NTU Journal of Engineering and Technology (ICSDT2025) special issue
DOI: https://doi.org/10.56286/ntujet.icsdt2025

IRAQI Academic Scientific Journals

P-ISSN: 2788-9971 E-ISSN: 2788-998X

NTU Journal of Engineering and Technology

Available online at: https://journals.ntu.edu.iq/index.php/NTU-JET/index

Laser based Packed Red Blood Cells Volume (PCV) Determination System

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Article Informations

Received: 15-03- 2025,
Accepted: 28-04-2025,
Published online: 01-03-2026

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Key Words:
The packed red blood cells volume,
Arduino board 2560 mega,
Erythrocyte volume.

A B S T R A C T

It is common knowledge that hematology test panels include measurements of the packed cell volume (PCV), also known as the hematocrit, because they are so helpful in any hematologic workup. The packed red blood cells volume (PCV) value can be calculated in a variety of ways. Some of them use direct approaches, while others use indirect ones. The most straightforward and cost-effective method, which is frequently used as a direct means to assess PCV but has a chance of human mistake and trapped plasma, is using a manual ruler to evaluate PCV. In our search, we developed and built an electronic circuit to assess PCV that relies on the Arduino board. The novel measurement tool is made up of red laser (650 nm) emitters to take advantage of the red light's specific absorption by erythrocytes (red blood cells), which is higher than the red light's lowest absorption by blood plasma. The photocell then receives the transmitted light, and the Arduino board processes the photocell's signal. The PCV evaluation method is reliable because of the change in light intensity between the incident and transmitted light after passing through a centrifuged blood sample. The device's six lasers and photocells make it easier and more accurate to calculate the ratio of erythrocyte volume to total blood volume. Last but not least, a PCV blood analysis can be made utilizing a programmable Arduino board 2560 mega (with determined mathematical formulae that are stored in Arduino memory to calculate and screen Values).

1. Introduction

The concentration of hemoglobin and oxygen saturation provide evidence of the patient's capacity to transport oxygen, for this reason, the process is tested in this case because it is considered the most vulnerable case. In the case of surgery, the hematocrit is checked, in addition to checking the hemoglobin concentration before the surgery, to avoid the patient's dangerous stage, such as blood loss or bleeding. For this, clinical examinations are conducted for low blood volume and anemia.[15].

One of the modern and advanced technologies for diagnosis and clinical examination is the use of lasers in the medical field. As a laser application, laser light is used in many clinical examination tests. In addition to other uses of the laser are under research and development. [13].

Dr. J. E. Pettit and Dr. S. M. Lewis [1] funded a method for measuring the radioactivity in a blood sample before injecting red cells with an anticoagulant for people exposed to radiation doses. They made some appropriate corrections on the other samples to measure the percentage of red blood cells.

"Ahmed" A. Naser Alamiry, "Talib" Hassan Ali and Moayed Naji Majeed [2] describe an effective and easy-to-use method that allows the measurement of different forms of hemoglobin using quantitative analysis. Where he examined eighty blood samples from several people with different levels of hemoglobin concentrations using the hemoglobin electrophoresis technique at the Faculty of Medicine - University of Dhakkar. Hemoglobin abnormalities were diagnosed on the basis of hemoglobin electrophoresis.

M. Jedrzejewska-Szczerska and M. Gnyba[3] presented a low-cost and high-accuracy method using specific optical methods to measure hematocrit. The hematocrit value was estimated based on Raman spectroscopy, in addition to low-coherence interferometry.

Ernest Krystian et al.[4] designed a system to test clinical blood tests for patients and the elderly who cannot control the change in the proportions of blood components. He used the spectroscopic method to measure the hematocrit ratio within appropriate parameters of measurement. The findings demonstrated that the suggested system's measurements, which rely on the spectroscopic method, are the most appropriate and precise.

Eiman Hussein, MD, Azza Enein [5] determined how the method of collection impacted 30 units of RBC that had undergone apheresis (ARBC) and 30 units of RBC that were manually collected were tested for red blood cell quality in vitro (MRBC). This was accomplished by measuring the concentrations of sodium, potassium, adenosine triphosphate (ATP), 2,3-diphosphoglycerate (2,3-DPG), glucose, red cell mass volume (RCM), rate of hemolysis, pH, and sodium and potassium. Eight aplastic anemia patients who had both components of RBC transfusions had their post-transfusion hematocrit (HCT) values compared.

Sinan S. Mohammed Sheet, Mohammed S. Jarjees [6] constructed an automated HCT measurement system using a microcontroller. The Atmega 2560 Arduino microcontroller and a mix of light-emitting diodes and photodetectors were used to build the gadget. The HCT is calculated using the transmission and absorption characteristics of red light (660 nm) flowing through a centrifuged blood sample in a capillary tube. The results are used to calculate hemoglobin (HB) and packed cell volume PCV).

Zena Ahmed Alwan, Suhair Mohammed Yaseen, Huda Farooq Jameel [7] built a crude gadget that comprises of a digital camera attached to a computer that processes blood picture data using particular MATLAB software. As a result, it is able to decode the image and determine the PCV using a certain code scheme. In contrast to PCV readings that were input on a computer, this unique testing tool has the capacity and advantages of regularly commenting on measured PCV as normal or abnormal. Our measurement technique yields precise findings when compared to industry standards, which minimizes the amount of effort required to remove the hepatitis C virus from the blood (PCV). With this technique, sample analysis and PCV identification are quick and simple.

This study uses laser light to introduce a novel design of the HCT reader to solve the flaws of prior investigations. To prevent interference between LD lights and phototransistors, dielectric strips are utilized. It was also decided to compare the outcomes of (proposed) automated systems with those of conventional methods in order to assess and validate the suggested system.

2. Research Method

The three stages of this study were as follows: first, the development and application of an automated system for computing HCT blood levels samples separated by centrifugation; second, the results were verified by comparing them to laboratory procedures; and third, the computation and based computation of the PCV and HB values on the HCT values.

2.1. Blood sample preparing

When it comes to measuring the volume proportion of erythrocytes in whole blood, the term "hematocrit" initially referred to a tool or process. Though they are frequently used interchangeably, "packed cell volume" and "packed cell volume" are synonyms. The term "packed cell volume" (PCV) has been adopted by the subcommittee to describe the quantity measured by centrifugation, whereas the term "hematocrit" has been reserved to describe the components and/or methods used in the determination [8]. The tube is sealed with synthetic clay before being spun at 10,000 RPM for five minutes while blood is drawn. The blood sample is then divided into layers. The PCV value is calculated by dividing the volume of erythrocyte cells by the total volume of the blood sample. As illustrated in Fig. 1, the layer lengths rather than layer volumes of the centrifuged samples can be determined thanks to the use of a capillary tube.

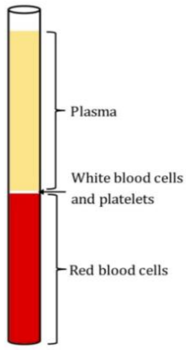


Fig. 1. A capillary tube contains a multilayer of centrifuged blood samples.

2.2. Conventional technique of measurement the HCT

The hematocrit test measures the proportion of red blood cells in your blood. This is referred to as packed cell volume (PCV) or erythrocyte volume fraction. It is regarded as a crucial component of a person's complete blood count, along with hemoglobin concentration, white blood cell count, and platelet counts. [8,9].

By dividing the volume of RBCs by the volume of whole blood, the HCT or PCV is computed. The height of the RBC layer and the volume of the total blood sample are measured using a micro hematocrit reader Fig. 2. The results are then displayed as a decimal number or percentage fraction. Examples of mathematical equations that can be used to calculate the concentration of HB and PVC, respectively, are shown in Formulae 1 and 2. [10,11].

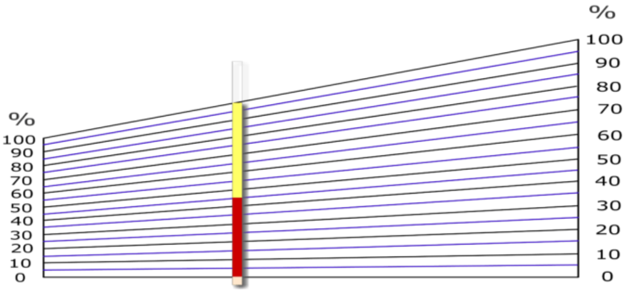


Fig. 1. The micro hematocrit reader.

$$PCV\ \% = \frac{\textit{The height of RBCs layer}}{\textit{The height of the whole volume of the blood sample}} \times \mathbf{100} \quad \text{....... 1}$$

$$HB = \frac{PCV-1}{3} \quad \text{........... 2}$$

2.3. Suggested mechanized method of measurement the HCT

The proposed automated method employs a set of six laser diodes (laser light with a wavelength of 650 nm). Compared to other sources, laser light has a significantly higher level of color purity. This means that the color of the light emitted by a laser is nearly identical, or monochromatic. The high degree of directionality of laser light is another distinguishing feature. To prevent light interaction between the LDs and ensure that the given laser LD activates the appropriate phototransistor, an optically separated substance is employed to separate the LDs. The architecture of LD and optical transistor detectors with isolated materials is shown in Figure 3. Between the LD and phototransistor detectors, the blood sample that has been centrifuged will be put into a capillary tube. As a result, the signals from the phototransistors can be utilized to calculate the blood volume and total blood concentration in the capillary tube. The microprocessor will then receive the signals from the detectors and compute (PCV) and (HB) levels, displaying findings LCD.

Fig. 3. The positioning of the isolated material with the LDs and phototransistor detectors.

2.4 The Arduino Atmega 2560 microcontroller

The suggested solution uses an Arduino Atmega 2560 microcontroller [12]. This type of microcontroller is viewed as an accessible and economical substitute. In contrast to previous variations of the Arduino microcontroller, it includes additional input/output ports and memory. There are 54 digital input/output pins and 16 analog input pins [12]. A 16 MHz crystal oscillator and a DC power connector are features of the Arduino Atmega 2560 microcontroller. This microcontroller is ideal for this study because of its features. The Arduino Atmega 2560 microcontroller is shown in Fig. 4.

Fig. 2. Microcontroller "Atmega" 2560 for Arduino.

A flowchart diagram of the microcontroller's operational program is shown in Figure 5. The microprocessor will process the data from the detectors and utilize Equations (1) and (2) to calculate levels of (PCV) and (HB), individually. Following that, the calculated figures will be guided to the LD for display. Fig. 6 shows a schematic design of the proposed system.

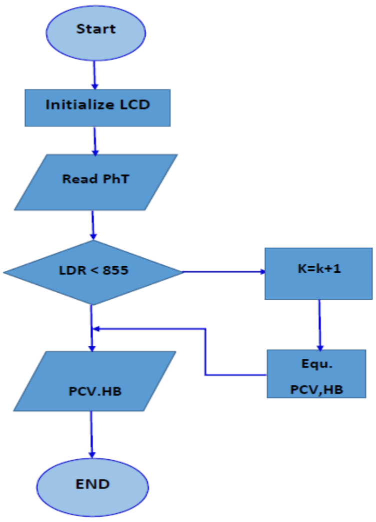


Fig. 3. The flow chart for the microcontroller's operating system.

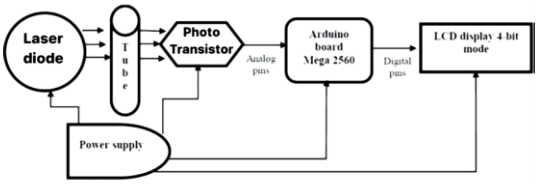


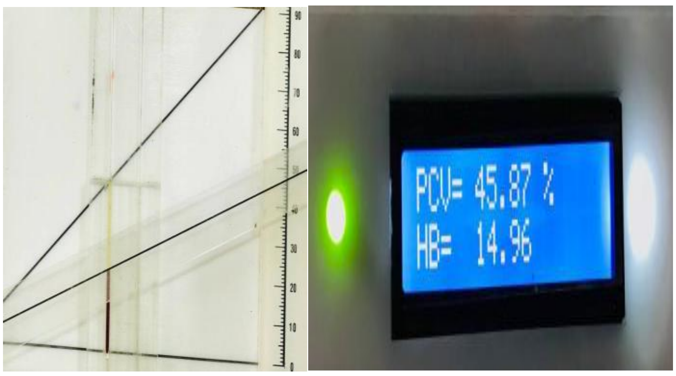
Fig. 4. The suggested system's schematic diagram.

3. Results

It was devised and realized the recommended automated system for measuring PCV. A blood sample was acquired and analyzed from 8 persons (4 males and 4 females) of various ages (mean: 33.16 7.19 years) to validate the applied system. The proposed automated system's results were compared to the traditional PCV calculating method. The readings for the automated and conventional methods are compared in Table 1. To acquire an optimal result and reduce human error, an expert in medicine measured the previous method. It is important to note that there is just a small difference between the two readings, which may be the result of subjective error. A comparison of various picture readings from the two systems is shown in Fig. 7.

Table 1: Differences in readings between the automated and traditional methods.

Samples	Gender	Age (Years)	Automatic readings PCV%	Manual Readings PCV %	Difference %
S1	Male	35	45.87	45	0.87%
S2	Male	42	43.72	43	0.72 %
S3	Male	25	46.52	46	0.52%
S4	Male	47	37	37	0%
S5	female	35	38.75	38	0.75%
S6	female	40	30.77	30	0.77 %
S7	female	24	40	40	0%
S8	female	55	32.63	32	0.63%



(a)

(b)

Fig. 7. The comparison of the results, (a): For female 24 years, (b): For male 35 years.

In the presence of the optically isolated substance, Fig. 8 illustrates a comparison between traditional readings and readings from the suggested automated system. Due to the comparatively high size of the phototransistor compared to the length of the capillary tube, there was a tiny variation between the two readings due to the usage of a limited number of phototransistors, when the same number of laser diodes were utilized. To make the readings more precise, the suggested automated system requires the employment of a larger number of phototransistors, which resulted in the emergence of those small variations in the readings. Additionally, until the desired current was reached, the current entering the laser diode through a variable resistance was varied to alter the intensity of the laser light delivered. In order to prevent the laser light from penetrating the blood, the resistance value was necessary and determined.

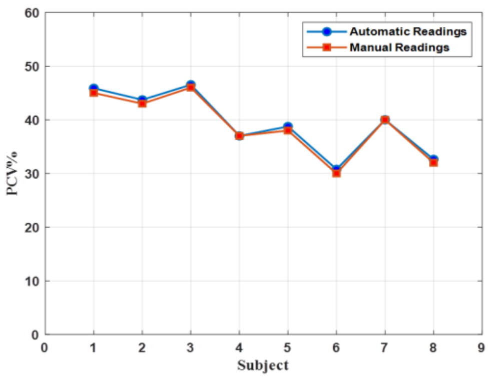


Fig. 8. PCV measurements utilizing automated techniques, isolator materials, and traditional techniques.

4. Conclusion

In a study called packed cell capacity (PCV), percentage of red blood cells is calculated using whole blood., as the quantity of red blood cells, whether raised or decreased, is a sign of the existence of various disorders. The goal of this research is to develop, test, and evaluate an automated method for assessing hematocrit in blood samples separated by centrifugation utilizing capillary tubes. It was discovered that the readings of PCV obtained using the traditional method and those obtained using the suggested automated methodology deviate slightly. To lessen the discrepancy between the readings, insulating materials were utilized between the laser diodes and the phototransistors. This study might be viewed as an attempt to provide a basic model for laser reading PCV, also a diagnostic model for a rapid, precise, and inexpensive HCT measurement tool. For a more precise reading in subsequent work, the green laser diode might be used in place of the red laser diode and the quantity of phototransistor receivers might be increased.

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