ISSN 2229-5518

Advanced Instrumentation System Using ARM Controller for Blood Analysis

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Abstract— Modern bio medical sciences incorporate soft tools to diagnose various parameters of human fluids. Conventional method of blood sample analysis makes use of laboratory technique of titration, which is operator dependent and could result in lot of errors depending on the skill of the operator. In order to eliminate the human errors involved in the conventional method, In this paper an attempt has been made to present a capillary centrifuge technique driven by high speed state of art DC motor controlled by a powerful processor resulting in accurate analysis of the blood samples. This paper brings out the various advantages of the proposed blood measurement technique in the form of accuracy of blood analysis, quickness and at a low price.

Index Terms— ARM Processor, Capillary tube, DC Motor, Optical Encoder, Photo detector, Photo diode, Stepup Chopper.

1 Introduction

Rapid advancement in electronics and embedded systems has led to a new beginning in the field of biomedical sciences. As a result of this various sophisticated equipments are being continuously developed in the recent past. These instruments have aided the physicians to treat the patients effectively. Further many instruments related to blood analysis have also been developed, but these equipments are too expensive and beyond the reach of medium scale laboratories and clinics. Hence, any attempts to develop a cost effective method or technique is needed and welcome. One such attempt to develop a simple instrument and technique to measure blood sample is presented in this paper.

This paper technique involves a dc motor which holds a capillary with blood sample and is rotated at high speed on time reference to give RBC and WBC count data the dc motor makes an attempt to design a low cost blood analyzer incorporating centrifuge technique. This method is simple straightforward and yields results fast. The centrifuge is effectively controlled by an ARM Controller to run the motor at 10,000 rpm. The controller also measures the blood information and logs it. The data obtained is compared with the standard equipment to show conformity of the result obtained [3-18].

2 Optimization of Capillary Tube

A capillary tube is a long, narrow tube of a fixed diameter. Typical tube diameters of capillary tubes range from 2 mm to 6mm and vary in length. The capillary tube selected for experimentation has the diameters 2mm and length 10cm. The choice of the capillary tube is based on the series of experimentation carried out on different capillaries. Based on this the capillary tube is optimized. The graph in fig.1 is plotted on time reference that yields blood dissociation. The graph clearly indicates that the optimized capillary tube gives effective results when rotated at 10000 rpm for 5 min.

TABLE 1
OPTIMIZATION OF CAPILLARY TUBE

Sl. No	Diameter (mm) of capillary tube	DC Motor Speed (rpm)	Spinning time (min)	Observation of blood sample in capillary
1	2	1000 - 10000	3	No layers formed
	2	1000 - 10000	4	No layers formed
	2	1000 - 6000	5	No layers formed
	2	6001 - 9000	5	Interleaving of RBC, WBC & plasma
	2	10000	5	Three distinct layers formed
2	3	1000 - 10000	3	No layers formed
	3	1000 - 10000	4	No layers formed
	3	7000	5	Interleaving of WBC and plasma
3	4	1000 - 10000	3-5	No layers formed
4	6	1000-10000	3-5	No layer formed

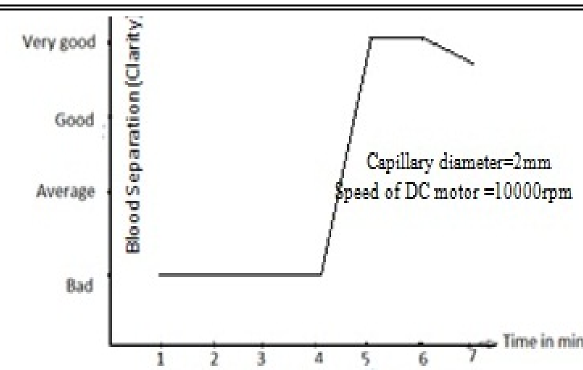

Fig. 1. Optimized Graph of Capillary

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ISSN 2229-5518

3 System Implementation Block Diagram

Block diagram of the system for separation and detection of the whole blood components is shown in fig.2 Mentioned below are the major components of system.

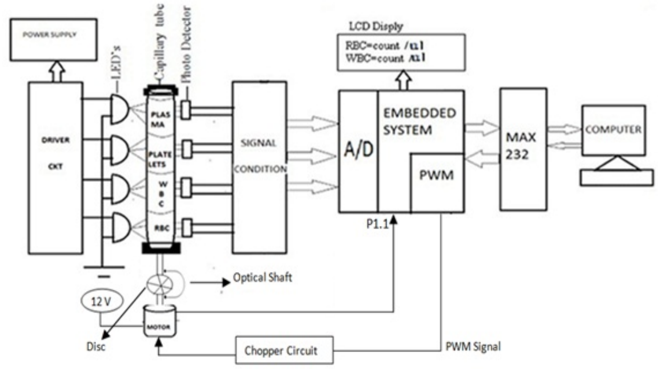


Fig. 2. Optimized Graph of Capillary

3.1 Motor Drive

In order to separate out different components present in whole blood such as RBC, WBC, Platelets & Plasma, a 12 V, 3.3 Amp,12000 rpm DC motor is used in centrifugal system, which has to be rotated at a speed of 10000 rpm for a duration of 5min. Speed of DC motor is controlled using PWM signal applied to chopper.

3.2 Photo Detector

The detector used in the system is in the form of single monolithic integrated circuit TSL 257, it is a high sensitivity, Low noise, light to voltage optical converter. It consists of photo diode & transimpedence amplifier with transimpedence gain of MΩ. It comes in the form of three lead plastic package with an integral lens [20] improved offset voltage stability and consumes less power. Light intensity to voltage Detector and LED light sources are placed opposite to each other in the form of columns on either side of the sample holder. The ARM processor gets among output from the detectors using on-chip A/D converter.

- Key features of photo detector
- IC containing photodiode, op-amp.
- High sensitivity and single voltage supply operation.
- Low noise and rail-to-rail output.
- High power supply rejection ratio.

3.3 ARM LPC 2148 Processor

ARM7LPC2148 controller with built in six channels A/D is used for data acquisition, processing and displaying the results [21, 22, 23] and hence, it is the key element in the present system design. Further, ARM7LPC2148 has advanced features to upgrade the system for future use as it has various inbuilt peripherals such as timers of 32 bits, 10 bits ADC(s) single or dual, DAC of 10 bits PWM channels, 45 fast GPIO lines with up to nine edge or level sensitive external interrupts, full speed USB 2.0, multiple UARTs, SPI, I2C bus and etc. In the present system, on-chip PWM channel is programmed to control the speed of the dc motor in the centrifuge system.

3.4 Display Devices

A low cost and compact 16X2 liquid crystal display is interfaced with ARM7TDMI LPC2148 processor and is used as the medium for displaying RBC and WBC count and LCD is interfaced to port 0(P.0-P0.15).

4 DC Motor

4.1 Principle of Operation

The DC machine is a highly versatile machine. It can provide high starting torques as well as high accelerating and decelerating torques. It is capable of quick reversals, and speed control over a range of 4:1 is achieved with relative ease in comparison with all other electromechanical energy-conversion devices. These are features that are responsible for its use in the really tough jobs in industry, such as are found in steel mills. Unfortunately, the need for a mechanical rectifier (in the form of a commutator) to convert the AC EMF that is induced in each armature coil to a unidirectional voltage makes it one of the least rugged of electric machines as well as more expensive.

4.2 Methodology Used for Speed Computation of DC Motor

In order to achieve a speed of 10,000 rpm the dc motor used is fed by step up chopper to the armature circuit, while maintaining the field constant. The resulting equations describe the relation with speed and chopper voltage applied to armature.

EMF equation of separately excited DC machine is given by

$$E = \frac{P\varnothing ZN}{60A} \quad \text{---} \quad (1)$$

Where, P = No. of poles
Ø = Flux
Z = No. of armature conductor
N = Speed in rpm
A = No. of parallel paths
For wave winding A = 2
For lap winding A = P
E = Voltage in volts

Since field is kept constant. Voltage E is directly proportional to speed of the Motor N, mathematically represented as

$$E \alpha N \quad \text{--- } 2$$

In equation 2, varied E will result in variations of N
It consists of an opaque disc mounted on the shaft of the motor whose speed is to be measured. The disc has a number of perforations around the periphery of the disc. An opto coupler is used to measure the speed of the motor. The resulting pulses obtained give one to one correspondence with speed. The figure shows the construction and the pulses obtained [1, 2, 19].

4.3 Measurement of Speed Using Optical Shaft

The numbers of Pulses obtained are fed to the port of LPC2148 ARM Controller and judicious software computes the speed of the motor by measuring the pulse width count. The count obtained is compared with the look up table to determine the speed. Any variation in speed is corrected by generating a

ISSN 2229-5518

new set of triggering pulses or firing angle to the chopper using look up table. The flow chart depicts the generation of chopper pulses and speed measurements.

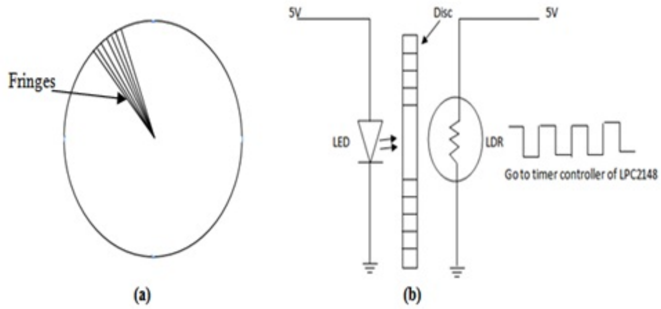


Fig. 3 . (a) Optical Disc with Shaft of 5000 fringes (b) Measurement of Speed with Disc Fringes.

4.4 Speed Control Algorithem & Flowchart

The LPC2148 ARM Controller is initialized with two ports, one port to sense the speed and the other port to send the firing angles (α) to the chopper to get the desired speed of 10,000 RPM. The controller is in a loop until the desired output is reached. The look up table is created and stored in memory for future modifications depending upon the need and analysis of the samples where count of the pulse width indicates the speed (N) of the motor in RPM and α indicated the firing angle of the chopper.

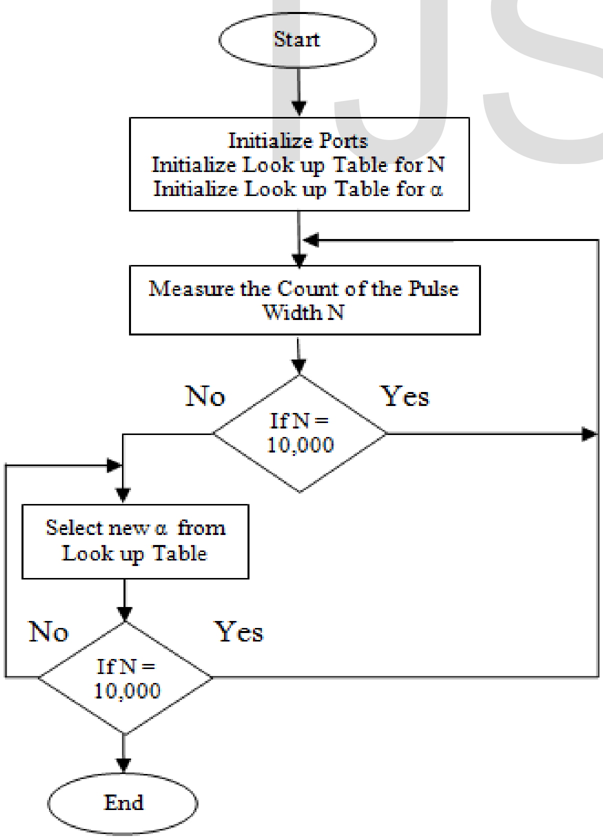
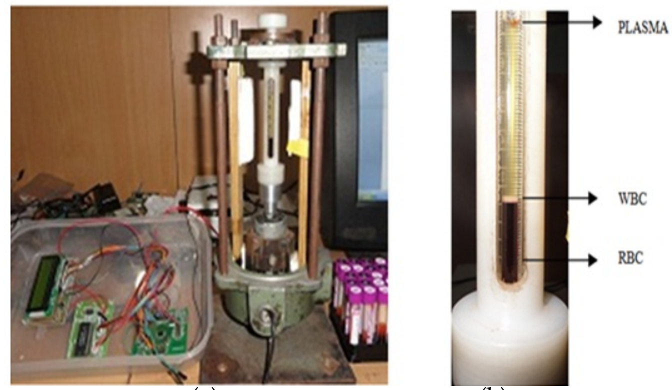


Fig. 4 . Flow chart to Determine speed (N) and firing angle(α)

5 Experimental Setup

The entire set up made for separation and detection of the blood components is as shown in Fig.5.



(a) (b)

Fig. 5 . (a) Experimental Setup (b) Sample Column after Separation

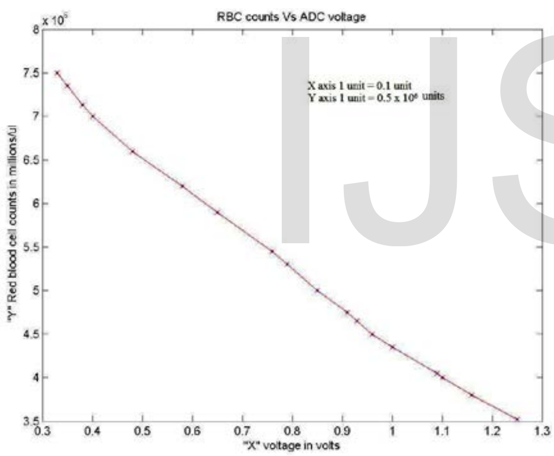
Sample holder containing whole blood, is rotated for a period of 5 minutes with a speed of 10000 RPM to divide blood into individual components. Fig 5(b) shows the resultant sample column with separated components. Since RBC contains some heavy particles such as iron, it settles down at the bottom of the capillary tube (can be seen as red in color) above which WBC cells get accumulated (can be seen as white in color), then the platelets (can be seen as a yellow circle on top of the WBC). Rest at the top of the column is plasma.
Resultant sample column is exposed to a photometric and this system measures the individual components such as RBC and WBC.

TABLE 2
RBC Vs A/D Readout

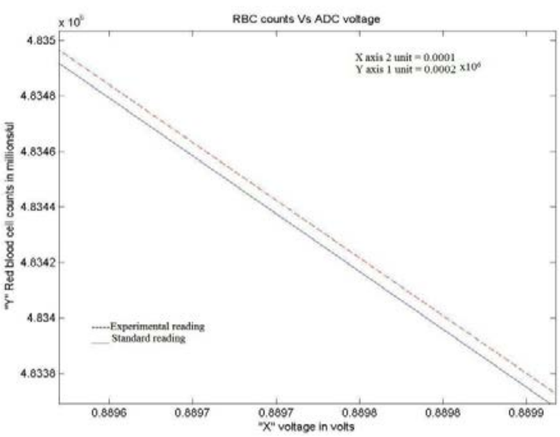
X Axis (Voltage in volts)	Y Axis (RBC count/ul) (Experimental reading)	UBM Fx-19 plus (Auto hematology Analyzer) RBC count/ul (Standard reading)
1.25	3520100	3520000
1.16	3800050	3800000
1.10	4000200	4000000
1.09	4050200	4050000
1.00	4350050	4350000
0.96	4500080	4500000
0.93	4650080	4650000
0.91	4750100	4750000
0.85	4999950	5000000
0.79	5299920	5300000
0.76	5450050	5450000
0.65	5899996	5900000
0.58	6199996	6200000
0.48	6600050	6600000
0.40	7000080	7000000
0.38	7130080	7130000
0.35	7350080	7350000
0.33	7500160	7500000

TABLE III
WBC VS A/D READOUT

X Axis (Voltage in volts)	Y Axis (WBC count /ul) (Experimental reading)	UBM Fx-19 plus (Auto hematology Analyzer) RBC count/ul (Standard reading)
1.52	10400	10350
1.56	9900	9800
1.58	9500	9550
1.62	9000	9050
1.68	8400	8375
1.69	8300	8250
1.76	7500	7600
1.81	7000	7100
1.85	6500	6700
1.97	5500	5600
2.01	5200	5250
2.03	5000	5050
2.05	4800	4850
2.09	4500	4550
2.12	4100	4300

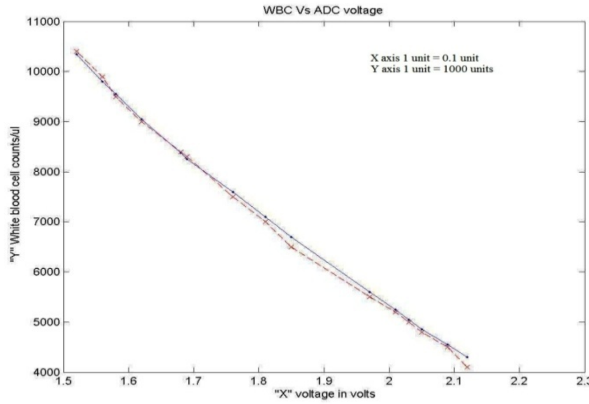


(a)

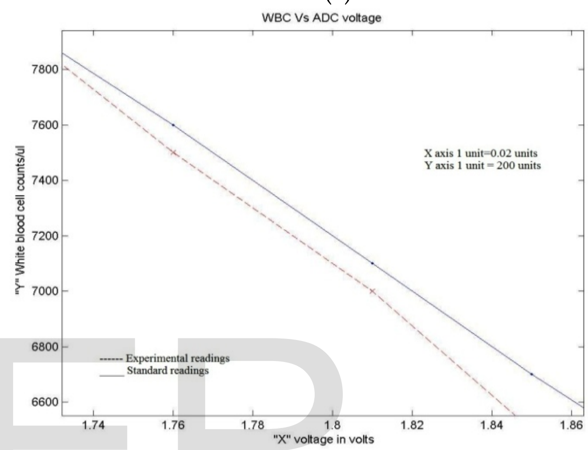


(b)

Fig. 6 (a) RBC Vs Voltage Plot (b) RBC Vs Voltage Plot Expanded



(a)



(b)

Fig. 7 (a) WBC Vs Voltage Plot, (b) Expanded Graph of WBC Vs Voltage

The photo detector TSL 257 gives the varying voltage range of 0.33 V to 1.25 V and 1.52 V to 2.12 V for RBC and WBC measurements respectively. Further these values are substituted in the calibrated equation to get the RBC and WBC count and then the same is displayed in terms of millions/micro-liter and thousands/micro-liter. Table. II & III shows the experimental results obtained which is compared with the standard instrument measurements. Table.II show RBC count Vs A/D converter read out and Table.III show WBC count Vs A/D converter read out measurements (RBC and WBC) taken by the standard instrument.

RBC & WBC Vs voltage graph and its enlarged view is shown in the fig 6 and fig 7. Results are drawn after calibrating photometric system with the standard hematology analyzer (UBM Fx-19).

6 DISCUSSIONS

The experimental set up was tested effectively and the results obtained were critically compared with the standard results obtained from the standard test equipment Kx-21, Transia, Japan (Auto hematology analyzer). The variations obtained were in the order of ± 10%.The experimental results obtained are authenticated by a reputed pathologist. (Certificate Enclosed).

7 Conclusion

This paper has led to the analysis of blood mainly RBC and WBC effectively by using centrifuge method. This method has the advantage of low cost, accurate analysis of blood and can be used in remote areas with the help of battery/dc power. Further the set up can be made more users friendly by interfacing this equipment to a PC, for data logging which serves as a ready reference for the physicians.

Acknowledgment

We would like to thank Vijayanagar Institute of Medical Sciences (VIMS), Bellary, Karnataka for their support in providing blood samples and accessing their labs in order to calibrate our photometric.

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