First Undergraduate Research Experience: Pulse Oximeter Design

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***Abstract*- All undergraduates (UG) who set aside research for faculties and professionals are not only missing interesting moments in their graduation, but also fail to grab the extra bit of information which will assist them in their career. Formal education is an integral part of learning but research experience gives hands on experience which class room coaching fail to deliver. These activities not only enhance technical skills but also develop vital life skills like team work, communication skills and problem solving ability. The style of project submission and reviewing gives the student an overview on industrial product development cycle. A Humanitarian Technologies lab established in our institution gave us ample opportunity to work with projects which benefit human life. In this paper we present the research work we carried out in pulse oximeter design and implementation, and thereby bring out the UG research experiences – benefits, challenges, knowledge developed, expertise acquired etc.**

***Keywords*—UG research, oximeter,**

I. INTRODUCTION

Undergraduate Research experience is a sweet part of the academics for the students who have really undergone one. It's also a satisfactory part of the teachers who teach theory courses to be able to guide one such team of UG students. For, it's through this first step, the students begin to taste the research aspect which is going to help them very much in future either for the campus placements or for their higher studies. We should also note that many universities in India do not provide space for such research work and do not realize the potential hidden in such research work. In addition many teachers do not want to guide UG students in research work and prefer graduate students in their place. Also at UG level most students don't recognize the importance of research work as they are not aware of the potential benefits. Through this project and research we would like to highlight the importance of such research, the challenges faced, the knowledge acquired, project design and development phased involved etc.

From recent past, engineers have started aiming to solve complicated problems from societal needs and concerns. Until recently, reliable methods did not exist for accessing biological systems broadly at their molecular levels. It proves to be ample time to research on a medical instrument like pulse oximeter. Today, biomedical engineers are at the forefront of developing these powerful, innovative methods and employing them in exciting new ways for societal benefit. Students doing researches can carry out over a wide range of applications in human and environmental health and various diverse industries. The project areas to be found in the biomedical research programs, are ideal for learning how to effectively address important problems combining engineering principles and perspective with the knowledge and tools of modern molecular life sciences.

Oxygen saturation refers to the percentage of haemoglobin that carries oxygen. When there is no haemoglobin carrying oxygen, the oxygen saturation is said to be 0 % , similarly when all the haemoglobin is carrying oxygen, the saturation is 100 %. So, oxygen saturation gives an idea on percentage of haemoglobin that is carrying oxygen. healthy adults for saturations in the range of 70 to 100%.

Pulse oximetry is achieved by electromagnetic radiations of appropriate frequencies depending on the absorption spectra of oxygen. Light and IR radiations are emitted from respective emitters. The emitted radiations travel across the probes and reach the light/IR detectors. Then a microcontroller measures and calibrates the amount of oxygen in the blood. Pulse Oximeter can find its use in various medical applications such as monitoring patient during transport, respiratory monitoring during narcotic administration etc. Pulse oximeters are preferred over other techniques because they are: non-invasive, easy to use, cheap, compact in size

II. PROBLEM DEFINITION

It is very necessary to get the basic skills, because by the time any student graduates, the technology/field that they have dreamt to work with, would have advanced a lot from the date of joining for the UG course. Even a student who is a bit weak in academics is motivated if he/she is exposed to a working model for a particular technology rather than just theoretical explanation. The advancements in the field of biomedical engineering paved the way to include several reformations in the health sector. The way these two technologies, engineering and medicine, have started combining has given hopes to undergraduate researchers.

III. RELATED WORKS

In [1] the research works by students regarding, the key enabling technology for hydrogen economy, fuel cells have been overviewed. This paper presents a brief idea of the development and technology of fuel cells with its integration to

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the undergraduate electrical engineering education. The undergraduate research works in renewable energy are an innovative and attractive way to make students aware of contemporary issues in areas like energy, globalization, technologies, and attract them to pursue graduate studies in this area.

The research work mentioned in [2] gives an idea on the works, nearly 200 in number, regarding the natural language processing. The funded research projects were undertaken by the students who participated actively in the research venture. The study of the subject was done in an improvised manner so that the research expanded their knowledge in various areas of their curriculum including artificial intelligence and other such branches of computer science. The research document [3] is a Micromouse project -integrated with the power electronics. This project brought about a complete development on software, hardware and design skills, coz its a competition based research and the full potential of the project team will be put to test and they will work hard.The objectives of the projects such as challenging the programming skills of the students, teaching team integration for an efficient hardware and software development, and solving engineering problems inorder to have a better Micromouse design

IV.BLOCK DIAGRAM / DESCRIPTION

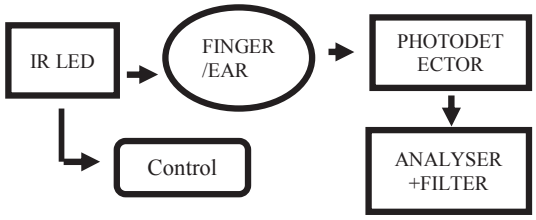

Fig.1: The proposed Oximeter design block diagram

Figure 1 shows the block diagram of the proposed Oximeter Design for our research. The circuit design may be segregated into two main parts. The first part is for transducing the physical signal and the second for analyzing the received data. The first is achieved by using an infrared, red led pair (emitter detector pair). The second is achieved with the help of a microcontroller. The physical signal is measured in terms of intensity variations in the absorption spectra. Then these are analyzed electrically using IR detector and Light Dependent Resistance. Potential at the point near the varying resistor is fed into the microcontroller using a potentiometer setup as shown in the Figure 2.

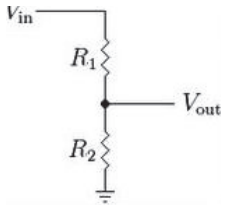

Fig.2: A simple voltage divider circuit for signal analyzing.

Vin is supplied by the microcontroller following a code for making it rapidly blink. The value is read in both On state and Of state separately. The latter is the value obtained from the external light source interference. This value is taken as the noise and the former value is data combined with the noise. Comparing the two values, we obtain the pure Infra- Red emission spectra.

V.DESIGN METHODOLOGY

The value is read at the rate determined by the speed of communication of the serial port . Every time hundred value are taken and their mean is taken and fed to the computer. This method made the value come at a slower rate and hence readable, but cannot give accurate values. Values were read continuously for real time plotting. In the first circuit implemented the values obtained were not accurate and the sensitivity of the system was very low. Hence the potentiometer was set and the value of R1 was increased. It was observed that as the value of R1 increased the potential at the point decrease and the sensitivity of the system increases showing the peaks in the heart beats clearly visible.

A. Specifications:

Microcontroller	Atmel ATmega168 or ATmega328
Operating Voltage (logic level)	5 V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20 V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	8
DC Current per I/O Pin	40 Ma
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz
Dimensions	0.73" x 1.70"

Only 4 pins are used and the serial communication ports RX and TX. Two of the pins are used as digital write pins so as to write the values to the emitters to power them (The two emitters are infrared red and the other is red light emitting diode). The other two pins are used as analog read pin, which reads the values from the two detectors. The values obtained in the analog read pins are serially output through serial ports. These were first displayed in the Arduino background using serial monitor. After monitoring and verifying these values this was plotted in MATLAB.

B. Serial Communication

The data obtained from the microcontroller consists of the spectra values after the absorption by the blood. These values

are serially fed into MATLAB, where we plot the absorption spectra. The values which we get from the ARDUINO UNO (microcontroller) are plotted real-time using the MATLAB. Firstly we tried to use external programs such as FREEMAT for obtaining the values serially and then plot it using MATLAB. Then we coded MATLAB itself to get the values directly from the ARDUINO through the communication ports and plot the spectra. Arduino works with a specified delay and it continuously reads the analog values of the led and IR detector and sends to the nd is then read by the MATLAB.

Firstly when we tried to connect ARDUINO with MATLAB, after first successful connection the stack got overflow for the succeeding connections. The problem was with the serial COM variable, the port has to be closed after reading every value and has to be reopened for further values. So we cleared the com variable at each instance and reused it again. The MATLAB code was modified accordingly and the problems were rectified. Through this procedure we were able to obtain the real-time plots of absorbed IR and red LED spectrums. The obtained spectrums are filtered and analyzed to obtain the dissolved oxygen content in the blood and the pulse rate. The flowchart of the entire setup is shown in Figure 3.

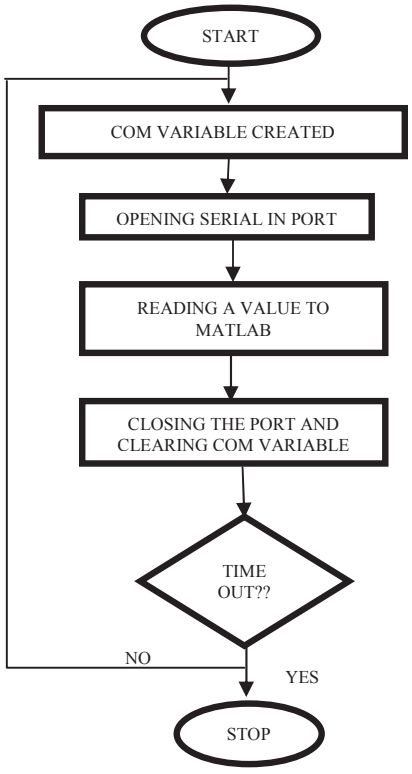

Fig.3: Serial Port and Matlab Interfacing Flowchart

C. Noise Filtering

Oxygen saturation is the ratio of the total haemoglobin concentration to oxyhemoglobin concentration in arterial blood, and provides information on heart and lung functions, organ-specific perfusion, cardiovascular status, hypoxia diagnosis, etc. This application has been extended from the area of medicine to sports such as scuba diving, mountaineering and so on. The pulse oximeter, which non-invasively monitors the oxygen saturation in blood, shoots two wave lights—red light (660 nm) and infrared light (940 nm) through a finger or earlobe, and obtains oxygen saturation readings from absorbance of the two differently transmitted waves. These parts were used purposefully because these are the sensitive areas of the body where absorption via bone is minimum. The accuracy of the pulse oximeter, however, tends to decrease due to motion artifacts, external lights, etc. Among them, motion artifacts are the main factor in the deterioration of accuracy. Motion artifact noise results from a patient's respiration and movement.

Generally, the frequency band of respiration is 0.04–1.6 Hz; the frequency band of pulse wave of the pulse oximeter is 0.5–4 Hz; the frequency band of the noise due to a patient's movement (finger movement, finger tremble, change of finger probe due to walking, etc.) is 0.1 Hz or more. The frequency spectrum of noise due to a patient's movement is overlapped with that of the signal of the pulse oximeter. The use of band pass filters allows the removal of the noise.

D. Pulse Rate Detection

The pulse rate detection is done using the IR AC signals. The IR signals minimum and maximum threshold values are determined using the following formula:

Max Threshold = 40% below the maximum IR value

Min Threshold = 40% above the minimum IR value

These threshold values get updated if there is any change in the amplitude level of the IR signals.The pulse rate detection algorithm detects the numbers of samples between two consecutive threshold(max) crossing points. The algorithm then calculates the pulse rate using the following formula.

Pulse Rate = (60 * Sampling Rate) / Number of sample between threshold crossing points.

VI. TESTING

The testing done in various phases may be classified as software and hardware. The circuit first implemented was not giving proper expected readings. Hence it was stimulated and tested using Proteus simulation software as shown in Figure 4

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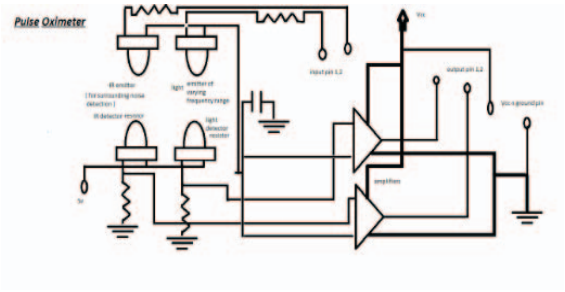

Fig.4: Simulation Circuit

Circuit was implemented on board and a Digital Storage Oscilloscope was used to visualise the real time spectrum. After making some changes to the circuit this value instead of giving into the DSO was fed into the microcontroller .The range of value was tested and adjusted before real timeplotting using MATLAB. Software testing was done by coding in arduino and compiling it hence by making it error free to burn into the microcontroller.

VII. RESULT

The academics and research go hand in hand and supplement each other. The student go through a vast range of subjects while working on a research project that they do not witness in class. Some of the topics will not be clear with mere classroom knowledge but through research it is possible to dig into the topics and also explore other topics related to academics, which helps in further researches and studies. Student's creativity increases and also they start thinking out of the box. In this case the topic pulse oximeter made the students clear about the photoplethysmography technique and further this made us made us study various programming languages and filtering techniques.

VIII. TOOLS AND THEORIES LEARNED/ SKILLS ACQUIRED

Various phases of the project are listed below:

a. The infrared emitter detector pair was physically implemented
b. The value obtained from this was displayed using arduino
c. This value is taken into MATLAB by interfacing MATLAB and arduino
d. The obtained frequency domain is compared to the absorption spectra of blood oxygen
e. The graph is plotted using MATLAB

The students learned many simulation softwares and also implemented various theoretical concepts. They also learned microcontroller coding languages for Arduino board. It gave them a good idea on how microcontrollers work and also gave an insight into the internal architecture .The simulation softwares used were Multisim and Proteus . Learning these tools helped them simulate and verify concepts in academic subjects like electric circuit theory. By doing this project they also came to know how to do the documentation. Working in the research lab also helped us build an excellent relationship with different faculty members. We came to understand the significance of 'team work' and how it helps in keeping up the timeline.

They completed automatic room lighter, digital thermometer and few other mini projects before attempting pulse oximeter. Room lighter is the set up through which the intensity of light in the room is detected, analysed and mapped analogously to voltage supplied to light emitter. Hence light intensity in the room is buffered around a desired value. The digital thermometer was made using the same detector part, as in oximeter. Implementing thermometer helped them in getting in understanding concepts of circuit theory.

IX. CHALLENGES FACED

A. Formation of an interested group

A dedicated group to form is the first challenge that a UG research has to face. A youth always likes to have the time remaining after the academic backlogs to be devoted to sports, games and other such activities. In that case, the generation of appetite, towards a project work which is outside the curriculum, in a student's mind needs proper motivation from the mentor. Moreover proper understanding between the group mates is a prior necessity.

B. Sustain the motivation

Remaining motivated to do the project is another big task. Undergraduate students many a times get frustrated if the expected results are not obtained even after repeated efforts. Proper counseling on the outcome of the project can help in facing these challenges. The mentor's advice to stay during vacations sometimes leads the students a disinterest towards the work. In short every problem regarding the negative attitude of the group towards the work should be taken care off.

C. Time Management

The students should be able to spend dedicated amount of time every day for satisfactory outcome. Many days student won't be able to work even for an hour due to academic load. Also during the time of periodical tests a sudden pause happens in the research work. It takes time to regain the spirit of doing the work after the break. Health problems faced by one student may cause the whole team a lag in the process. Such challenges can be overcome by proper and effective planning of time management.

D. Academics and Research

Even though the research groups are formed voluntarily, the interference with the academics, sometimes leads to conflicts from the department. This tends one or more of students in a group into back foot. To avoid this, a proper balance between both academics and research work should be obtained.

XI. STUDENT BENEFITS

The following section describes in detail the benefits for the students in taking up UG research work.

A. Enable to perform better in final year projects

One of the main components of undergraduate studies is final year project. And to gain right skill for doing that project one has to get involved in mini projects and research work from the second year onwards. Such a group will have all the required features in their projects and will show a notable difference from other project teams. By the last years of undergraduate studies the group will have sufficient

knowledge to present research papers at various national and international conferences.

B. Confidence Building

Research work not only helps students gain knowledge about any theory course but also helps them to get rid of the boredom of theory classes. In addition it helps to develop a liking towards the theory courses. The students' lacuna of interest is eliminated. It also helps them to think widely when they are stuck at various stages of research and also makes them believe in their knowledge and to increase academic confidence.

C. Decision making Challenge

If a student plans on going to graduate school, he/she will end up doing research in some field. This means that having some amount of research experience will be valuable in determining the type of research that a student will do. The troubleshooting capabilities of the student also increases, which is the main characteristics many of the companies expect their employers to have.

D. Novel knowledge gaining

The skills and knowledge acquired through research cannot be achieved by any other means and will be a great help to the academics. The students get an exposure to various tools used for programming, simulation, and other process. This increases the area of the student to be placed in a good company during campus placements or to get a position as a research assistant in reputed universities.

X. FUTURE WORKS

The pulse oximeter can be implemented wirelessly by the help of technologies like Bluetooth or Zig-Bee .The values obtained in the hand held transducer part is propagated to a receiver linked to the microcontroller. Portable oximeters can be implemented by making the present system self-powered using specific power source and corresponding voltage converters .A 9Vsource and a 9-5V converter (LM7805) may be appropriately to achieve this. Multi-level oximeters use radiations of 3 or more wavelength, hence by making it more accurate and precise. More than one receiver emitter pair of different frequency may be used or MAX038 can be used to generate desired frequency Pulse oximeter can be taken one step ahead to implementing simple electro-cardio-graph, which can find wider range of applications in medical fields.

XII. CONCLUSION

Providing quality and timely health assistance by monitoring oxygen saturations is a growing concern as well as a basic need in the medical field. Though the present high-tech hospitals and medical centers have various technologies for this purpose majority of them are complex and quite expensive. In such a scenario the proposed model could be really effective. It can work independently at any suitable environment. Based on the experimental results achieved the following conclusions can be obtained. The design implemented above using an LED to transmit light through the finger, a photo detector to sense the transmitted light proves effective in measuring the vital parameters like the pulse rate and oxygen saturation. The components, design & technology used makes the system cost effective. Balancing the syllabus and the research in the given narrow time frame is undoubtedly a challenging job. On the other hand these researches also supplement the academic side. It demands at most sincerity from the student, but at the testing hour it surely will prove to be a boon. The undergraduate research work not only refines ones academic skills but also improves one's life skills like being a good team worker and leader. When both the student and mentor copes with the difficulties and adhere with the research work to the end certainly it shall help the student excel in his professional career. Longer a student is involved in research better he performs in their carrier

XIII. ACKNOWLEDGEMENT

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