CHAPTER 7
SUMMARY, CONCLUSION AND FUTURE SCOPE

7.1 SUMMARY

The aim of this research work is to propose a new bio-medical instrumentation system for separation and detection of whole blood components namely RBC and WBC of human blood sample. The research findings and contributions related to biomedical instrumentation are highlighted in the classified survey on different types of separation techniques adopted in conventional instrumentation systems. The literature review suggests that sufficient research has not been carried out to innovate and overcome the deficiencies or limitations of existing separation methods. The inherent drawbacks, technical and research gaps associated with each separation technique are the reasons why two new instrumentation systems namely ARM based instrumentation system and FPGA based instrumentation system are designed and finally tested for their suitability and adoption.

The deficiencies, limitations, and research gaps specific to separation techniques adopted in conventional instruments are summarized below.

1. The optical separation uses optical tweezers to focus a laser beam on RBC or WBC particles. The optical separation technique is complex and uses advanced sensors which are expensive.
2. Magnetic separation technique is a slow and complex process. It works based on magnetic properties of blood particles of RBC and WBC.
3. The electrical separation technique overheats the blood particles. The generic properties of the particles will change. This will alter the results.
4. Fluidic separation technique separates blood particles based on differential densities. It uses costly hydrodynamic equipment.
5. Dielctrophoretic virtual pillar array works based on size of particles. The problems with this technique are clogging and cost.
6. Thermal or acoustic separation technique is not efficient because thermal diffusion of particles influences the results.
1. The filtration technique mainly poses the problem of clogging of the filters and membranes used for the separation process.

2. The vibration technique consumes more time and more power for separation. The technique is expensive. The membranes and filters in the instrumentation get clogged.

3. The instruments using centrifugation technique adopt procedures which require more blood, more time and addition of reagents.

The following are the general drawbacks in the conventional instrumentation systems using different separation techniques.

1. Use of more blood sample
2. Addition of reagents, gels or diluting agents
3. Processing time is more.
4. Instruments work on AC supply.
5. The Instruments are expensive.
6. They are not portable
7. They are not easy to operate.
8. Service charges are more

The proposed new instrumentation systems of ARM based instrumentation system and FPGA based instrumentation system, adopt the separation technique of centrifugation and the design features and working procedure ensure that the technical and research gaps are addressed in them.

7.2 CONCLUSION

After the development of the ARM based instrumentation system and FPGA based instrumentation system, they were tested in real time with 12 blood samples to find RBC and WBC. The blood samples were collected from Amruth Diagnostic Laboratory, Bellary, Karnataka without violation to professional ethics. The same 12 blood samples were tested in Kx-21, Transasia for comparison and authenticity of results. The compared results clearly confirm that the procedure adopted in both the systems gives precise RBC and WBC counts by overcoming the limitations of
existing methods. Table 7.1 compares the salient features of conventional systems, ARM based instrumentation system and FPGA based instrumentation system.

Table 7.1 Comparison of conventional systems and developed new instrumentation systems

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Parameters</th>
<th>Conventional Systems</th>
<th>ARM based instrumentation system</th>
<th>FPGA based instrumentation system</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Adding gels or reagents or diluting agents</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Volume of blood required</td>
<td>Large (More than 2 ml)</td>
<td>Small (Less than 1 ml)</td>
<td>Small (Less than 1 ml)</td>
</tr>
<tr>
<td>3</td>
<td>Testing time</td>
<td>More than 30 minutes</td>
<td>5 minutes</td>
<td>5 minutes</td>
</tr>
<tr>
<td>4</td>
<td>Portability</td>
<td>Bulky and non-portable</td>
<td>Small and portable</td>
<td>Small and portable</td>
</tr>
<tr>
<td>5</td>
<td>Power supply</td>
<td>AC</td>
<td>DC (Two batteries of 24 V and 5 V)</td>
<td>DC (Two batteries of 12 V and 5 V)</td>
</tr>
<tr>
<td>6</td>
<td>Separation technique</td>
<td>Any of the available techniques</td>
<td>Centrifugation</td>
<td>Centrifugation</td>
</tr>
<tr>
<td>7</td>
<td>Cost</td>
<td>High cost</td>
<td>Low cost</td>
<td>Low cost</td>
</tr>
<tr>
<td>8</td>
<td>Flexibility</td>
<td>--</td>
<td>Software centric and flexible</td>
<td>Hardwired logic not flexible, fastest.</td>
</tr>
<tr>
<td>10</td>
<td>Cost of service</td>
<td>High</td>
<td>Very less</td>
<td>Very less</td>
</tr>
<tr>
<td>11</td>
<td>Operators to handle the system</td>
<td>Well trained</td>
<td>Less trained</td>
<td>Less trained</td>
</tr>
</tbody>
</table>

The accuracy of both the instruments is measured in terms of the average errors in values of RBC and WBC as noted below. (Section 5.1 and Section 6.1)

ARM based instrumentation system:

Average error for RBC = -0.006452 %

Average error for WBC = 0.0119429%
FPGA based instrumentation system:

Average error for RBC = 0.0017948 %

Average error for WBC = 0.0017453 %

The average errors in RBC and WBC in FPGA system are less. Hence the FPGA based instrumentation system is finally proposed and selected as low cost alternative to find RBC and WBC of human blood, for adoption in rural areas. This system is very much valuable to medical practitioners working in rural areas to find out the RBC and WBC by themselves, instead of referring the cases to costly testing centres.

The device has the great service impact to the large population spread in rural areas in India where there are more power failures. The designed bio-medical instrument has revolutionary value when it can be popularised as a low cost alternative to the existing conventional and costly instruments.

7.3 LIMITATIONS OF THE PRESENT WORK

Adequacy and sufficiency parameters in terms of number of test samples are considered based on the limitations and constraints in procuring the blood samples for calibration of the instrument (19 blood samples) and validation of the instruments (12 blood samples)

The number of blood samples used for the research work was dependent on the availability of the blood samples with Ms Amruth Diagnostic laboratory, Bellary and support extended by them. The quality and performance of the designed instrumentation system would have been improved if more number of samples had been used in calibration and validation of the instrumentation.

7.4 SCOPE FOR FUTURE WORK

The FPGA based instrumentation system can be further developed with refinements and added features, such that it becomes an ASIC (Application Specific Integrated Circuit) design. This can popularised among NGO’s and non profit groups working in health care such that it reaches rural areas. Further research and work are
needed in this direction to make it a multi functional device, to measure not only RBC and WBC but also other vital parameters like haemoglobin content, platelets in blood samples.

An IoT enhancement can be done to the equipment, so that result can be directly delivered to the physician and the patients. Or an add-on technology can be developed to interface with the existing equipment which may help in integrated diagnosis of different blood parameters of patients.

The equipment can be interfaced to a PC for data logging which serves as a ready reference for the physician so as to make it user friendly.