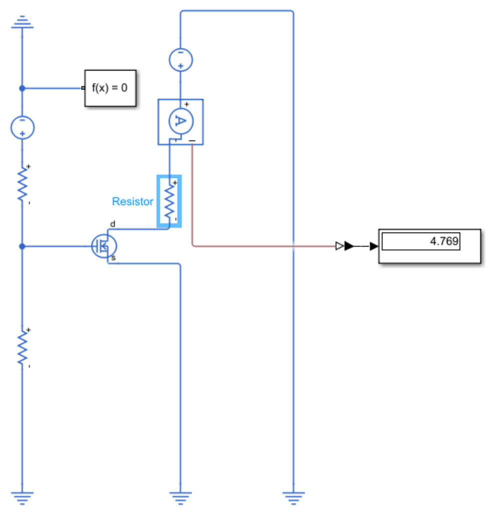
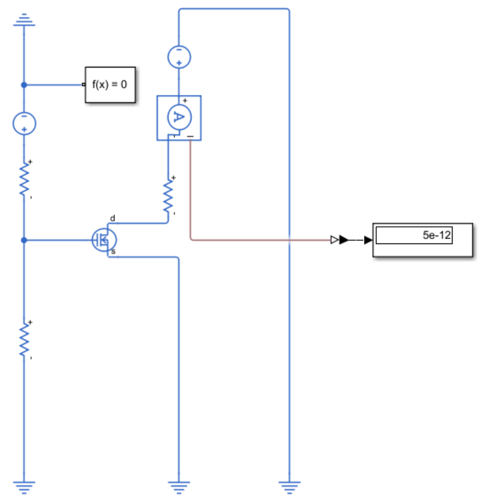
Component	Specification	Function	Notes
Sensor	Copper Probes	Fluid Detection	Utilizes saline conductivity for simple implementation.
Resistor R_1	$100\ K\Omega$	Pull-up Resistor	Sets logic to HIGH when empty; limits current to $50\ \mu A$.
Resistor R_2	$220\ \Omega$	Current Limiter	Protects the LED from overcurrent/burning out.
Output	Active Buzzer	Audio Alarm	Provides audible warning for staff outside the room.
Power	5V DC	Power Supply	Safe low voltage; compatible with USB or batteries.

6. Circuit Design

Circuit Configuration: Common Source N-Channel MOSFET (Switching Mode).

Key Connections:

- **Gate (G):** Connected to the midpoint of the voltage divider formed by the 100kΩ pull-up resistor and the fluid probes.
- **Source (S):** Connected directly to Ground (GND).
- **Drain (D):** Connected to the negative terminal of the Load (Buzzer & LED).
- **Load (Buzzer):** Connected between the positive supply (+5V) and the Drain.

	
Circuit simulation with very big R ("probes in air ")	Circuit simulation with very R ("probes in water")

Safety Considerations: The current passing through the probes (and potentially the fluid) is governed by Ohm's Law:

$$I\ probe = VDD/R\,pullup = 5V\ /100,000\Omega = 50\mu A$$

This current is extremely low (0.05 mA), which is well below the threshold for electrical shock or significant electrolysis, ensuring patient safety

7. Working Principle (Voltage Divider)

Step-by-Step Operation:

1. **Initialization:** The system is powered by 5V. Probes are inserted into the drip chamber.
2. **Normal Operation (Bag Full):** The saline solution connects the two probes. This creates a low-resistance path to the ground. So, Voltage at the gate will get divided between the 100 k-ohm (pull-up resistor) and the 5k-ohm with a ratio **20:1** so voltage at Gate is about 5V / 20 = 0.025 V (less the threeshould)
   - Result: $V_{GS} < V_{th}$. MOSFET is **Cut-off**. Output is **OFF**.

3. **Depletion Event:** The fluid level drops below the probes. Air replaces the fluid. Air is an electrical insulator (Infinite resistance).

4. **Signal Inversion:** With the ground path broken, the 100kΩ pull-up resistor pulls the Gate voltage up to the supply voltage (5V).

5. **Alarm Activation:**
    - Result: $V_{GS}(5V) > V_{th}(0.8V -> 3V)$. The MOSFET enters the **Ohmic (Triode) Region**, acting as a closed switch.
    - Current flows through the Drain, activating the **Buzzer** and **LED**.

8. References

[1] Pypendop, J. (1996). *Liquid level sensing and monitoring system for medical fluid infusion systems*. U.S. Patent No. 5,563,584A. Google Patents.