Portable Mini■Incubator Blood Analysis System

Field■Ready Lactate Analysis Prototype

1. Introduction

This project describes the design and implementation of a portable blood analysis device intended for use in field conditions (military, emergency medicine, remote care). The primary goal is to enable rapid lactate measurement from a single blood drop, with incubation, analysis, risk assessment, and real■time data transmission.

2. Motivation & Use Case

Blood lactate is a critical biomarker for detecting hemorrhage, sepsis, shock, and tissue hypoxia. In battlefield or remote scenarios, traditional lab analyzers are unavailable. This system aims to provide a compact, rugged, and autonomous solution usable by non■specialists.

3. System Overview

- Single blood drop input via disposable strip
- Thermal incubation chamber (37 °C)
- Electrochemical lactate sensing
- ESP32 microcontroller for control & communication
- Local dashboard + HTTP data streaming

4. Hardware Architecture

The prototype is built around an ESP32 microcontroller. A heating plate controlled by a temperature sensor ensures incubation stability. A commercial lactate strip reader module provides analog output, which is digitized and processed locally. All components are enclosed in a 3D■printed portable enclosure.

5. Software Architecture

The software stack includes a signal simulation module, real■time risk classification (NORMAL / ALERT / CRITICAL), HTTP data transmission, and a web■based dashboard. The system is designed for later migration to embedded firmware without architectural changes.

6. Prototype Development Steps

- Simulation of physiological data (Python)
- Local HTTP server and dashboard
- ESP32 firmware development
- Integration of lactate sensor module
- 3D■printed enclosure assembly

7. Future Extensions

The enclosure and electronics are designed to allow future integration of glucose sensing, multi■analyte strips, Bluetooth medical device pairing, and secure military■grade data transmission.

8. Conclusion

This project demonstrates that a compact, field■deployable blood analysis system is technically feasible using off■the■shelf components. The architecture is scalable, modular, and suitable for real■world prototyping and validation.