Smart Industrial / Home Safety Monitoring System

5FTC2135 - Analogue and Mixed-Signal Design

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Project Overview

We designed and implemented a multi hazard safety monitoring system capable of detecting:

Metal Object Proximity

Door/Window Intrusion

Water Leakage/Level

Temperature Hazards

Abnormally Loud Sounds

Manual Panic Touch

The system uses an ESP32 microcontroller to integrate digital & analogue signals, perform real time processing, and display alerts on an OLED interface with LED + buzzer support.

Problem Statement & Motivation

THE PROBLEM

Most low cost safety devices only detect one type of hazard, such as smoke, motion, or water. This creates significant blind spots in comprehensive safety coverage.

Overlapping Risks: Water leaks near electronics.

Dynamic Environments: Loud machinery masking audio alarms.

Blind Spots: Lack of metal detection in industrial zones.

OUR SOLUTION

We developed a compact, cost effective, mixed signal system to cover all essential hazards in one unified platform.

Comprehensive Coverage: 6 Sensors in 1 Device.

Unified Alerts: Centralized OLED & LED Status.

Cost Effective: Affordable for homes & small workshops.

System Architecture

Input Sensors

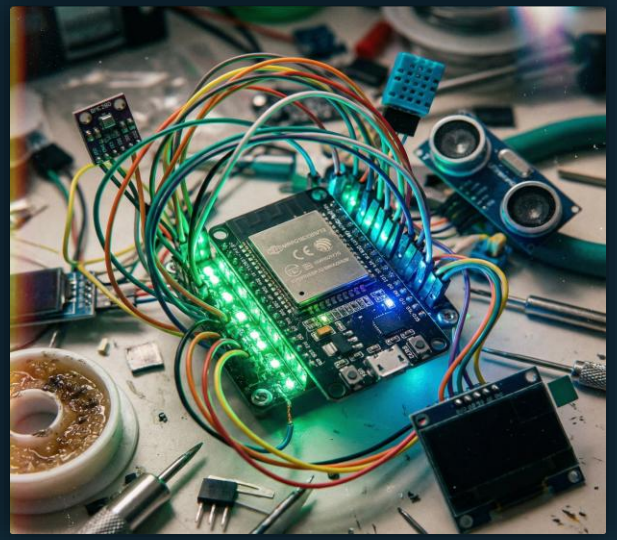
- Metal proximity (SN04N)
- Door/window state (Reed Switch)
- Water level (Float Switch)
- Temperature (DS18B20)
- Touch trigger (TTP223)
- Sound level (SY-M213 + LM358)

Processing (ESP32)

- Digital GPIO readings
- Analogue ADC sampling
- Signal filtering & debouncing
- Threshold detection
- Multi sensor decision fusion

Outputs

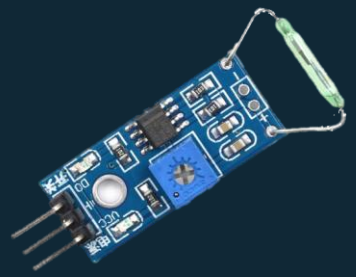
- OLED display (I²C)
- RGB LED for visual alerts
- Buzzer for audio warnings



Sensor Details: Digital

SN04N Proximity Sensor

Detects metal objects using electromagnetic induction. Features a 12V output signal that is safely scaled down to 3.3V for ESP32 compatibility.

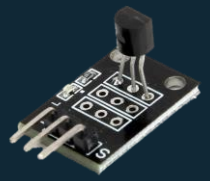


Magnetic Reed Switch

Monitors the opening and closing state of doors and windows, providing immediate intrusion detection. Simple and reliable for binary state monitoring.

Float Switch (Water Level)

Triggers alerts when water rises above a predefined level or when a leakage occurs, crucial for flood prevention and water damage mitigation.



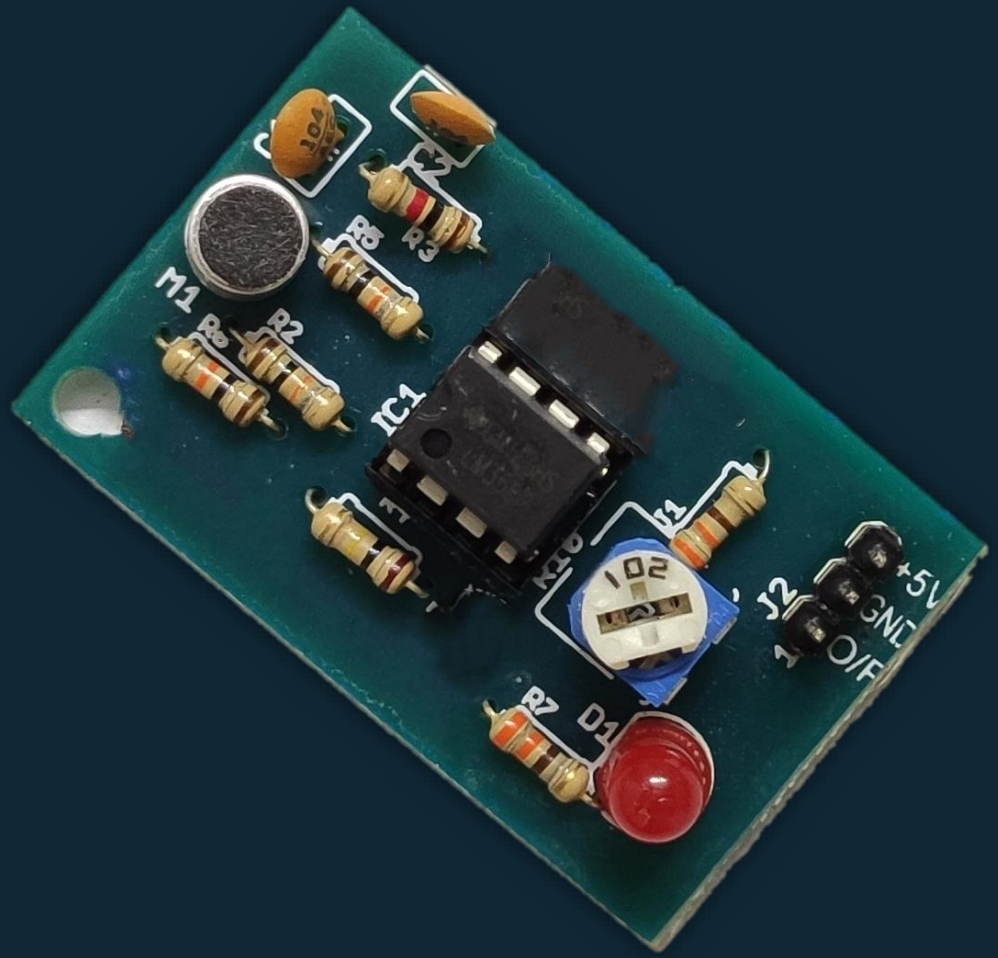
DS18B20 Temperature Sensor

Provides accurate digital temperature measurements using a OneWire protocol, enabling precise environmental monitoring and hazard detection.

TTP223 Touch Sensor

Serves as a highly responsive emergency or panic button, allowing for manual activation of alerts in critical situations.

Sensor Details: Analog



SY-M213 Microphone + LM358 Amplifier

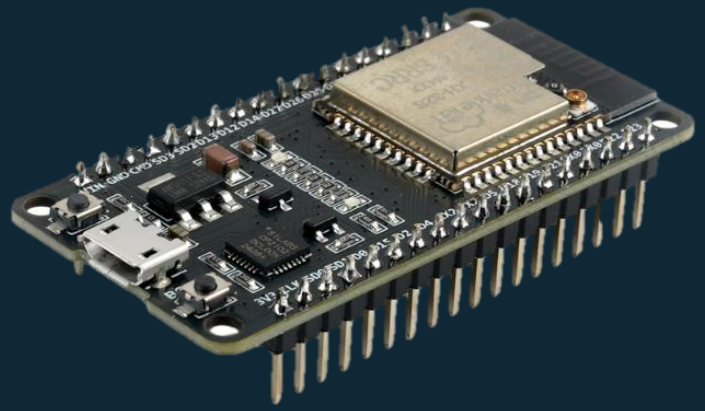
- **Non Inverting Amplification:** The LM358 operational amplifier boosts the weak microphone signal for clearer processing by the ESP32.
- **Noise Reduction:** An integrated RC (Resistor, Capacitor) filter is employed to effectively remove unwanted electrical noise and interference from the audio signal.
- **Digital Conversion:** The amplified and filtered analog waveform is then fed into the ESP32's Analog to Digital Converter (ADC) for digitization, enabling software based threshold detection of abnormally loud sounds.

Mixed Signal System Design

Our system exemplifies mixed signal design, integrating both analog and digital components for robust hazard detection.

Why It's Mixed Signal

- **Digital Inputs:** Reed, float, metal, temperature, touch sensors provide discrete ON/OFF or digital data streams.
- **Analog Input:** The microphone produces a continuous AC signal representing sound waves.
- **Analog Processing:** LM358 amplifier and RC filters condition the microphone's analog signal before digitization.
- **Digital Processing:** ESP32 handles GPIO logic, software debouncing, and complex threshold checks on all sensor data.
- **Digital Communication:** OLED via I²C, buzzer via PWM, and RGB LED via GPIO enable digital control of outputs.



Key Concepts Used

ADC Smoothing

Implemented sample averaging to reduce noise and stabilize analog readings from the microphone.

Noise Mitigation

Utilized RC filters for analog signals and strategic grounding to minimize electrical interference.

Debounce Algorithms

Developed software debouncing for mechanical sensors to prevent false triggers from contact bounce.

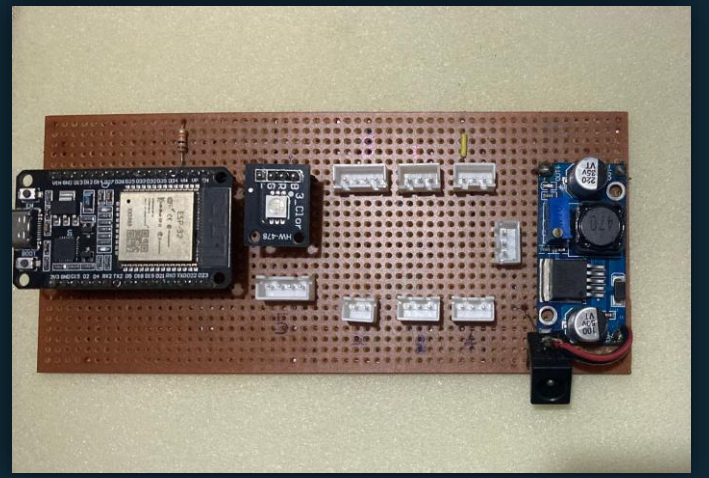
Multi Sensor Fusion

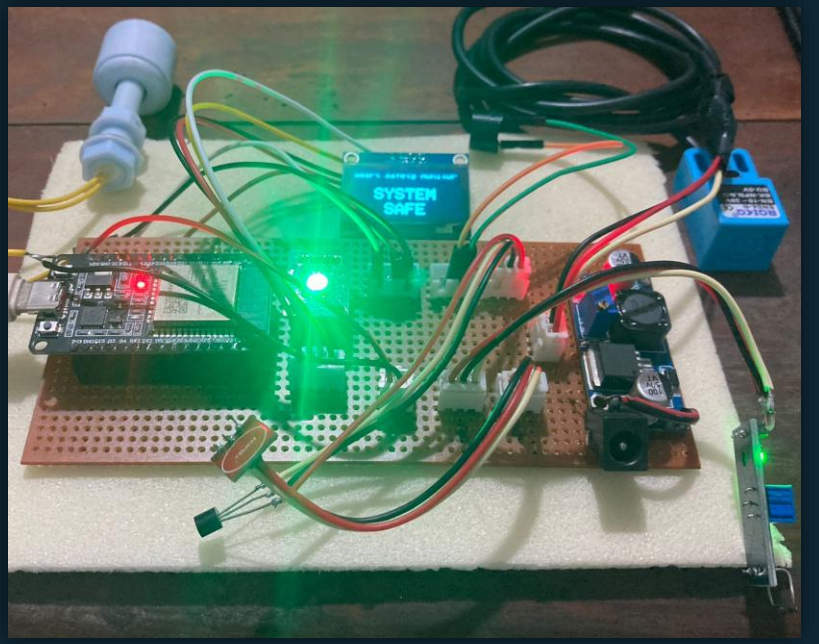
Combined analog and digital hazard evaluations for more accurate and reliable threat assessment.

Hardware Implementation & Enclosure

Prototype Build

- Fully wired and soldered on a dot board, ensuring robust connections.
- Careful routing of wires to minimize interference and improve signal integrity.
- Stable power conversion: 12V → 5V → 3.3V for reliable component operation.
- Safe voltage-dividing for SN04N (12V to ESP32-safe 3.3V) to protect the microcontroller.
- Strategic grounding to reduce electrical noise across all sensors.
- OLED, RGB LED, and buzzer neatly mounted for clear user feedback.



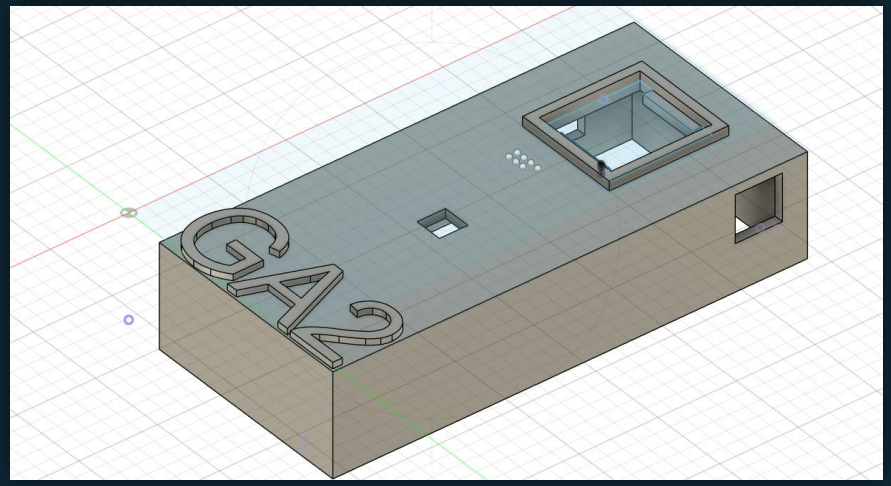


Stability

- No random resets during operation.
- Consistently accurate readings from all sensors.
- Sensors operate simultaneously without interference.

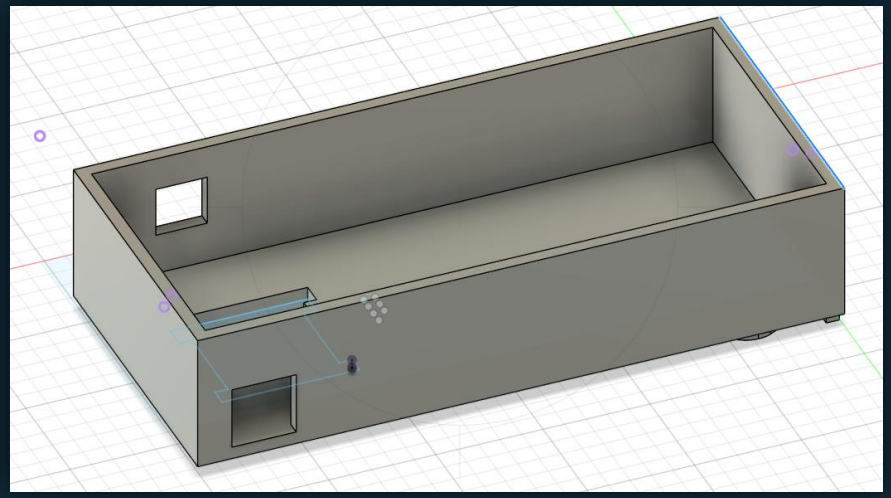
3D Printed Enclosure

- **Design:** Custom designed using Fusion 360, featuring a dedicated OLED window and ventilation grill for the sound sensor.
- **Ergonomics:** Cut outs for SN04N, float switch, and USB port, with internal space optimized for the ESP32 board and wiring.
- **Durability:** Reinforced side walls for enhanced structural integrity.
- **Branding:** "GA02" branding integrated on top for a professional touch.

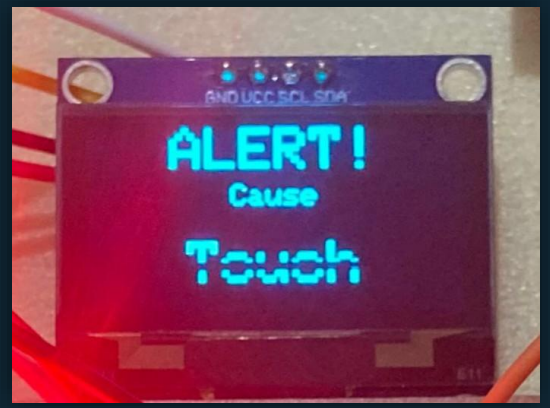


Benefits

- Achieves a professional, product like finish.
- Enables cleaner cable management, reducing clutter.
- Provides protection from dust, handling, and environmental factors.



User Interface & Output System



SAFE Mode

- Green LED indication
- Displays "System Safe" message on OLED

STATUS Mode

- Provides real time environmental awareness
- Live readings of temperature, door status, water level, sound, and metal detection

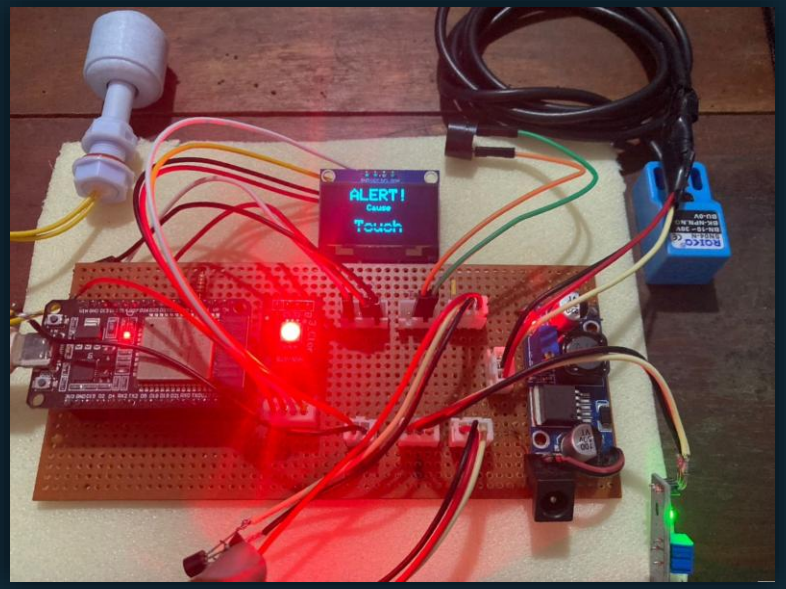
ALERT Mode

- Flashing screen with red LED
- Pulsating buzzer for urgent audio warning
- Lists specific hazard cause (e.g., “Water”,“Door Open”)

The RGB LED indicates risk levels, the buzzer provides audible warnings, and the OLED delivers readable information, creating a comprehensive user feedback system.

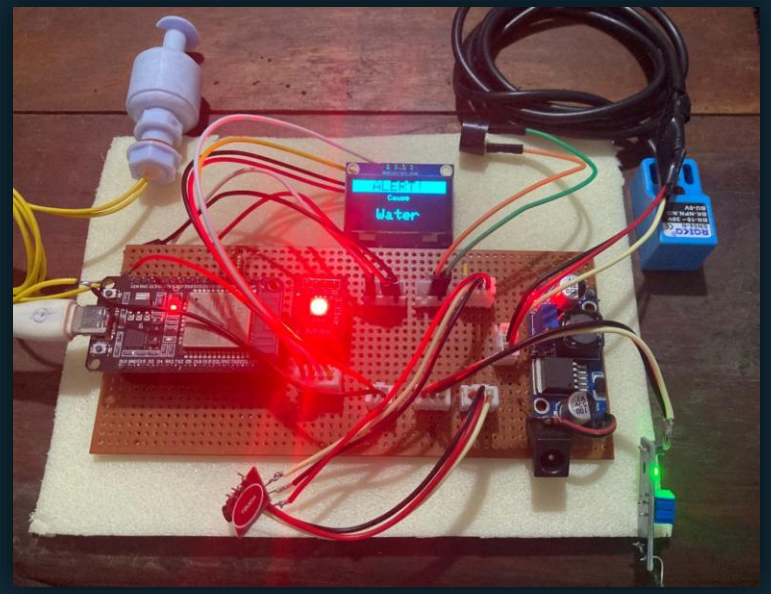
Testing & Validation

- Metal detection with tools and objects
- Door open/close tests using reed switch.
- Water level tests using float switch
- Noise tests with claps/taps/high dB sources
- Temperature variation using heat source
- 1hour continuous reliability test



Results

- Fast detection response across all sensors.
- Stable ADC readings for analog inputs.
- Strong noise rejection
- No system freezing or malfunctions observed.
- Consistent alert operation for every detected hazard.



Conclusion & Future Improvements

Conclusion

- Successfully built a fully functional mixed-signal safety monitoring system
- Integrates 6 sensors with ESP32 using analogue + digital methods
- Clean user interface with OLED, LED and buzzer alerts
- Stable and reliable performance in real world tests
- Affordable design (LKR 3,500–3,900)

Future Enhancements

- Wi-Fi / IoT integration for cloud monitoring & Mobile notifications and dashboard
- Custom PCB design instead of dot-board
- Battery backup system for power failures

Thank You!