International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 01 | Jan 2026 www.irjet.net p-ISSN: 2395-0072

A Novel Approach to Non-Invasive Hemoglobin Estimation using Optical Sensor

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Abstract - *Monitoring blood hemo globin (Hgb) levels is crucial for a variety of illnesses' diagnosis, evaluation, and treatment. An economical and effective hemo globin measurement method is becoming more and more in demand worldwide, especially in developing countries. This article provides a thorough review of several continuous, non-invasive hemo globin monitoring strategies, emphasizing those that employ embedded platforms for picture analysis. It also talks about the best non-intrusive method that may be used everywhere. There are still not many commercially feasible non-intrusive hemo globin monitors on the market, despite continuous attempts by research organizations. Compared to typical invasive procedures, non-invasive hemo globin monitoring techniques offer a number of benefits, such as a high accuracy rate of 90.9% and the removal of infection concerns related to blood samples and needles. Usually, these non-invasive methods make use of wearable sensors that can be affixed to the skin for ongoing monitoring, like a finger probe. This method is especially beneficial for broad use since it eliminates the need for intrusive procedures, which lessens patient discomfort and improves safety. An Arduino Uno (with an embedded system), a MAX30105 light-sensing diode-photodiode, several UV LEDs, a liquid crystal display (LCD), and an I2C are the hardware components that make up the system suggested in this study. This arrangement helps to overcome problems brought on by variations in blood volume brought on by cardiac cycles by enabling the computation of an average hemo globin concentration from samples collected over a one-minute period. Such devices may eventually give doctors access to real-time data, facilitating quicker diagnosis and treatment. This will be particularly helpful in urgent circumstances where prompt action can significantly impact patient outcomes.*

Key Words: **Non-Invasive, Hemoglobin, Embedded Platform, Arduino Uno, MAX30105, Liquid Crystal Display, I2C Module, PPG (Photoplethysmography), Multiple LED's, Optical Sensor**

1. INTRODUCTION

Blood is a crucial part of the human body that performs several vital tasks that keep us alive. It circulates throughout the body to maintain body temperature, send signals to different organs, and provide nutrition, hormones, and oxygen. A key component of this process is hemo globin, a protein present in red blood cells that carries oxygen from the lungs to all of the body's tissues. Millions of individuals worldwide suffer from anemia, a disorder caused by the body's inability to properly distribute oxygen to its organs due to a lack of hemo globin. Anemia affects people of all ages and backgrounds, and the World Health Organization (WHO) estimates that 1.6 billion people worldwide, or roughly 30% of the population, suffer from it.

Measuring hemoglobin levels precisely is crucial for diagnosis and treatment since anemia has a substantial negative influence on health. Invasive techniques like blood draws, which call for medical personnel to gather samples, have historically been used to evaluate hemoglobin content. Despite their effectiveness, these techniques have a number of disadvantages, such as the possibility of infection, discomfort for the patient, delays in receiving findings, and less compliance from those who require recurrent testing. With the advancement of medical technology in recent years, non-invasive hemo globin measurement techniques have been developed. Compared to conventional methods, these non-invasive methods—such as spectroscopy, pulse oximetry, and near-infrared light—offer a number of benefits. These techniques offer a quicker, safer, and more pleasant alternative to check patients' hemo globin levels without requiring blood samples.

Systems for non-invasive hemo globin monitoring are very useful in a variety of clinical contexts, such as critical care, surgery, and the treatment of chronic illnesses. Healthcare providers may monitor a patient's condition continuously and in real time with these devices, eliminating the hazards and pain of repeated blood draws. Additionally, they are particularly helpful in places with low resources, where access to trained healthcare professionals or laboratory facilities may be restricted. Apart from its clinical uses, non-invasive devices also lower the danger of infection and cross-contamination, which makes them perfect for use in routine checkups or emergency scenarios.

2. SYSTEM DESIGN / PROPOSED SYSTEM

This section outlines system design for Non-Invasive Hemoglobin Device shown in figure 1 & figure 2.

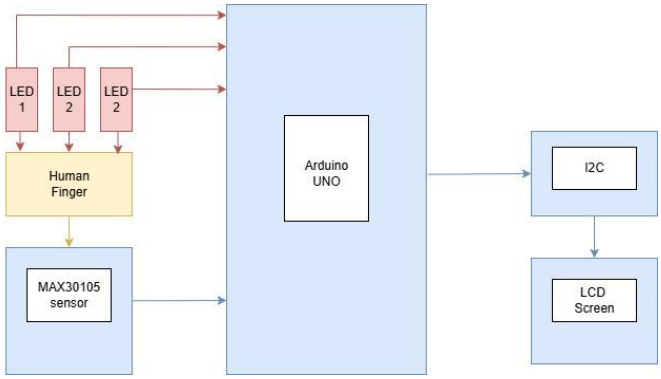


Fig -1: Block Diagram of Non-Invasive Hemoglobin Device

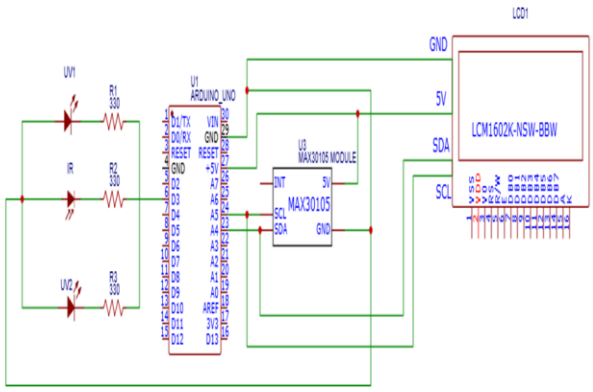


Fig -2: Schematic Diagram of Non-Invasive Hemoglobin Kit

The system's design is broken down as follows:

[1] Acquisition of Signals: Through the skin and blood vessels, the MAX30105 optical sensor will emit light at various wavelengths (from the UV LEDs). Specific amounts of light at various wavelengths are absorbed by the hemoglobin found in blood. The sensor records information that indicates the amount of hemoglobin in the blood by measuring the amount of light that is transmitted and reflected.

[2] Signal Processing: The Arduino Uno processes the signals that the MAX30105 sensor receives. The Arduino determines the absorption at various wavelengths by reading the light intensity data. Hemoglobin levels are estimated using the link between hemoglobin concentration and light absorption. To guarantee precise hemoglobin estimation, the Arduino will carry out the required calculations using preset algorithms.

[3] Data Display: Next, the LCD panel shows the determined hemoglobin concentration. In addition to providing real-time hemoglobin level data, the LCD might have a graphical user interface for additional visual feedback. The system can signal the abnormal condition by displaying warnings or alert messages on the screen if the levels are too high or too low.

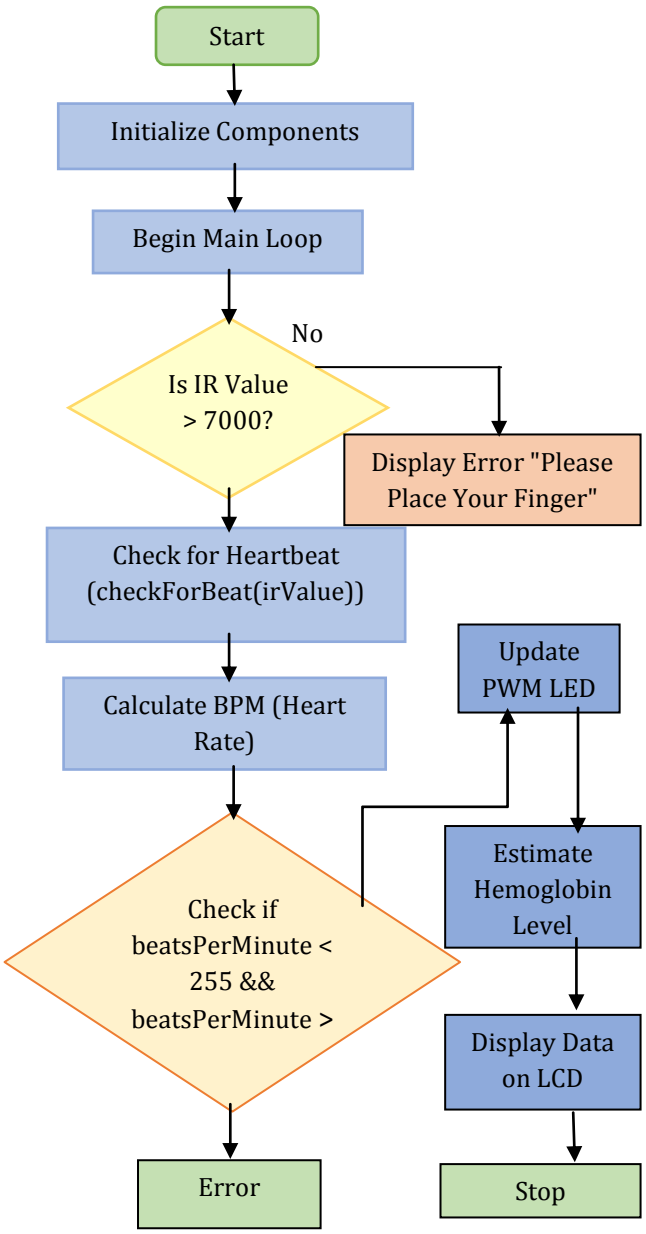
[4] LED Wavelengths: Because of their capacity to interact with hemoglobin, the various UV LEDs will emit light at a specific wavelength. To increase measurement accuracy, the LEDs will either be employed in tandem or alternately to emit light onto the patient's finger. The hemoglobin absorption spectra will be used to determine the wavelength. In order to detect human finger intervention and provide an additional command for UV LEDs to begin emitting light, an additional infrared LED is fitted to the kit.

[5] Housing and Sensor Mounting: The Arduino, LEDs, and MAX30105 sensor will all be enclosed in a clear glass shell. The sensor can effectively detect reflected light, and the transparent housing makes sure that the light that is released may penetrate and reach the skin. Ideally, the glass housing can be placed on the body to measure blood flow or worn on the skin like a bracelet. It is made to be comfortable for the user.

[6] Power Source: The gadget will be powered by a USB power source or a battery. The device can operate for extended periods of time without requiring frequent recharging thanks to the low power consumption of the Arduino Uno and MAX30105 sensor.

[7] User interaction and calibration: In order to obtain reliable readings, the device must be calibrated. To guarantee accurate hemoglobin readings, the user can complete a quick calibration procedure before to using the instrument. Using instructions shown on the LCD panel, the Arduino Uno will walk the user through this procedure.

2.1 FLOW CHART



Algorithm of Code:

Initialize Serial communication for debugging.
Set up the MAX30105 sensor for heart rate and pulse oximetry measurements.
Initialize the LCD display to show messages.
Set up the UV and IR LEDs for sensing.
Set up variables for heart rate calculation and storage.
Display the message "Hemoglobin detection" on the LCD screen.
Continuously run the following steps in the loop() function.
Read the infrared (IR) and red light values from the MAX30105 sensor.
If IR > 7000 (indicating finger placement):

- Call checkForBeat(irValue) to detect pulse.

If pulse detected:

- Turn on UV and IR LEDs.
- Print average BPM (beatAvg) to Serial monitor.
- Calculate delta (time difference) using millis().
- Calculate BPM: BPM = 60 / (delta / 1000.0).
- If BPM is in range (20-255), store in rates[].
- Calculate average BPM from last 4 readings.
- Adjust IR LED brightness using PWM control.
- Read UV and IR intensities (UV and IR not defined in code).
- Estimate hemoglobin: Hemoglobin Level = (UV Intensity - IR Intensity) * 100.
- Display hemoglobin level on LCD.

If no pulse is detected (i.e., IR value is less than 7000), display a message asking the user to "Please Place Your Finger".
Repeat loop for continuous updates and readings.

3. RESULT & DISCUSSION

Fig –3(a): Hardware Prototype
3(b): Initialization of the kit

Fig-4: Estimated Hb Level of a person

The Non-Invasive Hemoglobin Monitoring Kit is initialized in Figure-3(b). Where the device turns on and becomes ready for measurement. The estimated hemoglobin level of 11.79 g/dL is shown in Figure-4. indicating a somewhat reduced hemoglobin concentration.

The first stage in the hemoglobin estimate procedure, initializing the Non-Invasive Hemoglobin Monitoring Kit, is shown in Figure-3(b). The system starts this phase by turning on the parts that are necessary for detecting and processing the needed data, such as the Arduino UNO embedded system and the MAX30105 optical sensor. After the system has been set up, the user inserts their finger on the sensor, which initiates the light absorption and reflection analysis procedure that is necessary to determine the blood's hemoglobin concentration.

The estimated hemoglobin level of the subject, in this case 11.79 g/dL, is shown in Figure-4. Using the optical sensor and the Arduino-based system's real-time processing capabilities, this outcome was obtained. With a hemoglobin level of 11.79 g/dL, the individual may have mild anemia because it is slightly below the normal range, which is normally between 12 and 17 g/dL for adults. This is merely an estimate, though, and additional clinical testing—like a blood test—is required for a final diagnosis.

4. CONCLUSION

In conclusion, the Non-Invasive Hemoglobin Monitoring Kit represents a potential development in the field of medical diagnostics. Real-time hemoglobin level monitoring removes the need for intrusive, conventional blood tests, which makes the procedure less time-consuming and more comfortable for patients. In emergency scenarios, where prompt and precise evaluation of a patient's status is crucial, the device's user-friendliness and speedy results are especially advantageous. Additionally, this gadget is affordable and compact, which makes it suitable for a variety of healthcare settings, including home care settings, small clinics, and major hospitals.

The device's overall functioning and dependability are improved by the seamless and non-intrusive monitoring made possible by the Arduino UNO embedded system. The Arduino-based system is perfect for long-term monitoring and interaction with other medical technologies since it offers an effective platform for ongoing health assessments. A significant advancement in non-invasive diagnostics has been made possible by this device's capacity to deliver precise, real-time hemoglobin level data without causing discomfort or interfering with the patient's regular activities.

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