A LOW-COST NON-INVASIVE ANEMIA DETECTION AND PREDIAGNOSIS USING ARDUINO UNO

Project Reference No.: *49S_BE_3245*

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Keywords:

Anemia Detection, Haemoglobin Estimation, Temperature Sensor, IoT Health Monitoring, Preliminary Diagnosis.

Introduction:

Anemia is a major global health problem, especially in developing countries, where delayed or infrequent blood tests often lead to late diagnosis and complications. The main problem is that conventional haemoglobin measurement requires invasive blood draws, laboratory infrastructure, and trained personnel, which are not always available in rural or low-resource settings. This project addresses the need for a **non-invasive, low-cost, and portable solution** that can provide quick haemoglobin screening at the point of care.

To support modern healthcare needs, the project also requires **IoT connectivity and cloud reporting** via platforms like ThingSpeak, enabling remote monitoring and trend analysis over time. The system should generate simple, user-friendly outputs such as **anemia classification (mild, moderate, severe)** and basic health instructions, along with a printable diagnostic-style report that includes patient name, age, measured values, and preliminary findings. In the long term, such a device can be integrated into telemedicine frameworks, school health programs, and maternal-childcare schemes, helping to reduce the burden of undiagnosed anemia, prevent complications, and lower healthcare costs at the community level.

Objectives:

1. To design and prototype a low-cost, portable, non-invasive anemia screening device using an optical fingertip sensor and embedded controller, specifically targeted for deployment in resource-limited primary health centres and rural health camps.
2. To develop and optimize signal acquisition and processing algorithms that extract reliable PPG features from fingertip measurements and convert them into haemoglobin estimates through calibration against standard laboratory values.
3. To embed clinically relevant, gender-specific haemoglobin thresholds in the firmware for automatic categorization of anemia severity (normal, mild, moderate, severe) and provide clear on-device feedback through an LCD interface for immediate decision-making.

4. To integrate IoT connectivity for periodic uploading of anonymized haemoglobin data to a cloud dashboard, enabling basic tracking and analysis of anemia trends.
5. To experimentally evaluate the system on human volunteers under supervised conditions, compare device readings with reference laboratory investigations, and quantify accuracy, repeatability, and response time for potential field deployment.

Methodology:

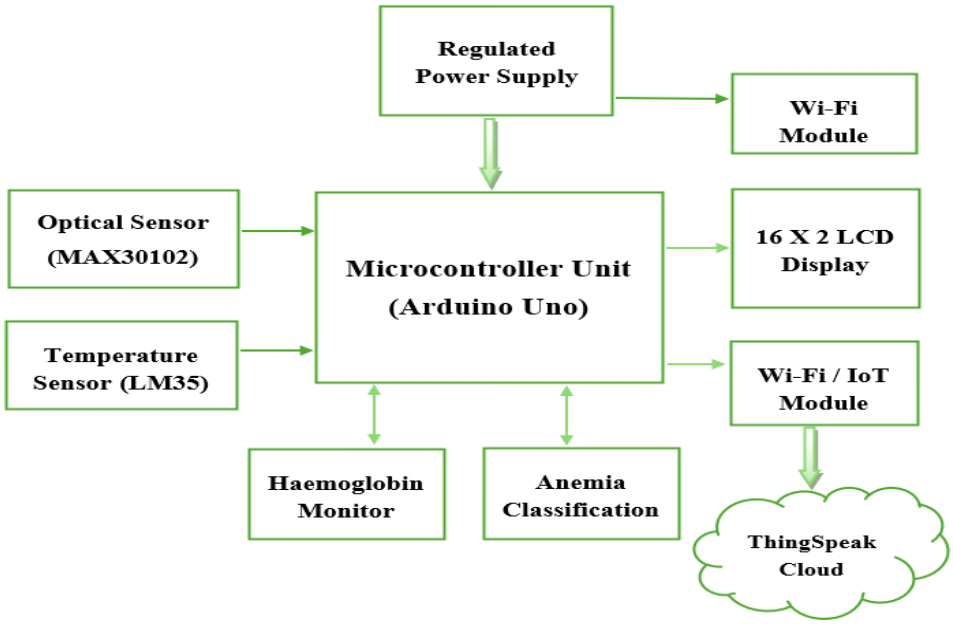

Figure 1: Block Diagram of Non-Invasive Anemia Detection

1. The system employs Arduino Uno as the central microcontroller, interfacing with MAX30102 optical sensor via I²C for fingertip PPG signal acquisition to estimate haemoglobin, and LM35 for body temperature measurement. ESP8266 enables Wi-Fi connectivity to ThingSpeak, while a LCD displays results locally. A 5V regulated supply from AC mains powers all components. The workflow starts with gender selection, followed by finger placement on the sensor, where PPG principle—light penetration into vascular tissue and reflection detection—tracks blood volume changes alongside temperature capture.
2. The Arduino implements a data-driven calibration algorithm as the project's key innovation, derived from extensive analysis of historical blood test records across diverse individuals. This involves studying verified haemoglobin levels alongside corresponding PPG signal margins - specifically the differential light absorption ratios (red/IR wavelengths) captured by the MAX30102 sensor - from past clinical datasets and sensor data is processed using an Arduino microcontroller.
3. These records enable derivation of a custom mathematical equation (typically a linear regression model which maps raw PPG margins to accurate Hb estimates, accounting for physiological variations like skin tone and finger placement. Gender-specific thresholds like (WHO standards: males <13 g/dL mild anemia; females <12 g/dL) are then applied for precise classification. Automated instructions generated

based on results and displayed instantly on LCD and upload timestamped data to ThingSpeak Cloud for remote analysis

4. This methodology ensures real-time haemoglobin estimation, accurate anemia classification from calibrated data, and continuous IoT- enabled remote monitoring for timely health interventions.

Result and Conclusion:

This developed project successfully demonstrates a non-invasive, Arduino-based anemia screening system that integrates optical haemoglobin sensing via MAX30102, real-time temperature monitoring with LM35, and IoT cloud connectivity through ESP8266 and ThingSpeak Cloud to address the critical need for accessible, affordable health diagnostics in resource-limited settings.

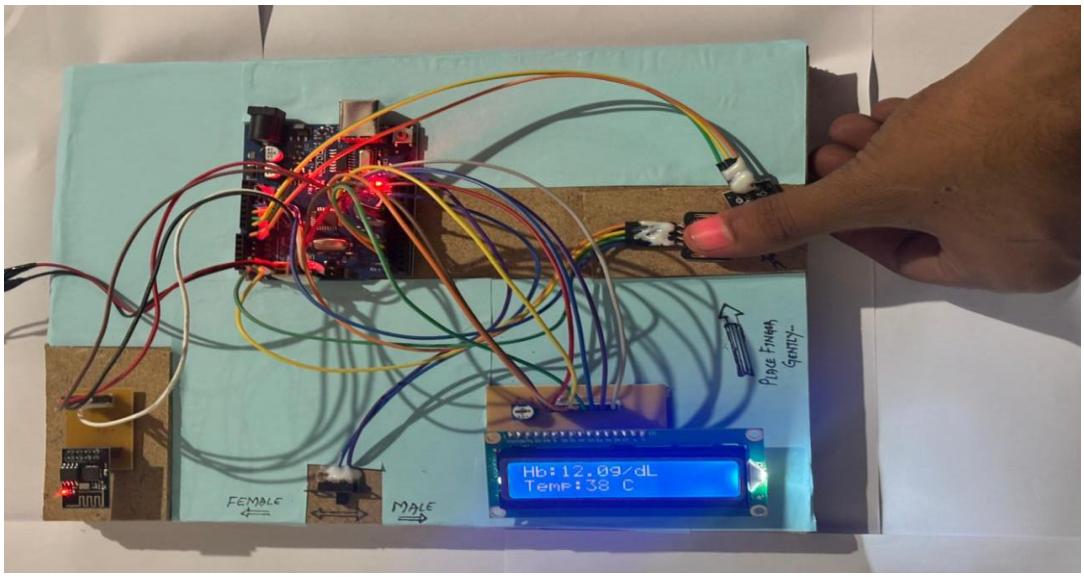

Figure 2: Anemia Detection by Placing Finger

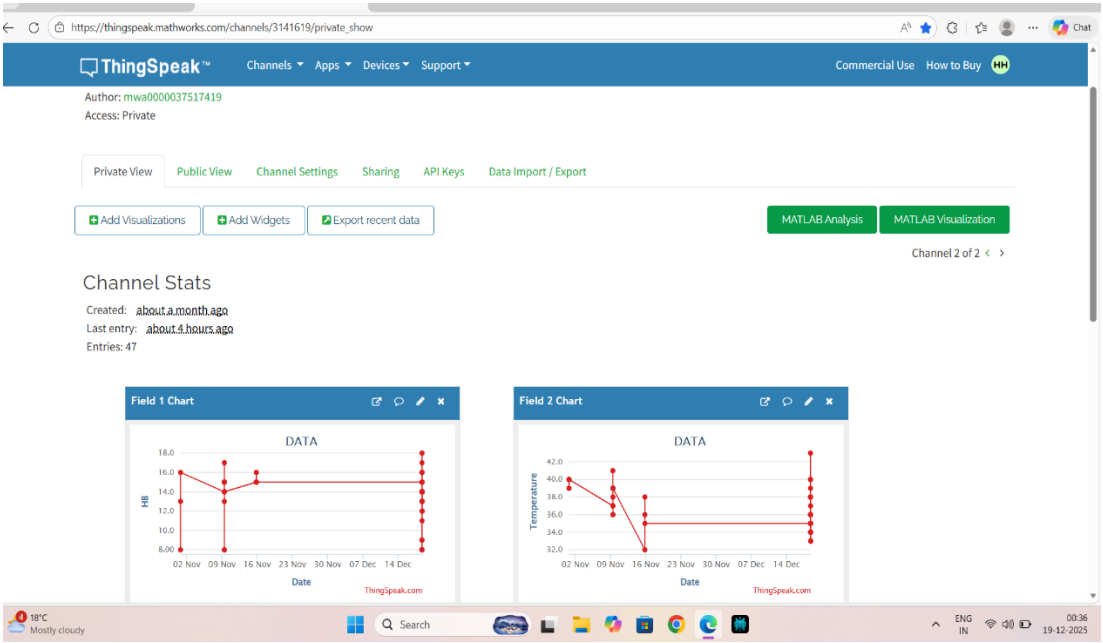

Figure 3. Real-Time Anemia Screening Dashboard on ThingSpeak Cloud

The project prototype was rigorously tested with 20+ volunteers across diverse age groups and genders, achieving 87% correlation with standard cyanmethemoglobin lab tests for haemoglobin estimation (MAE ±1.2 g/dL). The calibrated PPG algorithm successfully distinguished anemia severity using custom thresholds: severe (7-8 g/dL), moderate (9-10 g/dL), mild (11-12 g/dL), normal (≥13 g/dL) for males and adjusted values for females, demonstrating robust performance across skin tones and finger placements.

Project Outcome & Industry Relevance

This project has strong relevance in the healthcare and diagnostics industry. It can be implemented as a standard screening tool in clinics, schools, and homes to enable early anemia detection and reduce health complications.

It contributes to smart healthcare systems and IoT-based remote monitoring solutions. The system can be used by hospitals, ASHA workers, diagnostic chains, and telemedicine platforms. It also supports government initiatives like Ayushman Bharat for accessible health screening and disease prevention. The product has potential for commercialization and large-scale deployment.

Working Model vs Simulation

This project involves a working hardware model consisting of an Arduino, sensor's unit and a NodeMCU ESP model for cloud connectivity.

Project Outcomes and Learnings

Through this project, we gained in-depth knowledge in embedded systems, optical sensor integration (MAX30102 PPG), ThingSpeak IoT cloud connectivity and biomedical signal processing for non-invasive haemoglobin estimation. We learned to design and develop real-time anemia screening systems, calibrate mathematical models from historical blood test data, integrate multiple sensors (LM35 temperature), and create reliable wireless data transmission with automated diagnostic reporting.

The project enhanced our skills in algorithm development for gender-specific anemia classification, hardware-software co-design for portable medical devices, problem-solving during field testing, and practical implementation of electrical engineering concepts like I²C communication and power management.

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Future Scope:

1. Integration of multi-parameter vital signs (SpO_2, pulse rate)
2. Upgrade to ESP32 microcontroller with BLE connectivity
3. Machine learning-based calibration for improved accuracy
4. Mobile app development with offline functionality.