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Development of a Microcontroller-Based Portable Hemoglobin Meter Using Optical Sensing Techniques

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Abstract:

Hemoglobin is a protein pigment that is carried by oxygen throughout the body. The determination of iron deficiencies and anemia among the people is quickly helped by them to recover. Hence, the main purpose of designing the portable instrument is for the detection of hemoglobin to be accurate. Here, the microcontroller-based hemoglobin meter portable instrument with a color sensor is constructed using a RED LED of wavelength 620-660 nm and an OLED display. The samples for the detection of hemoglobin were collected and analysed during blood donation camps at Bordi, Gholwad and Umbergaon. Iron deficiencies among the people were quickly determined with less expense.

Key words:

Hemoglobin detection, Microcontroller-based hemoglobin meter, OLED display, RED LED (620–660 nm), Anemia detection

Introduction: The compelling need for accessible, affordable, and user-friendly instrument-free molecular diagnostics for a vast majority of the global resource-limited settings has been realized by the pandemic world. Moreover, even before the pandemic situation, crucial roles in human life were recognized to be played by colorimetric sensors as biomedical and environmental tools. [1-10] Colorimetric sensors that are easy to use, portable, instrument-free, low cost, and offer sensitive and selective detection toward various analytes are required for point-of-need and point-of-care applications. Colorimetric sensors are classified under optical sensors that display a single-, dual-, or multi-color change in the presence of detected target molecules. Valuable tools for laboratory-based testing for their accuracies and reliable measurements are represented by traditional molecular biology, biochemistry, nucleic acids, protein, and immunology-based assays. Time-consuming, technically challenging procedures that can only be performed by trained, educated professionals are involved in traditional nucleic acid and protein biological assays, and sophisticated expensive laboratory settings are required by them. Such methods are deemed out of reach, and/or not implementable for use by any literate people, and not accessible for a vast majority of the global population living in a resource-limited economy.[16-19] Hence, a huge positive impact on human life in this pandemic era is offered by new user-friendly, cost-effective, instrument-free molecular detection approaches, such as colorimetric assays and sensors, for everyone on the planet, and the whole healthy undeniably connected world is intellectually strengthened. In addition to human health-related accessible and point-of-need molecular diagnostics, other equally important areas are included, such as food and agriculture quality and safety, environmental analysis, and human-caused, politically driven unpleasant biosecurity and biothreat issues that

require large-scale rapid on-site molecular diagnostics suitable for both resource-limited and economically sound settings.

Theoretical background:

Prior to the time of Sir Isaac Newton, the nature of light and color was rather poorly understood. Existing misconceptions were dispelled by Newton's meticulous experiments with sunlight and a prism, and the realization that the color of light depended on its spectral composition was led to by them. Even though Newton was preceded by Grimaldi in making these discoveries, attention was received much later by his book on the subject, and credit for the widespread dissemination of the new ideas is given to Newton. [1-6]. While a physical basis for color was established by Newton's experiments, a system for colorimetry was still a long way off. Before a system to measure and specify color could be developed, an understanding of the nature of the color sensing mechanism in the human eye was necessary [7,8]. While some progress in this direction was made in the late 18th century, confusion between color vision and the nature of light was contributed to by the prevalent anthropocentric views. The way for a better understanding of both light and color was paved by the wider acceptance of the wave theory of light. It was hypothesized by both Palmer and Young that three receptors are possessed by the human eye, and the sensation of color is contributed to by the difference in their responses [9-12]. However, it was stated clearly by Grassmann and Maxwell that color can be mathematically specified in terms of three independent variables. Experimental laws of color matching that now bear his name were also stated by Grassmann. It was demonstrated by Maxwell that any additive color mixture could be "matched" by a proper amount of three primary stimuli, a fact now referred to as trichromatic generalization or trichromacy. The distinction between additive and subtractive color mixing was explained by Helmholtz around the same time, and trichromacy was explained in terms of spectral sensitivity [13-19].

Microcontroller:

The NanoEvery is Arduino's 5V compatible board in the smallest available form factor: 45x18mm.The Arduino Nano is preferred as it is a small, low price and easy to use microcontroller board.ATMEGA4809 chip with clock-20 MHz, Memory-6KB, Pinout-14 and USB, SPI, 12C, UART interfaces is used.

TEMT6000 Ambient Light Sensor:

Illuminance is measured. The total quantity of visible light emitted by a source is measured as illuminance. It is referred to as luminous flux and is measured in lumens (lm) per meter square. A single phototransistor makes up the TEMT6000, which is acted upon just like a simple NPN transistor. The greater the incoming light on the Base, the more the current is flowing from the Collector to the Emitter. The wide visible spectrum (390–700 nm) is worked in by the sensor. A near human eye response is given. The method of reflectance is used.

Experimental Work:

For the quick and accurate hemoglobin detection, as shown in the block diagram, the blood sample is taken on the strip. The red LED is used and the collimated light is directed onto the sample; the light is reflected back and sensed by the sensor (TEMT6000), which is a silicon

array NPN phototransistor, having peak sensitivity at 570 nm. This is a wide band sensor in the visible range. The output of the sensor is produced in the form of voltage. This output of voltage is given to the ARDUINO NANO EVERY (ATmega4809) Microchip. The ATmega4809 is an 8-bit microcontroller Command and control applications are highly responded to by this microcontroller, and the performance of real-time control systems is expanded by it. Intelligent hardware peripherals and low power capacity of AVR core are combined by this MCU. A high speed ADC is possessed by this MCU and it is made easy-to-Configure. This output is divided into 1024 parts for conversion, for which, an in-built ADC is used Output voltage is interpreted graphically, using the linear interpolation method, and the Hemoglobin values are calibrated and indicated in two decimal terms on the OLED Display. The number of readings can be taken by the sensor in less time. The output is averaged over. 0 0 During the process, the 45/0 CIE standard geometry is used through the method of reflection.

The readings of Hemoglobin values of blood samples measured by our own designed device were recorded and then compared with the values obtained by HemoCue Hb 301 for the same blood samples is illustrated in following Table.

Table-1: Comparative Study of Developed Device against Hemocue 201

Names	PHC Reading (Hemocue 201)	Developed Device
Dipika Ambat	8.2	8
Anita Umbarsada	8.5	9
Kalpana S.	8.5	8
Jayashree S. Meeri	9.1	9
Kalpana D. Shingada	9.4	9
Darshana D. Bujad	9.5	10
Urmila Amrut Shingda	9.3	10
Rajashree U. Mendarkar	10.2	9
Shaila A. Pura	10.1	9
Vajru P. Shingda	9.9	10
Vandana A. Umbarsada	10.4	10

Fig-1: Graphical Presentation of Developed Device against Hemocue 201

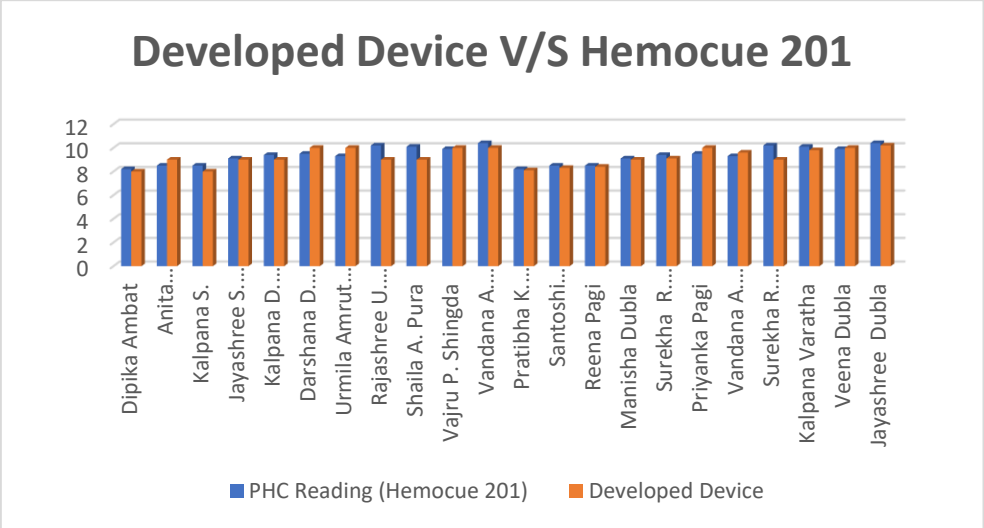


Table-2: Comparative Study of Developed Device against Hemocue 201

Names	PHC Reading (Hemocue 201)	Developed Device
Pratibha K. Dodka	8.2	8.1
Santoshi Dongarkar	8.5	8.3
Reena Pagi	8.5	8.4
Manisha Dubla	9.1	9
Surekha R. Maska	9.4	9.1
Priyanka Pagi	9.5	10
Vandana A. Varatha	9.3	9.6
Surekha R. Khatal	10.2	9
Kalpana Varatha	10.1	9.8
Veena Dubla	9.9	10
Jayashree Dubla	10.4	10.2

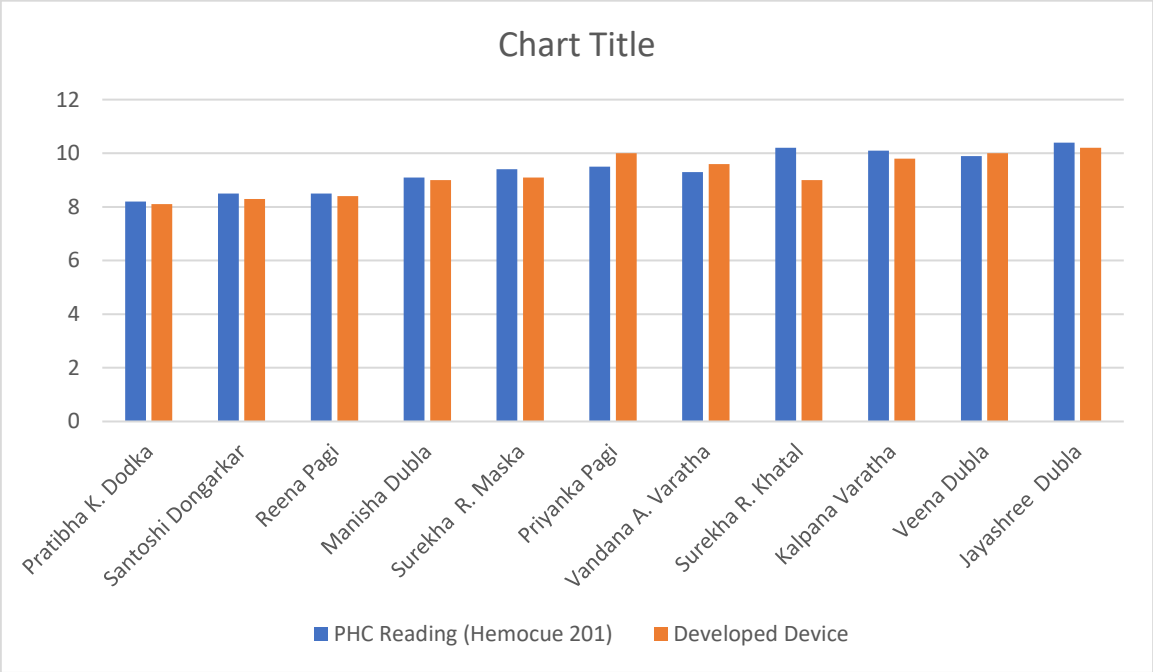


Fig-2: Comparative Study of Developed Device against Hemocue 201

Flow chart of procedure:

Wash the hand and wipe the tip of finger with 70% alcohol or spirit

↓

30 gauge lancet was used for piercing the finger

↓

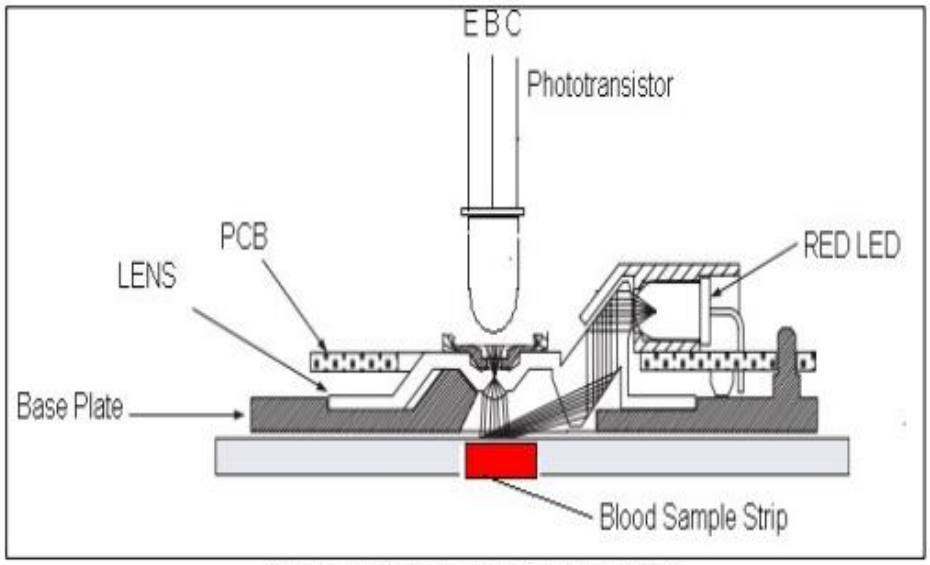
Strip of whatmann filter paper no 1 was used to collect drop of blood

↓

Strip with blood inserted in device to check the hemoglobin content of blood

Strip was disposed in Dettol solution to avoid any harmful consequences of blood

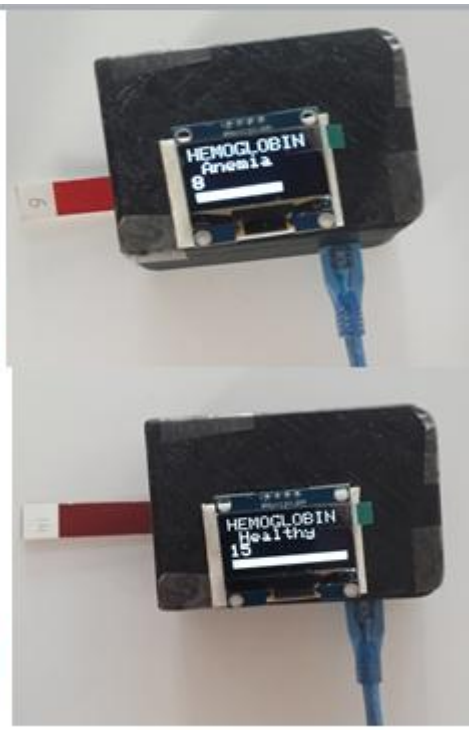
Fig-3: Block diagram of instrument



Schematic of the developed device

Fig-4: Working diagram of instrument

WHO Reference	
Hb Value	**Anaemia status**
14 g/dl	Healthy
12 g/dl or more	Not anemic
8-11 g/dl	Mild to moderate anemia
6-7 g/dl	Marked anemia
4-5 g/dl	Severe anemia
Lessthan 4 g/dl	Critical



Result and Discussion:

The hemoglobin concentration of blood samples was measured by both the standard PHC device (Hemocue 201) and the developed microcontroller-based colorimeter. The obtained readings of two sets of subjects are presented in Tables 1 and 2. The comparative results shows

that the readings from the developed device close to the standard instrument, shows the good accuracy and reliability.

In the first set, the PHC readings ranged from 8.2 g/dL to 10.4 g/dL, while the developed device recorded the values between 8 g/dL and 10 g/dL. The average deviation between the two instruments was within ±0.3 g/dL, the result are inside the permissible value for clinical hemoglobin measurement. A similar values are observed in the second set, where PHC readings ranged from 8.2 g/dL to 10.4 g/dL, and the developed system gave results between 8.1 g/dL and 10.2 g/dL. The co-relation between the readings from both instruments was found to be strong, indicating that the developed device can effectively reproduce the results of a standard for commercial colorimeter.

Minor variations are recorded values can be attributed to differences in optical alignment, ambient light interference, and the precision of the analog-to-digital conversion process. The created device maintained consistent linearity with respect to the PHC reference values in spite of these little differences. The precision and stability of the optical and electronic circuits used in the design are validated by this consistency.

Overall findings confirm that the microcontroller-based colorimeter can measure hemoglobin concentration as accurately as a Hemocue 201 device that is sold commercially. Thus, the study shows that it is possible to create an inexpensive, locally produced diagnostic tool that is appropriate for routine pathological usage in small-scale labs and basic health facilities.

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