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Research Paper

Automated Method for Hemoglobin Count Measurement Using IR Sensor for Donors in Blood Bank

Engineering

KEYWORDS : Hemoglobin, optical density, blood bank, IR sensor, Beer-lambert law.

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ABSTRACT

Accurate measurement of donor's hemoglobin (Hb) level is of utmost importance prior to donation in any blood bank. The Drugs & Cosmetics Act permits drawing of blood by blood banks only from donors with hemoglobin count greater than 12.5 g/dL. The blood banks still opt for manual methods of Hemoglobin screening owing to economic factors. But accuracy remains a problem with such methods since it depends heavily upon the technicians performing the tests. By using automated methods, the possibility of manual errors can be ruled out. Despite the availability of several methods for screening of hemoglobin, no technique has been found to be ideal and satisfactory for a blood donation setup. Hence this study proposes an IR sensor with an aim to reduce expenditure and eliminate false measurements. The optical properties of blood samples differ based on the hemoglobin level of the sample. This variation in the optical density is used to determine hemoglobin count in donor blood. When IR beam is passed across samples of different hemoglobin levels, certain amount of light is absorbed depending on the Hemoglobin concentration whereas the rest continues on to the receiver. The reduction in amplitude of light transmitted to the receiver is indicative of hemoglobin level in the sample.

INTRODUCTION

Hemoglobin (Hb) is an iron containing protein in red blood cells that plays an important role in respiration by maintaining an adequate supply of oxygen to the vital organs. The central structure of hemoglobin consists of an iron molecule that holds on to oxygen or carbon dioxide resulting in oxy and deoxy hemoglobin structures, respectively. Hemoglobin concentration which is an indication of its ability to carry oxygen and iron is usually measured in grams per decilitre (g/dL). The normal range for hemoglobin level is widely dependent on the age and gender of a person. The ideal range for women lies between 12-16 g/dL and 13-18 g/dL for men. Deviation from the ideal values often interferes with the vital functions of the body. A low hemoglobin concentration indicates anemia which in turn may be indicative of bone marrow disorders or kidney failure whereas higher concentration of hemoglobin may occur due to tumor, lung or bone marrow dysfunction. Apart from this hemoglobin can also affect the shape of RBCs thereby hindering the transport of respiratory gases. Hence testing of hemoglobin concentration in blood donors is crucial prior to blood donation in order to determine if the person is fit for donation of blood and to ensure better quality of blood product.

According to the Drugs & Cosmetics Act, blood banks are not allowed to collect blood from donors with a hemoglobin level less than 12.5 g/dL to ensure safety of the donors("The Drugs and Cosmetics Act and Rules," 2005). If blood is accidentally drawn from a donor with hemoglobin count less than 12.5 g/dL, it may affect the recipient and also render the donor anemic. On the other hand, donor blood with hemoglobin count greater than 16 g/dL causes the blood to be hyper viscous thus restricting its flow in the microcirculation.

There are numerous methods available for estimation of hemoglobin count in blood banks Among them, the most commonly employed method is the specific gravity method. This is owing to the need for a cost effective solution to meet with the large number of donors. This method uses copper sulphate solution adjusted to a specific gravity of 1.053, which in turn corresponds to 12.5 g/dL of hemoglobin(Phillips, Slyke, Hamilton, & Dole, 1949). But this method fails to offer quantitative interpretation thus resulting in inappropriate inferences. Another traditional method in usage is the cyanmethemoglobin method. This involves introducing a lysing agent in diluted blood in order to disrupt the RBCs thereby releasing hemoglobin, whose concentration is read using a spectrophotometer. This method has its own disadvantages(Nkrumah et al., 2011). Another portable method uses pre-coated strips over which blood is applied before inserting into the device. In this case, the concentration is displayed instantly. But this method is too expensive to be preferred by blood banks and displays falsely elevated values(Adam, Ahmed, Mahmoud, & Yassin, 2012)(Malukani, Gajjar, Gonsai, & Bhatnagar, 2014). Hemoglobin Colour Scale(HCS) test is simple, inexpensive and can be used for diagnosing anemia but does not suit blood banks as it cannot predict intermediate values more accurately(Ingram & Lewis, 2000)(Paddle, 2002)Taking into consideration the drawbacks of above methods, there is still a demand for portable, cost effective, automated and an accurate device for screening hemoglobin in a blood donation set up.

The IR sensor designed in this study is a simple approach towards eliminating the possibility of false measurements and to indicate if a person is eligible for blood donation. Here, hemoglobin concentration is measured by making use of the differences in optical density. In this method, the amount of sample taken, the preprocessing steps and the cost involved are reduced thus yielding a simple automated method for hemoglobin detection. As stated by the Beer Lambert's law, transmittance of the donor blood samples measured in the infra-red range provides information on concentration of Hemoglobin in the samples.

METHODOLOGY:

A. OPTICAL DESIGN

This optical system is based on the Beer-Lambert law. The system has been designed in such a way that the IR rays from the source are focused on to the sample through the collimator. The rays after passing through the sample fall on to the photodiode on the other side. The important factor to be considered in the design of this device is that the IR source, blood sample and the detector must always remain in the axis. Optical density of the blood sample varies with

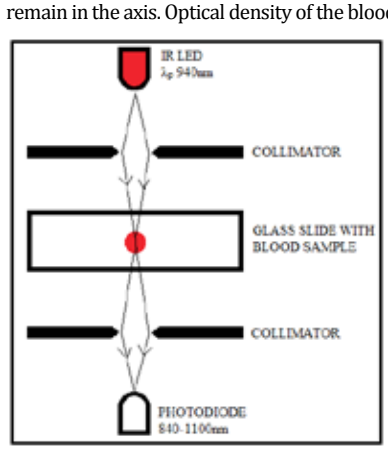

Figure 1: Optical design

hemoglobin count. Due to the variation in the optical density the transmittance varies which is detected by forward scattering. This transmittance is eventually used in identifying the hemoglobin count of the blood sample.

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B. HARDWARE COMPONENTS

The frequency generated from the oscillator circuit (10 kHz) is given to the sensor circuit where the sample to be examined is placed between the IR LED and photodiode pair. As the light from IR LED passes through the sample, due to absorption of light by the test sample, a variation in the light intensity is observed at the photodiode. Since the absorption varies between different blood samples, the voltage generated by photodiode also varies between each blood sample of different hemoglobin concentration. This variation is sent to the analog to digital convertor in PIC microcontroller. The values from the controller are then sent to the LCD.

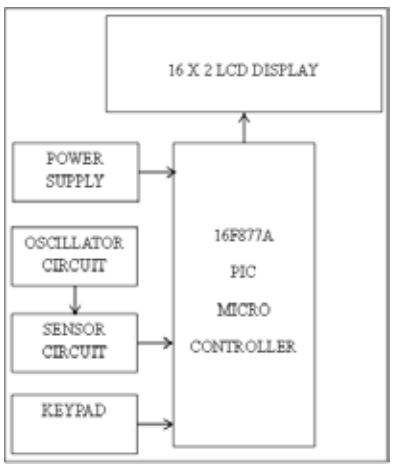

Figure 2: Block diagram of the proposed system

1. IR SENSOR PAIR

Infrared Emitting Diode (IR333C), of 5mm diameter is used in the device as the IR source. Having clear lens and made of GaAlAs material, it generates a peak wavelength (λp) of 940nm.

The constant frequency from 555 timer output is given to the anode of the IR LED and the cathode is connected to ground through 100 Ω.

PIN photodiode in a standard 5mm diameter plastic package is used as the photo receiver. It has a black colour lens made of silicon. Due to its black epoxy, the device is sensitive to visible and infrared radiation. The range of spectral bandwidth (λ) is from 840 to 1100nm, with peak sensitive wavelength (λp) at 940nm, hence it is best suited for IR333C.

The anode of the photodiode is connected to ground through a 100 Ω resistor and cathode to 5V power supply. When the infrared photon strikes the photodiode the current starts to flow from cathode to anode. The current has nowhere to go except through the resistor. As the current passes through the resistor the voltage raises across the resistor. This voltage output is then fed off to ADC in PIC. 0.1μF capacitor and an adjustable resistor are connected across to remove the ripple.

2. PIC MICROCONTROLLER

The microcontroller used for the proposed device is PIC16F877A, which is an 8-bit microcontroller. It features operating speed of 20 MHz, 200 ns instruction execution and 256 bytes of EEPROM data memory. Peripheral feature includes 33 Input-Output (I/O) pins and 5 I/0 ports. This PIC has 10-bit, 8 channel Analog-to-Digital (A/D) converter. The operating voltage range is from 4.0-5.5V.

PIC can only differentiate between HIGH (input greater than 2.5V) which will be read as '1', and LOW (input lesser than 2.5V) which will be read as '0' on input pins. But the output from the photodiode is analog in nature. Hence to solve this problem the signal from the photodiode is given to the A/D converter of PIC. The 10-bit A/D converter converts an analog voltage level to a digital number ranging from 0 to 1023 (2^{10} = 1024 states). The microcontroller can then efficiently process the digital representation of the original analog voltage.

The analog input is given to the Port A (AN 0, second pin) an 8-bit wide, bi-directional port. The given input charges a sample and hold circuit. The output of the sample and hold capacitor is given as the input to the converter. The converter then generates a digital result of the analog level via successive approximation. This A/D conversion, of the analog input signal results in corresponding 10-bit digital number which is a quantized representation of the original analog signal. The high and low analog reference voltage in this case is selected as the microcontroller supply voltage and ground respectively. The resolution of this A/D converter is 0.0048V.

C. SAMPLE COLLECTION

Blood samples for the trials were collected by venepuncture of the Median cubital vein, a superficial vein of the upper limb. This process was carried out by trained professionals in SRM Hospital, Chennai.

D. SAMPLE PLACEMENT

The device consists of a slide holder into which the glass slide can be slid into position. A standard glass slide of 75 mm X 25 mm X 1.30 mm was used throughout the test in order to avoid errors.

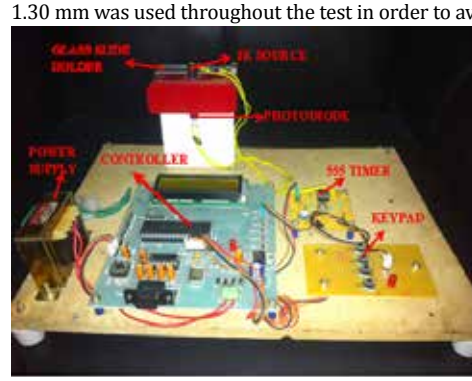

Figure 3: Hardware setup

A marking was made on the slide holder indicative of the position in which the blood drop is to be placed. 10μL of the blood sample was then placed in the appropriate position over the glass slide. The slide along with the blood drop was then introduced to IR rays.

RESULT

Table I displays the hemoglobin count of samples collected along with their ADC output readings.

TABLE – 1 OUTPUT READINGS

S.No	Hemoglobin Count (g/dL)	ADC output
1	15.9	70
2	15.4	90
3	15.4	90
4	15.2	91
5	13.3	104
6	12.6	107
7	12.5	109
8	12.4	110
9	11.3	12.5
10	9.8	140

Correlation co-efficient between the hemoglobin count and the ADC output obtained for all the samples is -0.9641. The output of the device as given in the table proves that hemoglobin count and the device output (transmittance) are inverse and linear in nature.

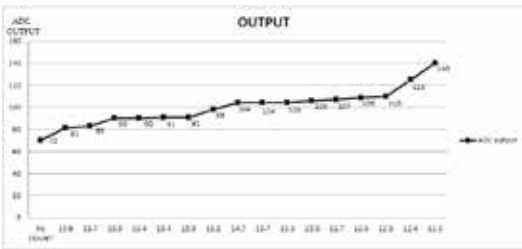

Figure 4: ADC output graph

Figure 4 shows the plot between hemoglobin count on the x-axis and the digital output of the device on the y-axis. The digital output for a hemoglobin count of 12.5g/dL is 109. Hence the donor's samples with ADC value 109 or lesser are eligible to donate blood.

Figure (a) Figure (b)

Figure 5: (a) LCD showing ADC output, (b) LCD showing eligibility to donate blood

Figure 5(a) shows the LCD displaying digital value as 104 while placing the blood sample of hemoglobin count 13.3 g/dL in the path of IR rays.

The LCD displays this value instantly without any time delay. Once the digital value is displayed, keypad can be used to navigate through the menus to display the eligibility of the person. Figure 5(b) shows the LCD displaying 'CAN DONATE' message for the person with hemoglobin count 13.3 g/dL.

DISCUSSION

Even though there are several options for determining hemoglobin count, there are currently no methods suitable for a blood bank setup. Hence the proposed method was designed with a view of providing quantitative results and reducing the cost of each test.

As the hemoglobin count increases, the absorption of IR light rays are also found to increase thus resulting in low transmittance detected on the photodiode. Hence the absorption is found to be greater in samples with greater hemoglobin count and vice versa.

As shown in the results, hemoglobin counts of over 25 samples have been tested with good accuracy. The setup has proved to be capable of distinguishing differences as small as 0.1 g/dL.

Prompt testing of the sample is important as the sample may undergo chemical disruption rapidly. The most important optical design factor is the placement of IR source, sample and detector in the same axis for detecting forward scattering. The other factors that affect the result are the grades of the slide and quality of the needles being used in the pipette. Grades of the slides have not been changed throughout the test.

CONCLUSION

In conclusion, the proposed setup for finding hemoglobin count has shown promising results. The IR LED and photodiode pairs have detected hemoglobin with 940nm as its peak wavelength.

This device can be a better choice over copper sulphate solution owing to the several disadvantages associated with the latter procedure(Shahshahani, Meraat, & Mansouri, 2013). The cost involved per test is also less compared to other devices like Hemocue® where the cost of each test is approximately 30INR(Tondon, Verma, Pandey, & Chaudhary, 2009) .

FUTURE REQUIREMENTS

According to the Drugs and Cosmetics Act, preliminary tests have to be conducted to check the temperature, pulse, systolic and diastolic blood pressure of the donors before donation. The person is eligible for donation only if all the above mentioned criteria are in the normal range. But few primary tests are not strictly being performed in blood bank which is a violation of law. Hence temperature sensor, blood pressure and heart rate monitor can be integrated with the proposed device to develop an exclusive device for blood donation camp.

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REFERENCE

Adam, I., Ahmed, S., Mahmoud, M. H., & Yassin, M. I. (2012). Comparison of HemoCue® hemoglobin-meter and automated hematology analyzer in measurement of hemoglobin levels in pregnant women at Khartoum hospital, Sudan. Diagnostic Pathology, 7(1), 30. doi:10.1186/1746-1596-7-30 | Ingram, C. F., & Lewis, S. M. (2000). Clinical use of WHO haemoglobin colour scale: validation and critique. Journal of Clinical Pathology, 53(12), 933–7. | Malukani, P., Gajjar, M. D., Gonsai, R. N., & Bhatnagar, N. (2014). Study of newer invasive and non-invasive methods of haemoglobin estimation in blood donor screening - A study on 200 donors. International Journal Of Current Research And Review, 06(04), 26–30. | Nkrumah, B., Nguah, S. B., Sarpong, N., Dekker, D., Idriss, A., May, J., & Adu-Sarkodie, Y. (2011). Hemoglobin estimation by the HemoCue® portable hemoglobin photometer in a resource poor setting. BMC Clinical Pathology, 11(1), 5. doi:10.1186/1472-6890-11-5 | | Paddle, J. J. (2002). Evaluation of the Haemoglobin Colour Scale and comparison with the HemoCue haemoglobin assay. Bulletin of the World Health Organization, 80(10), 813–6. | Phillips, R. A., Slyke, D. D. Van, Hamilton, B., & Dole, V. P. (1949). Measurement of specific gravities of whole blood and plasma by standard copper sulphate solutions. The Journal of Biological Chemistry, 305–330. | Shahshahani, H. J., Meraat, N., & Mansouri, F. (2013). Evaluation of the validity of a rapid method for measuring high and low haemoglobin levels in whole blood donors. Blood Transfusion, 11(3), 385–90. doi:10.2450/2012.0031-12 | The Drugs and Cosmetics Act and Rules. (2005), 1940. | Tondon, R., Verma, A., Pandey, P., & Chaudhary, R. (2009). Quality evaluation of four hemoglobin screening methods in a blood donor setting along with their comparative cost analysis in an Indian scenario. Asian Journal of Transfusion Science, 3(2), 66–9. doi:10.4103/0973-6247.53874 | |