Design and Implementation of a Hemoglobin Concentration Meter

Project Team

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ABSTRACT

The project team has proposed a construction of a hemoglobin concentration meter, which will measure hemoglobin concentration in the blood, with diagnosis of whether the result is normal or not.

The motivation for this project based on the desire to gain experience and a greater depth of understanding the laboratory instrumentation, and desire to implementing this design to have a hemoglobin concentration, and apply it for various age groups.

This report contains details of the design and installation of the project and the results obtained.

The idea at the beginning of the phenomenon of absorption of light materials, every material depends on the wave length which responds to it, and hemoglobin-related with cyanide is able to absorb light of a wavelength (530 nm), the working group adopted this characteristic in the design, and going through several phases of the project:

First stage: preparing blood sample by adding (5 ml) of cyanide solution to (20 µl) of blood .

Second stage: putting the sample to be medium to light path, and then penetrate light of the sample through light source (halogen lamp), and passes this light to the optical filter of (530 nm) to prevent other wavelengths penetration; the light which penetrate the blood sample sensed by photo detector which changed the voltage drop according to the light illumination on it, and therefore change depending on the concentration of hemoglobin in the blood sample.

Third stage: transfer data to the computer for processing it by LabView program; to apply Beer's laws of absorbed lights and thus get the blood concentration of hemoglobin

Operator work is summarized here by select of the age group to the body to compare if the result was normal or not.

ملخص المشروع

اقترح فريق العمل تصميم (جهاز لقياس تركيز الهيموغلوبين بالدم) ليكون قادرا على إعطاء تركيز الهيموغلوبين مع تشخيص ما إذا كانت النتيجة طبيعيه أو لا.

الحافز لهذا المشروع كان مستندا على الرغبة في اكتساب الخبرة وتعميق فهم الأجهزة المخبريه الطبية، والرغبة بتطبيق هذا التصميم لقياس تركيز الهيموغلوبين بالدم لمختلف فئات الأعمار يحتوي هذا التقرير على التصميم وتفاصيل تركيب المشروع والنتائج التي تم الحصول عليها .

تقوم الفكرة بداية على ظاهره امتصاص المواد للضوء، كلا تبعا للطول الموجي الذي يستجيب له ،و الهيموغلوبين المرتبط بالسيانيد له القدرة على امتصاص الضوء ذي الطول الموجي (530 nm) ،واعتمد فريق العمل هذه الخاصيه في التصميم، و يمر المشروع بعده مراحل :

المرحلة الأولى: معالجه عينه الدم بإضافة (5 ml) من محلول السيانيد إلى (20 µl) من الدم.

المرحلة الثانية : وضع العينة في المكان المخصص لها من الجهاز لتكون متوسطه لمسار الضوء، ومن ثم يتم اختراق الضوء للعينة من خلال مصدر الضوء (Halogen) ويمر هذا الضوء على فلتر ضوئي (530 nm) لحجب الأطوال الموجيه الأخرى من الاختراق ،وبعد اختراق شعاع الضوء للعينة يسقط على مجس ضوئي ليقوم بتحسس كميه الضوء النافذة من العينة، وبالتالي تغير الجهد تبعا لتركيز الهيموغلوبين في العينة .

المرحلة الثالثة: تتمثل في نقل هذه الاشاره الكهربائية إلى جهاز الحاسوب لمعالجتها عن طريق برنامج (LabVIEW) لتطبيق قوانين (Beer's law) لامتصاص الضوء وبالتالي نحصل على تركيز الهيموغلوبين بالدم .

يتلخص هنا عمل الطبيب المخبري في أن يقوم بإختيار الفئة العمرية ليقوم الجهاز بعد ذلك بمقارنته إذا ما كانت النتيجة طبيعيه أو لا.

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Chapter One
Introduction

1.1 Overview

Today, as the development of the science & modern technology which measure the concentrations of different substances in a solution such as hemoglobin; the laboratory instrument state to be one of the most important devices that gives information about many diseases of human body, specially blood diseases.

Our project "Design and Implementation of a Hemoglobin Concentration Meter" is used in clinical laboratory or hospitals to measure the hemoglobin concentration for all different ages; and this project useful to measure hemoglobin concentration for students in school.

This technique is used to measure the concentration of hemoglobin in blood by applying the theory of light absorption & the transmission of the light through the blood sample; absorption proportional related to concentration according to Beer's Law.

Hemoglobin concentration gives diagnoses to many diseases; there are many diseases that are affected by the concentration of organic substances in blood, for example; less in hemoglobin concentration means of anemia.

We had design and implement of a hemoglobin concentration meter with alarm for abnormal values; the device designed in such a way easily to have a value of the concentration; using PC (Personal Computer) to perform functionality.

1.2 Scheduling Table

The time planning includes two time estimation schedules; the first one show what has been done in the first semester, and the second shows the scheduling time of the second semester. This time management clarifies each step of the project and guarantees the full completion of the overall system.

The timing management will divide the system hierarchy according to the actions:

T1: *Preparing to the project:* this stage of the project primarily aims at identifying the contents of it, discussing the initial information, and evaluating the project tasks and levels.

T2: *The project analysis*: the analysis process includes extensive study for all possible design options of the project.

T3: *The project requirements analysis*: tasks have to be implemented, equipments will be needed to be provided, and data should be processed.

T4: *Conceptual Design:* project objectives, design block diagram will be done and we will show how our system works.

T5: *Studying project component and schematic analysis*: it is necessary to study the datasheet of the photo sensor to ensure that it will meet the requirements of the project.

T6: *Writing the documentation*: the writing began from the first phase to the last one in parallel.

T7: *Constructing the Circuits and Connections:* hardware implementation of the circuits that represent the system and subsystems of our project. It was started by building the light path.

T8: *Sub-System Testing:* at that stage, we tested each component of the project.

T9: *Software Implementation: it* was started with downloading the program of the LabVIEW which was used to implement the PC parallel port.

T10: *Software Testing:* after completing the whole software, it was tested to check if the hardware was running appropriately to give the Hemoglobin concentration value.

T11: *Overall System Testing:* we tested the project and implemented it to adjust the problems and errors and maintain it & calculate the percentage error.

T12: *Final Documentation writing:* the writing process and the implementation of the different stages of the project were done in parallel, in order to keep track on what had been done.

Table (1.1): The Task Duration

Task	Duration(weeks)	Dependencies
T1	3	-----
T2	3	-----
T3	4	T1.T2
T4	5	T3
T5	2	T3
T6	15	T4. T5
T7	5	
T8	4	T7
T9	5	T7
T10	4	T9
T11	11	T8. T10
T12	15	-----

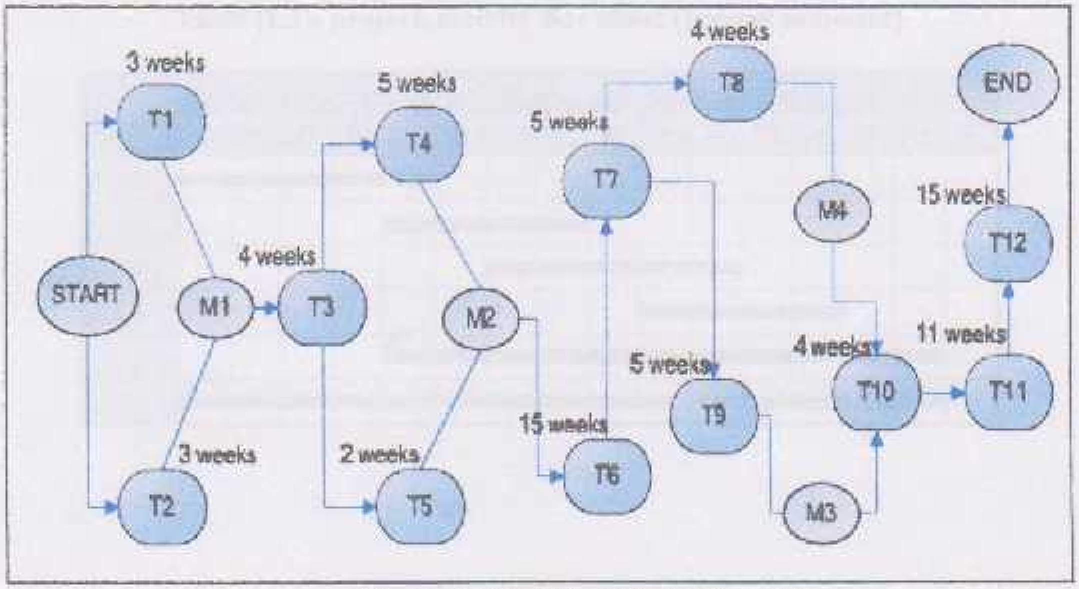


Fig. (1.1): Project Activity Network

Table (1.2): Project, Activity Bar Chart (First semester)

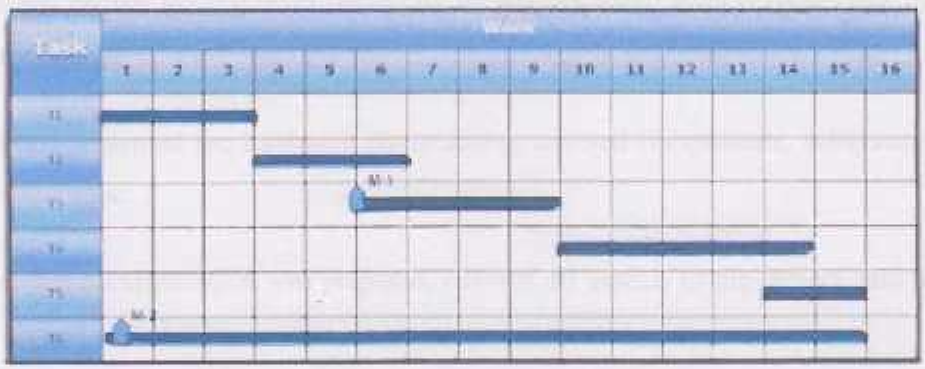
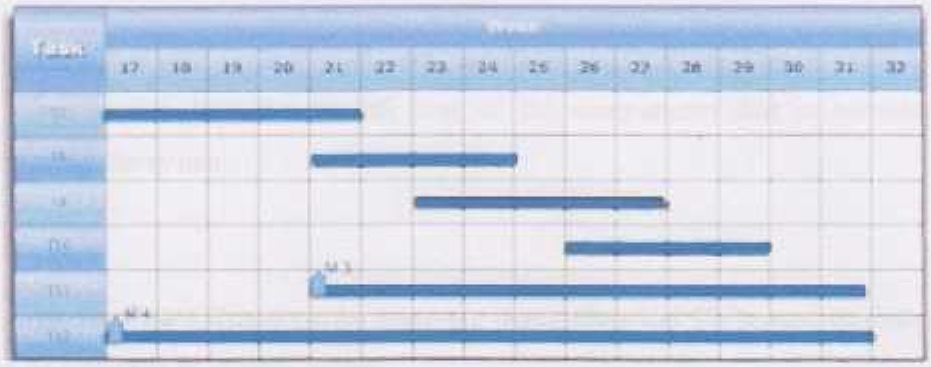


Table (1.3): project, activity Bar chart (Second semester)



In the project management tool used to produce this chart, all activities must end in milestones. Those are the basic milestones:

M1: this milestone has shown the project plan and hardware and software requirement.

M2: it has shown the top-level design of the project using flow diagram and the user interface design.

M3: it has presented the hardware constructing, covered components, subsystems, and integration tests.

M4: project documentation was prepared, covered all aspects of the project, and pointed to the project completion.

1.4 Estimated Cost

This section lists the overall cost of the components that is considered in implementing the system.

The Hardware Components, there are many electrical Chips and equipments have to be provided as in table below

Table 1.4: Hardware Cost

Component	Cost
Filters	$150.00
Cuvette & material	$20.00
DAQ & chips	$ 60.00
Electronics	$15.00
PC	$ 400.00

The approximated total cost for the project is $645.

1.5 Project Risk Management

During the implementation of the different phases of the project, many problems and risks have to be identified and solved in the early time of the project designing and manipulation. This should be done in order to operate the project in efficiently and effectively manner.

1.5.1 Hardware Risks

- Device failure: the DAQ may crash because of high voltage supply or other problems.
- The device operates differently from what expected.
- The Photo detector does not response.
- The DAQ chip connects wrongly to the computer which may damage it.
- Applying high voltage on the halogen lamp which may damage it.

In addition to these risks, other component risks may appear such as:

- Improper readings of sensors.
- An addition of noise from the outer environment.

1.5.2 Software Risks

There may be some risks with the software such as:

- Appearance of error in the block diagram which doesn't allow the program to Debug; such as not connected icons.

1.5.3 Group Risks

- Illness of one or more of group members.

- Group meeting difficulties.

1.5.4 Project risks:

- Supervisor change.
- Latency of devices arrival.

Recovery:

- Demand device at earlier time.
- Start working on the implementation earlier.
- Use alternate devices with the same functionality and less cost.

1.6 Human Development Resources

The team is composed entirely of three Biomedical Engineering undergraduate students who are interested in Laboratory instrumentation field.

The project Team: Nedaa S. Mraish & Amani F.Al-a'malh & Eman I. Hamad.

Supervisor: Eng. Abdallah Arman.

1.7 Report Road Map

The documentation for this project is divided into seven chapters. The followings explain briefly the contents of each chapter:

Chapter 1: Introduction

This chapter presents overview, literature review, project scheduling, and estimated cost, Project risk, Human Development Resources.

Chapter 2: Theoretical Background.

This chapter discussed the blood anatomy, theory of the project (main idea), hardware and software related to the project component.

Chapter 3: Project conceptual design.

This chapter explains the design concepts, project objectives, project design block diagram, how are system work, and front panel.

Chapter 4: Detailed technical project design

This chapter includes project phases, and subsystem detailed design.

Chapter 5: Software

This chapter includes software of the project (block), and flowchart which follow by the operator.

Chapter 6: System Implementation and Testing

This chapter includes testing of our design, experimental result, project safety & maintenance.

Chapter 7: Conclusion and Future work

This chapter includes conclusion, recommendation & future work.

Chapter

2 Theoretical Background

2.1 Blood Physiology.

2.2 Project Theory.

2.3 Project Components.

Chapter Two
Theoretical Background

2.1 Physiology of Blood and Hemoglobin

In this section blood component and hemoglobin structure will be explained: and shown the normal values of hemoglobin concentration.

2.1.1 Blood

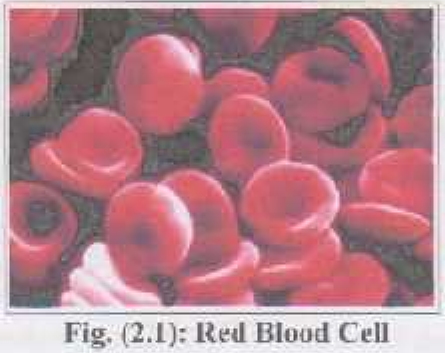


Fig. (2.1): Red Blood Cell

Blood is a circulating tissue composed of fluid plasma and cells (red blood cells, white blood cells, platelets).

The main function of blood is to supply nutrients (oxygen, glucose) and constitutional elements to tissues and to remove waste products (such as carbon dioxide and lactic acid). Blood also enables cells (leukocytes, abnormal tumor cells) and different substances (amino acids, lipids, hormones) to be transported between tissues and organs.

2.1.2 Anatomy of blood

Blood is composed of several kinds of corpuscles; these formed elements of the blood constitute about 45% of whole blood the corpuscles:

1. Red blood cells or erythrocytes (96%) [١٠]. In mammals, these corpuscles lack a nucleus and organelles, so are not cells strictly speaking. They contain the blood's hemoglobin and distribute oxygen. The red blood cells (together with endothelial vessel cells and some other cells) are also marked by proteins that define different blood types.
2. White blood cells or leukocytes (3.0%) [١٠] are part of the immune system; they destroy infections agents.
3. Platelets or thrombocytes (1.0 %) [١٠] are responsible for blood clotting or coagulation.

2.1.3 Anatomy of hemoglobin

Haemoglobin or hemoglobin (frequently abbreviated as *Hb* or *Hgb)* is the iron-containing oxygen-transport metalloprotein in the red blood cells of the blood in vertebrates and other animals .

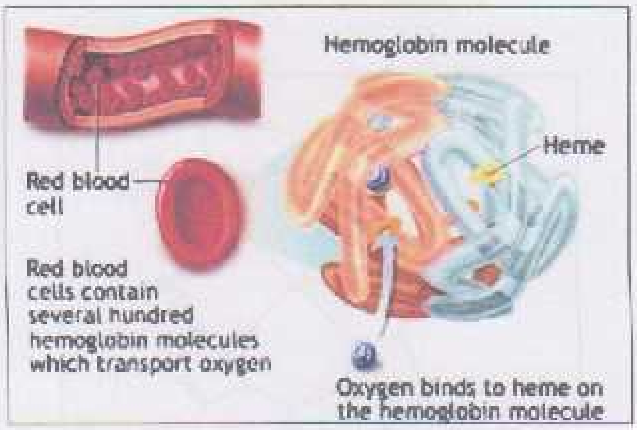


Fig. (2.2): Hemglobin Molecule [15]

The name *hemoglobin* is the concatenation of *heme* and *globin*, reflecting the fact that each subunit of hemoglobin is a globular protein with an embedded heme (or haem) group; each heme group contains an iron atom, and this is responsible for the binding of oxygen. The most common type of hemoglobin in mammals contains four such subunits, each with one heme group; see Figure (2.3).

Hemoglobin is the protein molecule in RBC that carries oxygen from the lungs to the body's tissues and returns carbon dioxide from the tissues to the lungs. The iron contained in hemoglobin is responsible for the red color of blood.

2.1.4 Hemoglobin structure and synthesis

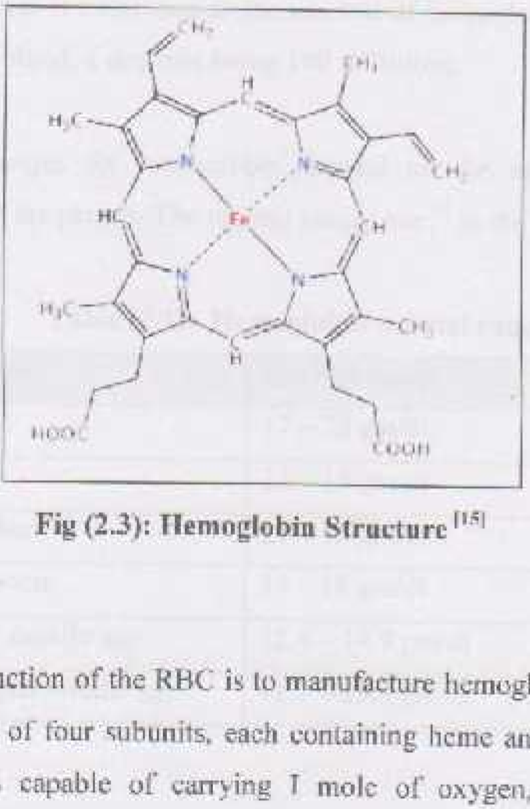


Fig (2.3): Hemoglobin Structure [15]

The primary function of the RBC is to manufacture hemoglobin; the hemoglobin molecule is composed of four subunits, each containing heme and the protein, globin. Every heme group is capable of carrying 1 mole of oxygen, and therefore each hemoglobin molecule is able to transport 4 moles of oxygen.

Hemoglobin (Hb) is synthesized in a complex series of steps. The heme portion is sythesized in both the mitochondria and cytosol of the immature RBC, while the globin protein portions of the molecule are synthesized by ribosomes in the cytosol [3].

2.1.5 Hemoglobin normal values

Hemoglobin level is expressed as the amount of hemoglobin in grams (gm) per deciliter (dl) of whole blood, a deciliter being 100 milliliters.

The normal ranges for hemoglobin depend on the age and, beginning in adolescence, the sex of the person. The normal ranges are [3] in the following table:

→ A Low hemoglobin level means:

Low hemoglobin is referred to as being anemic. There are many reasons for anemia. Some of the more common reasons are loss of blood (traumatic injury, surgery, bleeding colon cancer), nutritional deficiency (iron, vitamin B12, folate), bone marrow problems (replacement of bone marrow by cancer, suppression by chemotherapy drugs, kidney failure), and abnormal hemoglobin (sickle cell anemia).

→ A high hemoglobin level means:

Higher than normal hemoglobin levels can be seen in people living at high altitudes and in smokers, or some other infrequent causes are lung disease, certain tumors.

2.2 Project Theory

Our design depends on the idea of light absorption by the substance in a solution; but initially; we must add a special reagent to the solution before measure the concentration to prepare the blood sample; as explain later.

2.2.1 Main Idea

This design is one of the application on Beer's law which depend on the phenomenon of light absorption; which described by Beer's law.

First, we aimed to define Beer's law to have deep understanding of light phenomenon absorption.

Beers law: state that the concentration of a substance is directly proportional to the amount of light absorbed or inversely proportional to the logarithm of the transmitted light; see Figure (2.4).

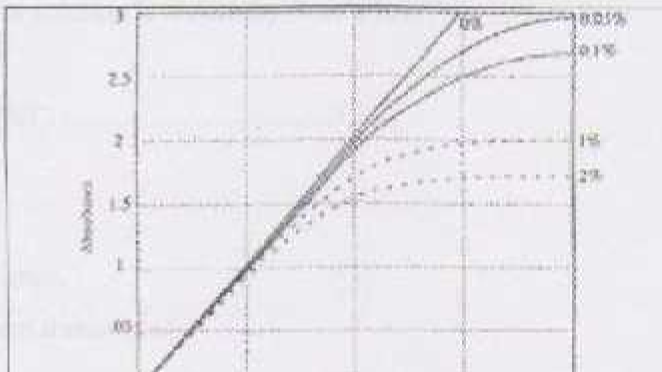


Fig. (2.4): Hb concentration vs. Absorbance [13]

Design and implementing of Hemoglobin concentration meter aimed to determine the concentration of hemoglobin; according to Beer's theory; the following equations prove the idea.

The concentration is calculated by the main equation:

$$C_u = C_s \frac{A_u * 251}{A_s} \text{ .... (2.1)}$$

Where:

C_u= Concentration of the unknown solution 'blood'.

C_s= Concentration of the standard solution (100 gm/dl).

A_u= Absorption of the unknown solution (contained Hb).

A_s= Absorption of the standard solution.

The mathematical relationship between absorption of radiant energy & the concentration of a solution is shown by Beer's law:

$$A = \log(\%T) \text{ .... (2.2)}$$

Where:

A: Absorbance.

%T: per cent transmittance.

Moreover, transmittance (T) is defined as the ratio of transmitted light (I) to incident light (I_0).

& $A = \log \frac{V_0}{V}$ .... (2.3)

Where:

A: Absorption

V_0: The output voltage from transmittance light through standard solution.

V: The output voltage from transmittance light through the solution.

2.2.2 Measuring of Hemoglobin

Several methods exist for measuring hemoglobin, most of which are done currently by automated machines designed to perform several different tests on blood. These machines are CBC (Cell Blood Counter), Chemistry Analyzer & Spectrophotometer.

The methods used for measuring Hb in blood are:

1. Oxyhemoglobin (HbO_2) method.

No longer widely used but still satisfactory method is the determination of hemoglobin as oxyhemoglobin . The main disadvantage is the lack of a stable stander for HbO_2; because of the method's simplicity; it is often used to compare level of hemoglobin when the absolute quantity is not needed, The HbO_2 method does not measure carboxyhemoglobin (HbCO) methemoglobin (Hi), sulfhemoglobine(SHb), all of which are inactive in transporting oxygen.

2. Chemical method (iron content)

This is the second method for measuring the hemoglobin concentration; Hemoglobin may be measured by determining the iron content of whole blood. The non hemoglobin iron in blood is negligible compared to hemoglobin iron. Iron must first be separated from hemoglobin usually by acid or by ashing it is then either titrated with $TiCL_3$ or complexes with a reagent to develop color that can be measured photo metrically.

Moreover based on the molecule, the iron content of hemoglobin is 0.347 per cent; the concentration of hemoglobin in blood (gm/dl) is calculated by dividing the iron concentration (mg/dl) by 3.47. Determination of the concentration of hemoglobin by measurement of iron content is too complex for routine work, but it can be used for checking other methods.

3. Hemiglobincyanide (HiCN) method

In our project we used this method; so by using to use cyanide which binds tightly with the hemoglobin molecule to form cyanmethemoglobin. By shining a light through the solution and measuring how much light is absorbed (specifically at a wavelength of 530 nanometers), the amount of hemoglobin can be determined.

On the other hand the advantage of HiCN method is that most forms of hemoglobin (Hb, HbO_2, Hi) are measured.

Now; we will show the description of the last method which we had used:

→ Hemiglobincyanide (HiCN) method principle:

First, blood is diluted in solution of potassium ferricyanide and potassium cyanide. The potassium ferricyanide and oxidizes hemoglobin's to hemoglobin (Hi; methemoglobin) and potassium Cyndi provides Cyndi ions (CN-) to from hemiglobincyanide (**HiCN**) which has a broad absorption maximum at a wavelength of 530nm; as shown in the Figure (2.5) below; the solution is measured in a photometer or spectrophotometer at 530 nm and compared with that of a standard (HiCN) solution.

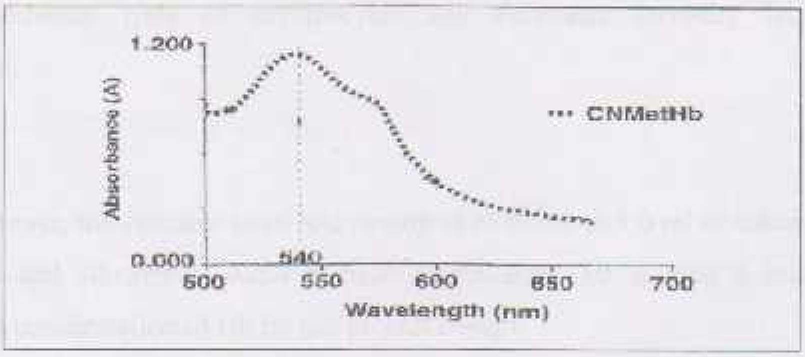


Fig (2.5): Wavelength vs. Absorbance [13].

This curve shows the relation between wavelength and absorbance by Hb in HiCN solution of blood sample.

Preparation of the solution

In our project the blood sample used is the whole blood with the Cyanide solution prepared by this method [3] by using of:

For 1liter water H_2O;

Potassium ferricyanide $k_3Fe(CN)_6$	0.200g
Potassium cyanide, KCN	0.050g
Dihydrogen potassium phosphate, kH_2PO_4	0.140g
Bicarbonate sodium $NaHCO_3$	1g
Distilled water to	1000ml

substituting dihydrogen potassium phosphate, kH_2PO_4 in this reagent for sodium bicarbonate, $NaHCO_3$, in shorten the time needed for Hb to HiCN of 10 minutes the detergent enhance lysis of erythrocytes and decreases turbidity from protein precipitation.

However, the operator must add twenty ul of blood to 5.0 ml of diluents (1:251), well mixed and allowed to stand at room temperature for at least 3 minutes; then measure the concentration of Hb by our project design.

2.3 Project components

In this section we provide a full explanation of each component and each part of this project.

The design consists of the following components:

1) DC Power source.
2) Light Components.
3) CB 68lp (Control Bored) connector & Parallel port.
4) DAQ (Data Acquisition)
5) PC (labview program).

2.3.1 The power source

Our project needs to convert the AC voltage to suitable DC voltage which then applied to the light source. See Figure (3.5) for block diagram, and Figure (4.1) for schematic.

The circuit of power supply contains:

1. Transformer: is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism) &, second, that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). By changing the current in the primary coil, one

changes the strength of its magnetic field; since the secondary coil is wrapped around the same magnetic field, a voltage is induced across the secondary.

2. Rectifier: is an electrical device that converts alternating current to direct current or at least to current with only positive value.

Here are waves which describe the operation of the rectifier.

Fig.(2.6) :Sine wave signal.[19]

In half wave rectification, either the positive or negative half of the AC wave is passed easily, while the other half is blocked, depending on the polarity of the rectifier. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half-wave rectification can be achieved with a single diode.

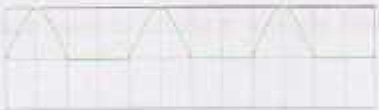


Fig.(2.7): Half wave rectifier signal[19].

While for full-wave rectification converts both polarities of the input waveform to DC (direct current), and is more efficient.

Fig(2.8): Full wave rectifier signal[19].

3. Regulator: designed to automatically maintain a constant voltage level.

2.3.2 Light Path Components

In our design the light path started with the halogen lamp until it reach the detector; the components of this path are:

1. Halogen lamp.
2. Slits.
3. Optical filter.
4. Cuvette.
5. Photo detector.

These parts are needed to place at black box of iron to provide any interference between it and the environment on other hand to create a straight line path for light.

1. **Halogen lamp**

We used the light source as halogen lamp; because its availability & suitable price. This type of lamp is used in the wavelength range of 350 - 2500 nm, voltage of the lamp must be very stable indeed 12v and 50 watt.

This lamp has a special characteristic like:

1. Halogen lamps (incandescent lamps) that contain halogen gases such as iodine and bromine that allow filaments to work at higher temperatures and higher efficiencies.
2. Halogen lamps consist of a tungsten filament inside a quartz envelope that is filled with halogen gas. In halogen lamps, the quartz envelope is closer to the filament than the glass used in conventional light bulbs. Heating the filament to a high temperature causes the tungsten atoms to evaporate and combine with the halogen gas. These heavier molecules are then deposited back on the filament surface. Moreover this recycling process increases the life of the tungsten filament and enables the halogen lamp to produce more light per units of energy.

2. **Slits (Lenses)**

Used to focus the light & prevent scattering, two lenses the first which sends a beam of parallel rays to the interference filter (#3). The second one is used to focus the beam in the center of the cuvette (#5), as shown in Fig. (2.9).

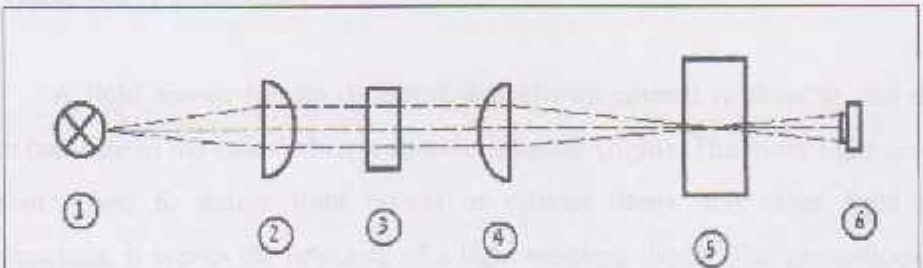


Fig. (2.9): Component positions.

3. **Optical filter:**

Here we used a special filter which allow to only one wavelengths passes through it & prevent the others; in our design we need an optical filter (GREEN) to allow just the wavelength of 530 nm to pass through the sample; which absorbed by the Hemoglobin after added the potassium Cyanide & Potassium ferricyanide which were explained before.

4. **Cuvette (Sample handling):**

The design, construction and material of the cuvette are all important to accurate measurements; so in our project we used tube covered by EDTA; to prevent blood clotting; (#5) Fig (2.9) ; having the following characteristic:

1. Optical windows (the sides through which the beam passes) are highly polished, parallel and flat.
٢. Entrance and exit surfaces are exactly parallel and orthogonal.
٣. Light path (distance between inner surfaces of windows) is tightly controlled.

5. **Detectors (Photodiode)**

A light sensor (photo detector) that allows current to flow in one direction from one side to the other when it absorbs photons (light). The more light gives more current. Used to detect light pulses in optical fibers and other light-sensitive applications, it works the opposite of a light emitting diode. The photodiode detects light and creates a conductive path that allows electricity to flow. The LED receives electricity and emits light.

Principle of operation

Photodiode is a p-n junction. When a photon of sufficient energy strikes the diode, it excites an electron thereby creating a mobile electron and a positively charged electron hole. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in field of the depletion region, producing a photocurrent.

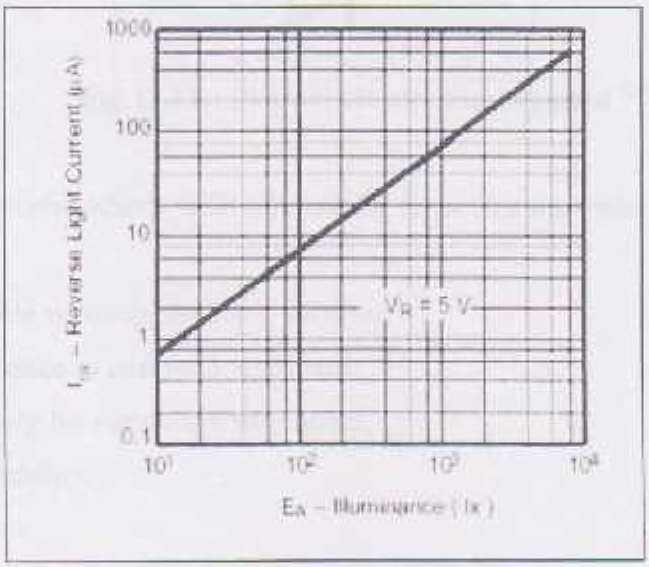


Fig.(2.10): Illumination vs. current produced across photodiode.[18]

Photodiodes can be used under either zero bias (*photovoltaic mode*) or reverse bias (*photoconductive mode*). In zero bias, light falling on the diode causes a current across the device, leading to forward bias which in turn induces "dark current" in the opposite direction to the photocurrent. This is called the photovoltaic effect.

On the other hand, reverse bias induces only little current (known as saturation or back current) along its direction. But a more important effect of reverse bias is widening of the depletion layer (therefore expanding the reaction volume) and strengthening the photocurrent. Circuits based on this effect are more sensitive to light than ones based on the photovoltaic effect and also tend to have lower capacitance, which improves the speed of their time response.

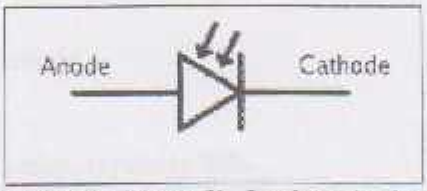


Fig. (2.11): Photodiode electrical symbol [20].

We prefer to use photodiode VTB 6061uvj for these characteristic:

- Available wavelength: 200 – 1100 nm [11]
- Performance to cost ratio: excellent.
- Sensitivity for our design very good.
- Good stability.

Fig. (2.12): Photodiode [11].

Advantages compared to photomultipliers [20]:

1. Excellent linearity of output current as a function of incident light
2. Spectral response from 190 nm to 1100 nm (silicon), longer wavelengths with other semiconductor materials.
3. Low noise.
4. Buggerized to mechanical stress.
5. Low cost.
6. Compact and light weight.
7. Long lifetime.
8. High quantum efficiency, typically 80%.
9. No high voltage required.

Disadvantages compared to photomultipliers:

1. Small area.
2. No internal gain.
3. Much lower overall sensitivity.

2.3.3 CB 68lp Connecter with parallel port.

To complete this design there is need of a CB 68lp connecter to interface between DAQ & the output of photodiode; it low-cost termination accessories with 68 pins terminals for easy connection of field I/O signals to the counter/timer devices.

Fig (2.13): CB-68lp [21]

It has a dimensions of (14.35 by 10.74 cm (5.65 by 4.23 in.)), this chip have 68 pins each one defined to DAQ if it analog input or digital input; each pin need ground & Vcc & it have output to act as input to DAQ chip.

→ Parallel port:

The Parallel Port is known as the printer port, which is the most commonly used port for interfacing computers with homemade projects. This port allows the input of up to 9 bits or the output of 12 bits at any given time, thus requiring minimal external circuitry to implement many simpler tasks.

Fig.(2.14): parallel Port

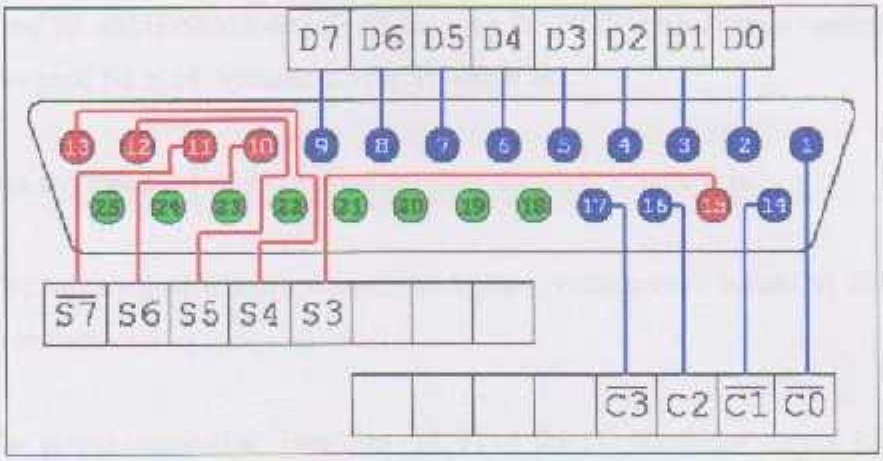


Fig.(2.15): parallel Port Pins.

2.3.4 Data Acquisition Card

This represents the next step in our project; which process the data & interface it with PC to complete the analysis of the signal until show the output concentration value.

It defines as collecting and measuring electrical signals from sensors, transducers, and inputting them to a computer for processing.

Fig (2.16): NI 6034E [21]

The NI 6034E/6035E/6036E device uses the NI data acquisition system; in our project we used NI 6034; because it's the available one.

As any electrical chip DAQ has cautions for using it, here is it:

1. The input signal mustn't exceed the highest voltage with which NI 6034E can come in contact.

2. The power connection: Two pins (14, 8) on the I/O connector supply +5 V from the computer power supply via a self-resetting fuse. Including power signals to ground and vice versa, that mustn't exceed any of the maximum signal ratings on the NI 6034E device which create a shock or fire hazard, or can damage any or all of the boards connected to the chassis, the host computer, and the NI 6034E device.

2.3.5 PC (LabVIEW Program)

LabVIEW (short for **L**aboratory **V**irtual **I**nstrumentation **E**ngineering **W**orkbench).

In our design we will deal with a LabView program to complete the analysis of the signals to reach our aim to measure the Hb concentration in blood solution and using Labview return to reasons here they are:

- It's a very easy way to process the signals.
- More simple than writing program or code by C++ language or visual basic (VB)

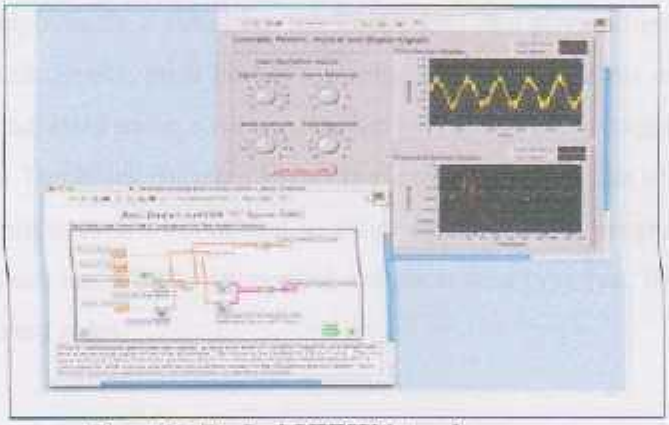


Fig. (2.17): LabVIEW interface.

First; we must define Labview program and mention its advantages over the other programs;

LabVIEW is a graphical programming system that is designed for data acquisition, data analysis, and instrument control

Programming an application in LabVIEW is very different from programming in a text based language such as C or Basic; moreover LabVIEW uses graphical symbols (icons) to describe programming actions. Data flow is 'wired' into a block diagram.

Since LabVIEW is graphical and based on a windows type system it is often much easier to get started using it than a typical language. Many engineers and scientists that would not normally try to program an application can get usable output easily with LabVIEW.

LabVIEW programs are called virtual instruments (VIs) The user interface is called the front panel, because it simulates the front panel of a physical instrument. The front panel can contain knobs, push buttons, graphs, and other controls and indicators. The controls can be adjusted using a mouse and keyboard, and the changes indicated on the computer screen. The block diagram shows the internal components of the program. The controls and indicators are connected to other operators and program structures. Each program structure has a different symbol and each data type (eg. integer, double-float etc) has a different color.

We implement a Beer's law on this program & show the output as concentration of hemoglobin in gm/dl; & giving ALARM for abnormal values; see Fig. (5.1), for more understanding to our work. (Details of the work will be introduced at chapter five)

Chapter

3 Project conceptual design

Chapter Three
Project conceptual design

In this chapter we are going to describe the main objectives of the project and the general block diagram.

3.1 Project Objectives:

This project supports many ideas and objectives that can be summarized as follows:

1. To design and implement hemoglobin concentration meter by using light absorption property.
2. Using the PC to read the system output and gives alarm for abnormal values.
3. To be used as an instructional purpose in the biomedical laboratory in our university.

3.2 General Block Diagram:

The following Figure (3.1) shows the block diagram of our project.

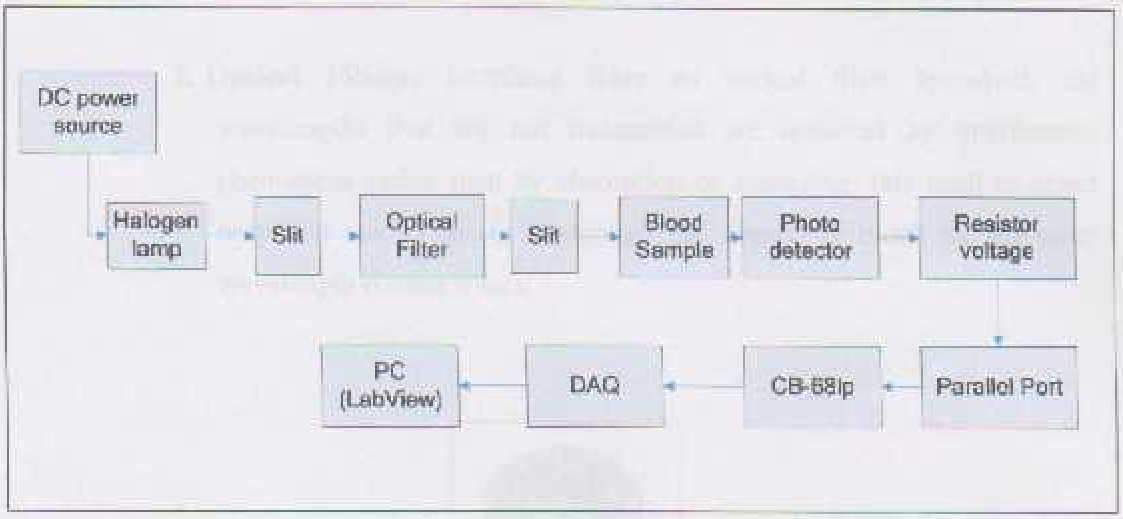


Fig. (3.1): General block diagram

In short, the sequence of events in our design is as follows:

1. The light source shines through the sample.
2. The sample absorbs light.
3. The detector detects how much light the sample has absorbed.
4. The detector then converts how much light the sample absorbed into voltage.
5. The voltage transmitted to a computer to calculate the value of hemoglobin concentration.

The last block diagram consists of several units to be accomplished and integrated to with each other to form the final hemoglobin concentration meter these units are:

1. **Light source:** Express as halogen lamp; 12v /50 w.

2. **Optical Filters:** Interfaces filter an optical filter in which the wavelengths that are not transmitted are removed by interference phenomena rather than by absorption or scattering; this used to select only 530 nm to passes it through the sample & block the all other wavelength (Green filter).

Fig. (3.2): Optical filter of 530nm.[22]

3. **Blood sample preparation & Blank solution:** Discussed in chapter 2.

4. **Photo detector:** Which detect the intensity of light; & give the output as voltage change according to light intensity changes; as shown in Fig.(2.10) to be sensed by DAQ then process it by LabView.

5. **PC (LabView program):** Which used to implement a block diagram that explain a Beer's law; shown in Fig (4.4)

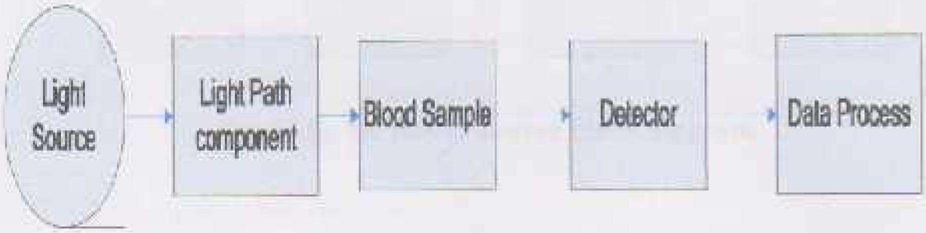


Fig. (3.3): General simplified block diagram

3.2.1 Light source block diagram:

This block diagram shows the basic circuits that connected with the Halogen lamp.

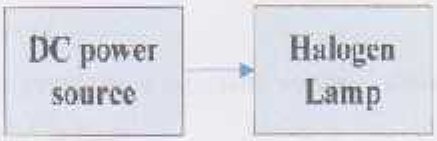


Fig (3.4): Light Source block diagram

The power source: the power must be of voltage & energy to make the lamp ON state all of 2A, this can achieve by the schematic shown in Fig. (4.1).

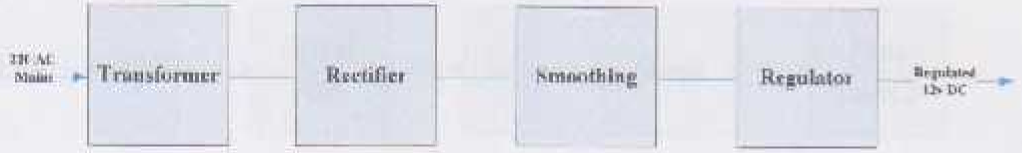


Fig. (3.5): Dc power source block diagram

→ Dc power source content:

1. Transformer: provides the necessary voltage reduction for the DC circuit as well as isolation from AC line.

2. Bridge rectifier: a full wave rectifier to convert AC output from the transformer to DC, but the DC output is varying.

3. Filter: to limit the voltage ripple. 'AC removing'. (1000 µF).

4. Regulator: provides a constant voltage; eliminates ripple by setting DC output to a fixed voltage.

3.2.2 Light path block diagram

This block shows the path that the light passes until it reaches the photodiode, these components discussed in chapter two.

Fig (3.6): light path block diagram

3.2.3 Data processing block diagram:

This block diagram shows the last component needed to complete our design; which is the CB-68lp, DAQ & finally the LabView program.

Fig. (3.7): Data processing block diagram

First; we will talk about DAQ and its details:

In our design we used the NI 6034E device, with analog input; then entered this signal to the PC to the LabView program.

→ Analog input:

The devices have a referenced single-ended (RSE) input; mode uses one analog input line which connects to the positive input of the devises PGIA; the negative input of the PGIA is internally tied to analog input ground (AIGND).

In our project we used the RSE mode; which have analog input from the output of phototransistor; using analog channels (ACH) pins & ground (AIGND) for each input channel.

→ Input Range:

The devices have input ranges of -10v to +10v; so the output voltage from receiving circuit mustn't exceed this value to provide DAQ from damaging.

→ Input Characteristics

- Number of channels .... 16 single-ended.
- Resolution .... 16 bits, 1 in 65,536
- Sampling rate .... 200 kS/s guaranteed
- Configuration memory size ....512 words

→ The used Pins in our project NI 6034E:

1. ACH; (ACH0,…,ACHn): Analog input channel.
2. AIGND: Analog input ground.

Fig (3.8):I/O Connector Pin Assignment for the NI 6034E/6035E/6036E

3.3 How System Works?

These steps show how the design work & what is the tasks of operator to have at the end a value of hemoglobin concentration.

- The operator prepares the blood sample as discussed in chapter two.

- The operator then must follow the flow chart; to appear the maximum & minimum values of hemoglobin concentration according to the age of the patient.

- After putting the blood sample in its holder the system work as follow:

  - ✓ The Halogen lamp gives light with all wavelengths.
  - ✓ The slits focus this light & prevent scattering.
  - ✓ The filter allows just the light of 530 nm to pass through the second slit.
  - ✓ The light passes through the sample; the output light from the sample is function of the hemoglobin concentration, as the concentration increased the transmittance light decreased & the absorbance increase (Beer's law).
  - ✓ The photodiode changes the light intensity on it to current pass through the resistor (voltage drop on R); see Fig (4.3).
  - ✓ Then connect CB-68lp to the receiving circuit; with pins which can interface with the DAQ;
  - ✓ The LabView program take the signal from DAQ and apply Beer's law on it with alarm system, see Fig (4.4), table (4.2) for more description.

3.4 Project front panel

In this project the final front panel was as show in Fig. (3.9) which having the patient information, the hemoglobin concentration and alarm of abnormal values.

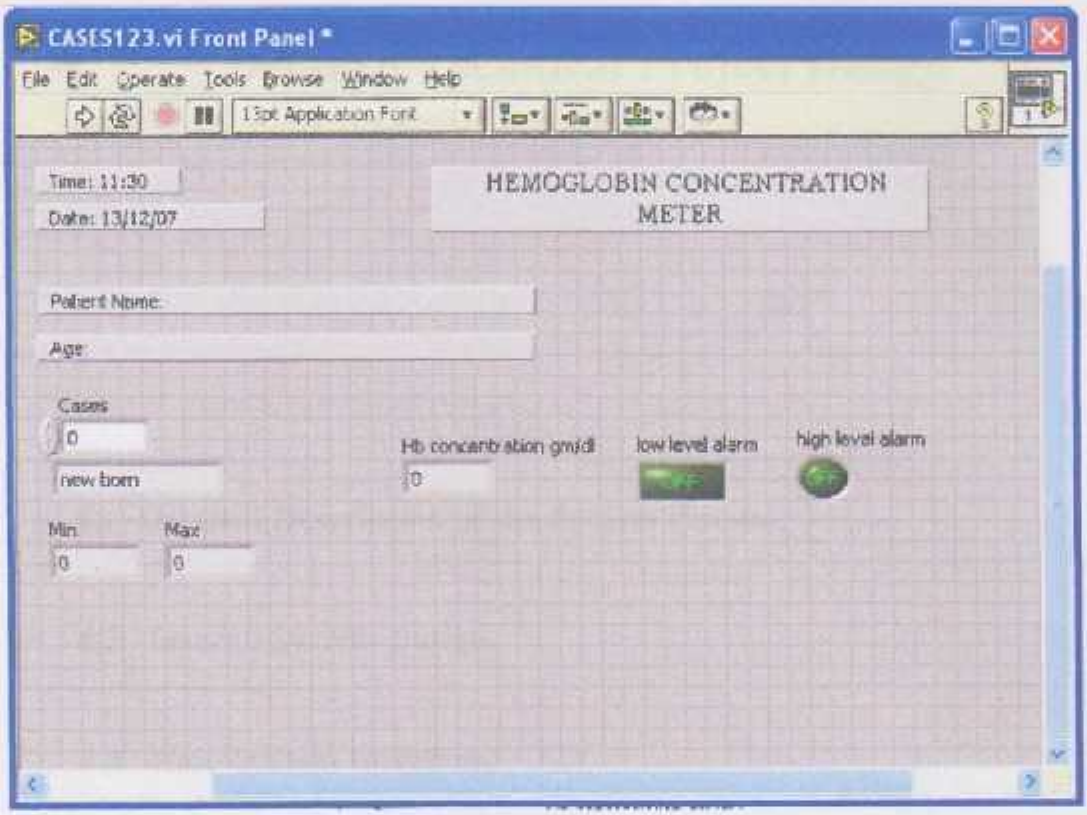


Fig. (3.9): Front panel design.

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Palestine Polytechnic University
(PPU)

Chapter

4 Detailed Technical Project Design

4.1 Detailed Description of the Project Phases.

4.2 Overall System Design.

4.3 User-System Interface.

Chapter Four

Detailed Technical Project design

After explaining the theoretical background, the general block diagram of the system, and how the system works, there is a need to view what is the design of this system in more specific, powerful and more formal terms. Therefore, this chapter describes the detailed system design with all its features that are necessary to make the system works well.

4.1 Detailed Description of the Project Phases.

The principle chosen for our project design is consist on Beer's law as described before, so our design built to achieve this law by each component in the design.

The detailed description of the project phases as follows:

- Filter phase: we will use an optical filter to allow only the wavelength of 530 nm to pass through the sample & blank solution.

- Sensory phase: we used a photodiode to detect the intensity of light passes out of blood sample & the light intensity passes out of blank solution to processed by DAQ and transfer it to PC.

- Processing phase: we used DAQ chip to transfer the output signals continuously to PC then apply Beer's law on it as shown in Fig (5.2)

4.2 Overall system design:

In this section we are going to show the schematics, characteristics, features, and the specifications of each component and subsystem.

- **Power supply subsystem**

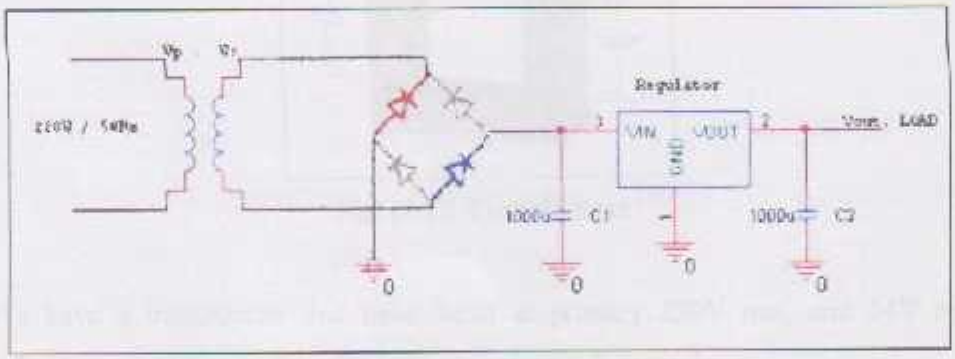

Fig. (4.1): DC power source circuit

This circuit converts the input of 220VAC /50Hz to 12 VDC; to supply the halogen lamp.

→ **Circuit component:**

1. Transformer: The transformer available is a Hammond Type C, Model 166G25, the secondary is center-tapped (this provides the ground output) and provides a 9:1 voltage reduction ratio.

2. Rectifier (full wave): The rectifier can be constructed using 1N4004 rectifying diodes.

3. Regulator: 7815 and 7915 are available to have at least +ve 12 v and -ve 12v output

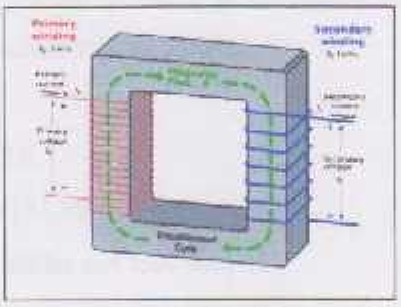

Fig. (4.2): Transformer [23]

We have a transformer that have input at primary 220V rms, and 24V rms at secondary; so according to the ratio between primary & secondary:

$$\frac{Vp}{Vs} = \frac{Np}{Ns} \qquad \text{.......................................(4.1)}$$

$\frac{Vp}{Vs} = \frac{220}{24} = 9.1$ → Turn ratio between primary and secondary is about 9:1.

& the secondary voltage calculate as this equation

Vs (p-p) = $Vs * \sqrt{2}$ ....(4.2)

So : Vs (p-p) = $24 * \sqrt{2} = 33.9V$

Vout (rectifier) = Vs – 1.4 ....(4.3)

Vout (rectifier) = 33.9 - 1.4= 32.5V.

$$Vdc = \left(1 - \frac{1}{2fRlC}\right) Voutrect$$

$$Vr(p-p) = \left(\frac{1}{FRlC}\right) Voutrect$$

$$RippleFactor = 1\% = \frac{Vr(p-p)}{Vdc}$$

$$\left(\frac{1}{FRlC}\right) Voutrect = 0.01\left(1 - \frac{1}{2fRlC}\right) Voutrect$$

If we use 1000μF by assumption, F is frequency equal 100Hz since full wave rectification, RL from calculation will be 1005Ω.

- Vdc= 32.33V.
- Vripple= 0.32V.
- Vin regulator [31.98 , 32.62]
- Rectifier should be not less than 35V.
- 15V Regulator specification should be more than 35V, 2A and not less than 70W.
- Capacitor value is 1000μF, 35V.

By this transformer we can use regulator of about ±24V.

- **Main circuit:**

The figure below shows the output of the photo diode which must connect to input of CB-68lp.

The output voltage $V = Isc * R$ .... (4.2)

Where:

I_{SC}: short circuit current that passes through the photo diode.

R: Resistance.

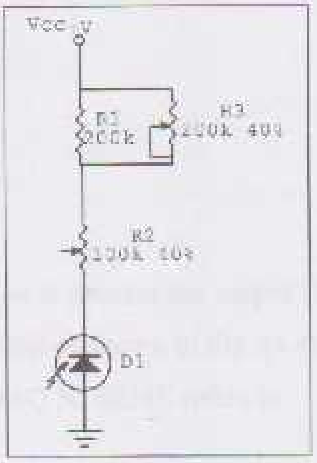

Fig. (4.3): Graphic of main circuit

The using of R_3 & R_2 is for calibration stage which determines the maximum & minimum values of transmittance as a background; first at full transmittance 100% set R_2; & for 0% transmittance which mean full absorption change R_3; & as that photo detector characteristic the internal resistance of photo diode change according to the illumination; at dark very high internal resistance GΩ.

Table (4.1): Electrical Characteristics of D_1.

No.	Symbol	Characteristic	Specification
1	I_{SC}	Short circuit current	MIN 260μA.
2	I_D	Dark current	MAX 2nA.
3	λ_{range}	Spectral application range	200 – 1100 nm.
4	R_{SH}	Shunt resistance	GΩ.

4.3 User system interface

The finally process steps is process the output DAQ signal to apply Beer's law by build block signal of the project as shown in Fig. (4.4), and each icon explain in table (4.2). The option of choosing DAQ NI 6034E refers to:

- No need to external circuit.
- Availability.
- No need for special codes.
- More easy to design with labView than other program language.

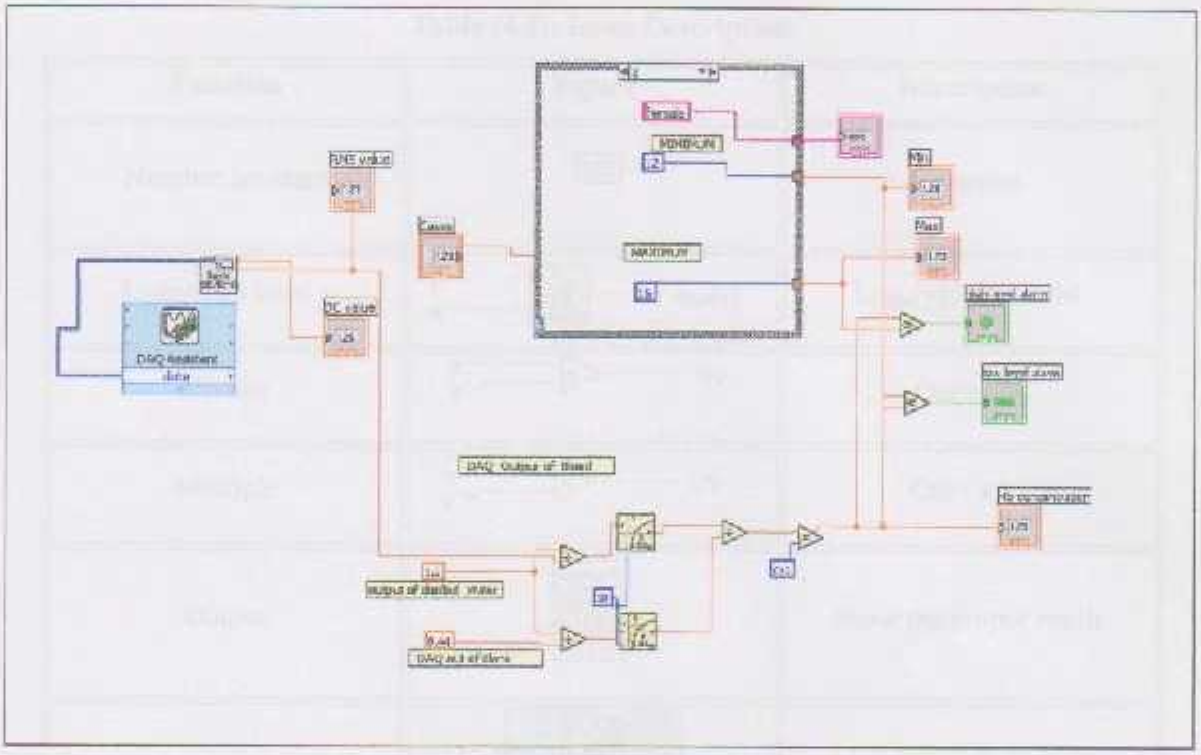

Fig (4.4): Block signal process design

Explanation & description of each icon used to build the block diagram on the LabView program which applies Beer's law.

Table (4.2): Icons Description

Function	Figure	Description
Number constant		Constant.
Logarithm base x		$Log_x(y)$; also x=10.
Divider		Out= x\y.
Multiple		Out= x*y.
Output		Show the output result.
Input signal		Input signal from DAQ.
Alarm		Give alarm for abnormal values.
Greater than		Compare two values (x, y). if x>y.
Less than		Compare two values (x,y). if x<y.

Chapter

5 Software

5.1 Software needed for the project

5.2 flowchart

Chapter five

Software

5.1 Software needed for the project

In our project as mentioned before we will use a LabView program; to process the output signal from DAQ; by applying Beer's equations as shown in the signal block Fig. (5.2).

This signal block diagram easy to implement in LabView as following stages:

- DAQ signals; as output of blood and standard solution
- Applying Beer's law Eq. (2.3).
- Comparing the concentration with normal values.

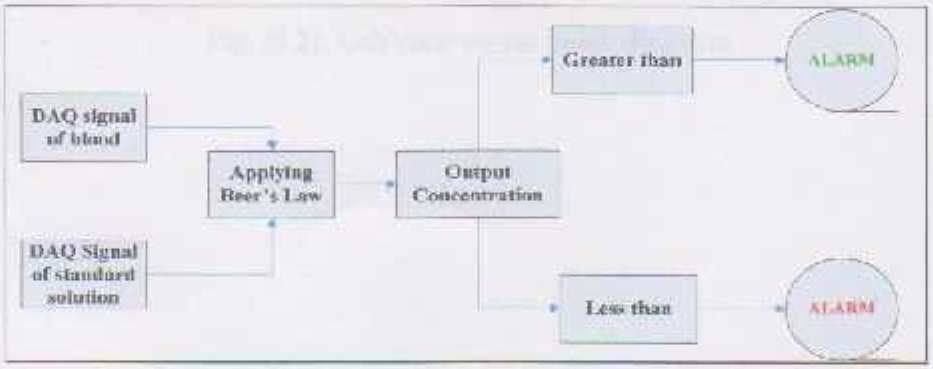

Fig. (5.1): General Alarm signal block diagram

This block diagram signal applied by LabView program as shown in Fig. (5.2).

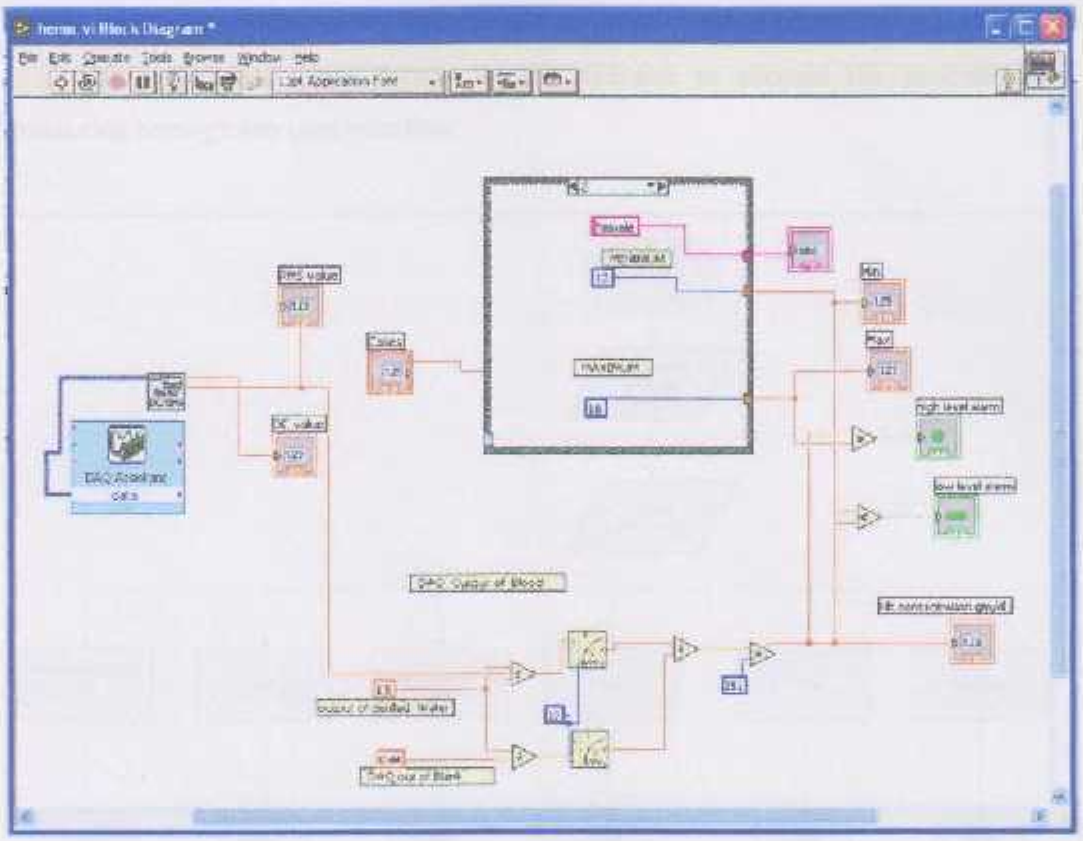

Fig. (5.2): LabView signal block diagram

5.2 Flowchart

This flowchart must follow by the operator to success the procedure for measuring hemoglobin concentration.

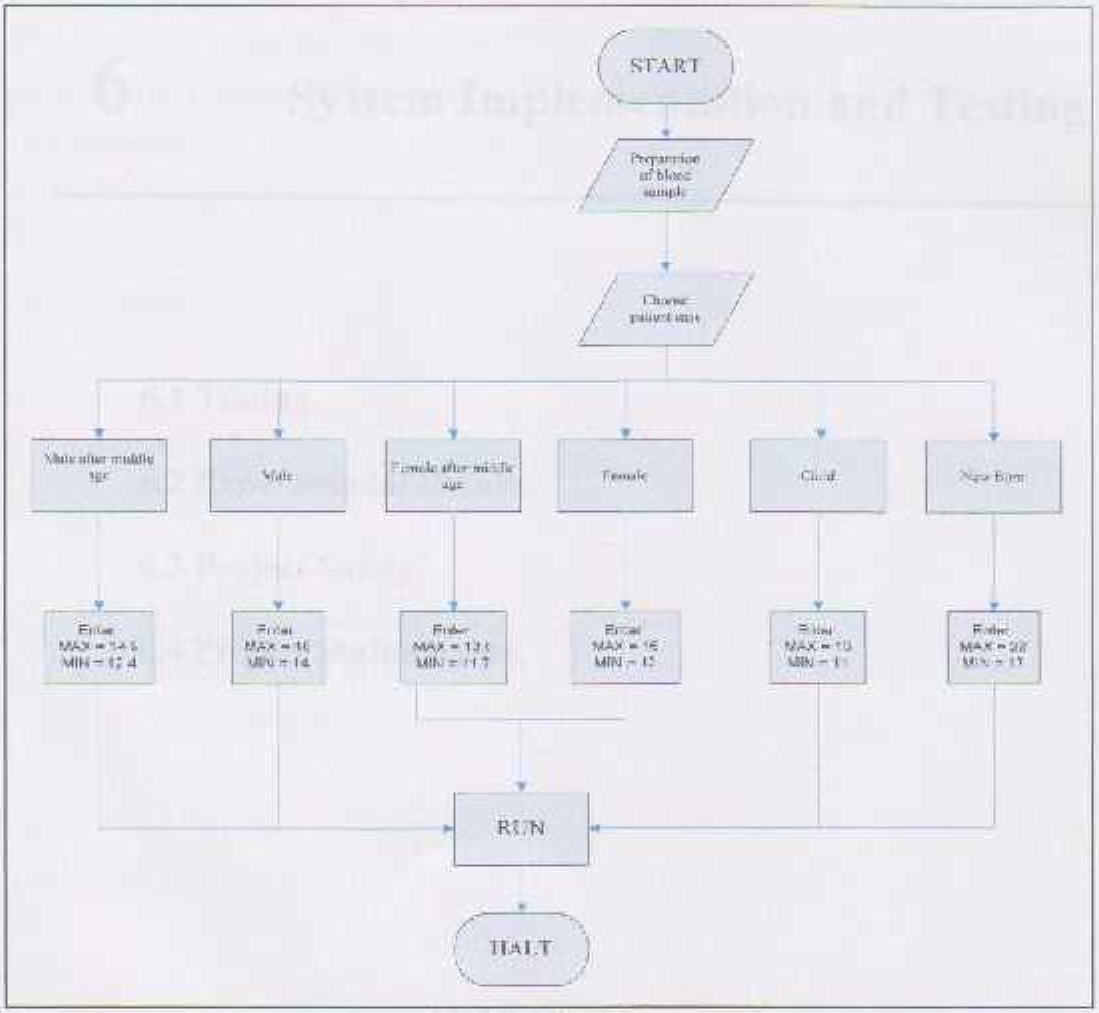

Fig (5.3): Flowchart.

Chapter

6 System Implementation and Testing

6.1 Testing.

6.2 Experimental Results.

6.3 Project Safety.

6.4 Project Maintenance.

Chapter Six

System Implementation and Testing

This chapter demonstrates the methods and procedures used to implement, test, and examine the system operation and behavior. System testing is an important and crucial step in implementing a system. It senses the effectiveness of that system just before introducing it to its users.

6.1 Testing.

In this section we are going to explain how the result oh hemoglobin concentration calculated.

First, to calculate the absorbance of the Cyanide solution ($As = \log (Vo/Vs)$) ; we measured the output voltage at full illumination by using the water as reference (Vo) which as shown in Fig.(6.1) : Vo = 1.45v.

Then, measure the output voltage at no illumination by using the Cyanide solution (Vs). Which as shown in Fig.(6.2); Vs = 0.44v.

So, the absorbance of the standard solution $As = \log (1.45/0.44) = 0.5179$ from this value we can determine the higher level & lower level of absorbance which ranged between 1.45 & 0.44.

6.2. Experimental Result

After finishing from collect all the design parts together, we test some blood sample on it.

First sample: Nedaa Amraish sample; at laboratory test the hemoglobin value was 10 gm/dl; at our design the hemoglobin value was 10.4 gm/dl as show on the front panel of LabView program.

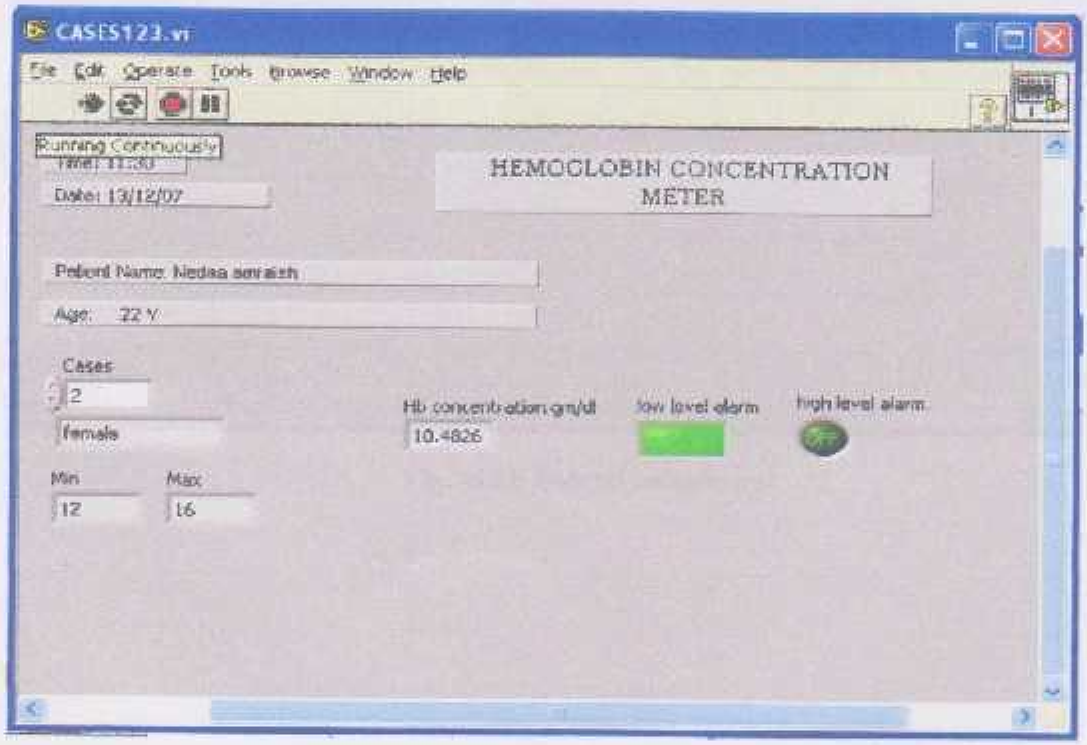

Fig. (6.1): First test sample

Second sample; Amani Al-Amleh sample; at laboratory test the hemoglobin value was 11.30 gm/dl; at our design the hemoglobin value was 10.77 gm\dl as show on the front panel of LabView program.

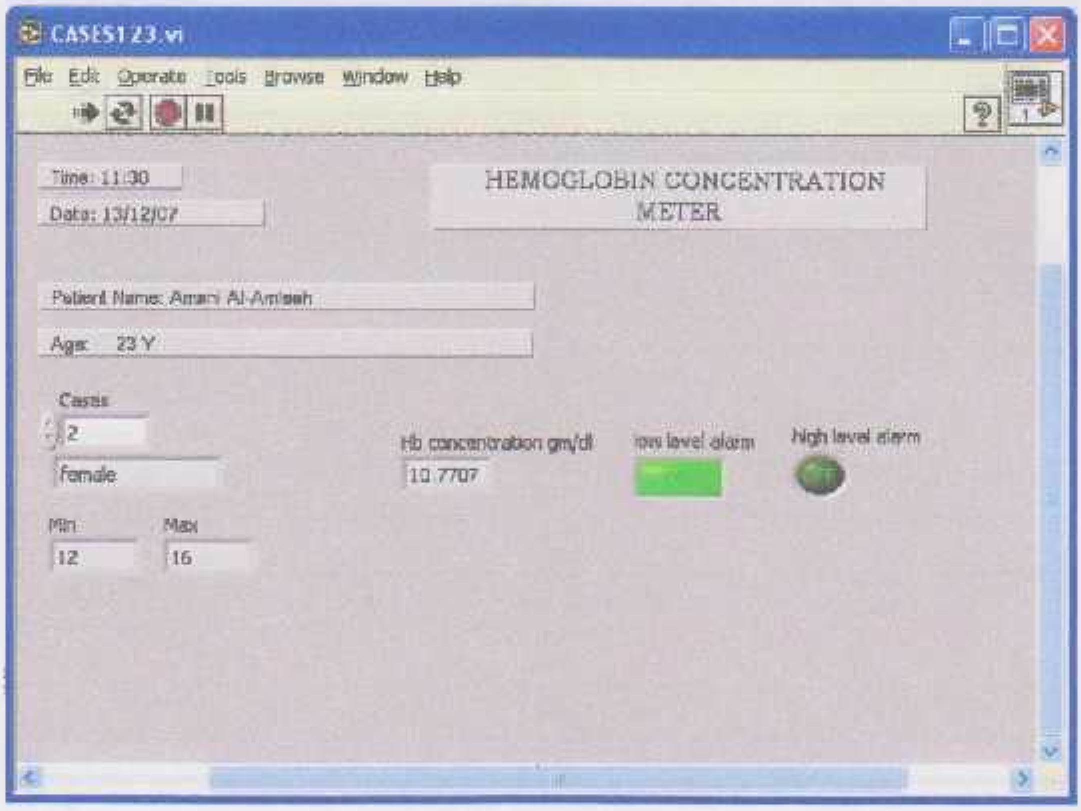

Fig. (6.2): Second sample test

Third sample; Eman Hammad sample; at laboratory test the hemoglobin value was 11.5 gm/dl; at our design the hemoglobin value was 11.91 gm/dl as show on the front panel of LabView program.

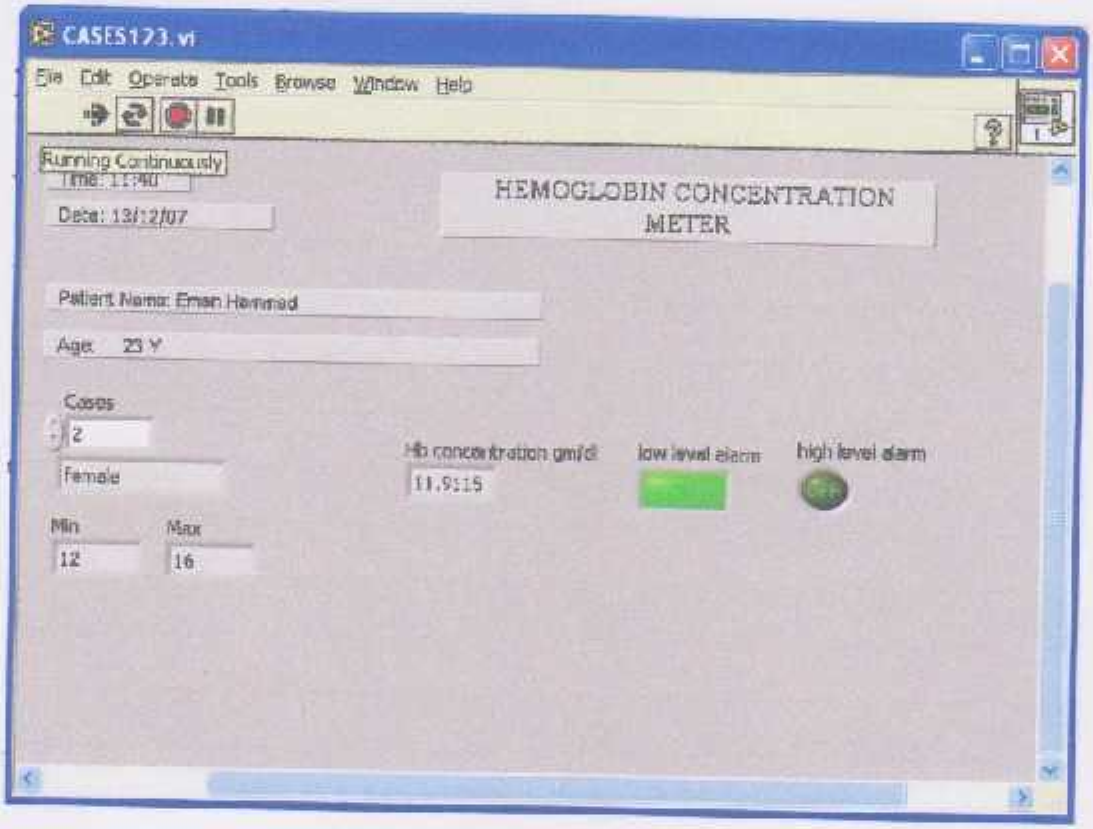

Fig.(6.3): Third sample test

Fourth sample; Dr. Al-Saheb sample; at laboratory test the hemoglobin value was 13.5 gm/dl; at our design the hemoglobin value was 14.5 gm/dl as show on the front panel of LabView program.

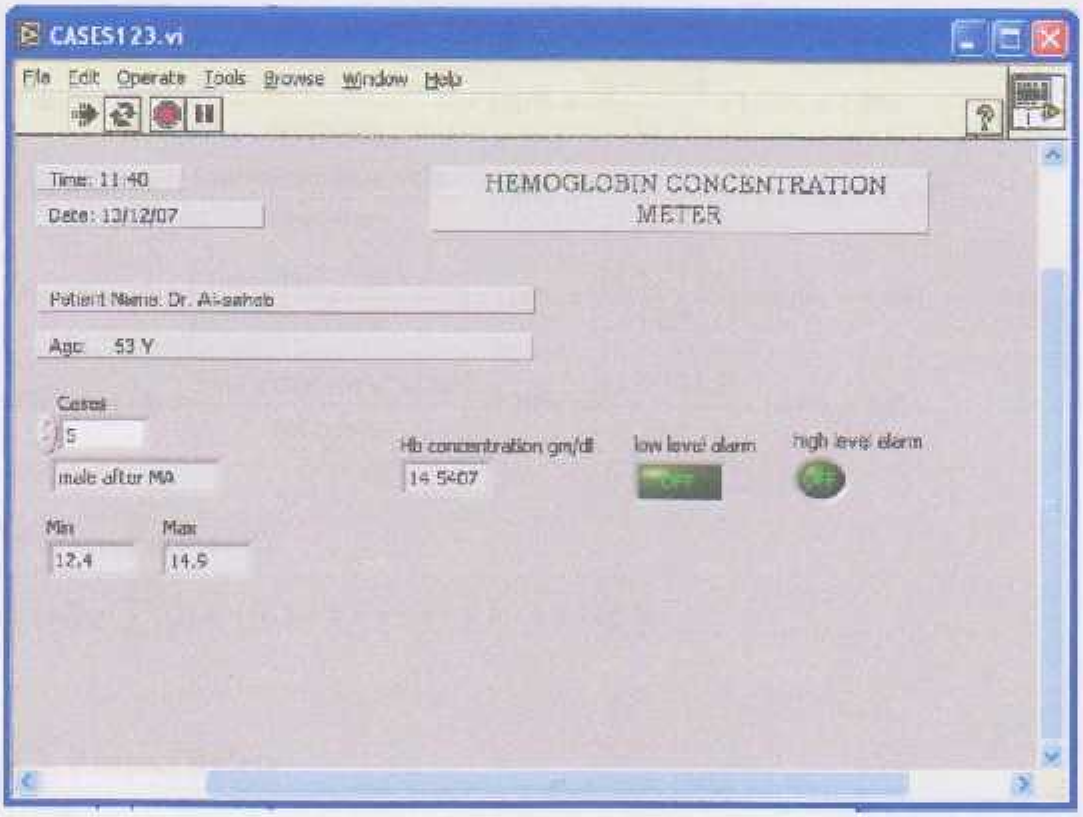

Fig.(6.4): Fourth sample test

→Error calculations:

At the end of our test for blood samples we are going to calculate the error percentage as following equations:

$$\text{The error (1)} = \frac{\text{true value - read value}}{truevlaue} \times 100\% = \frac{10-10.48}{10} \times 100\% = 4.8\%.$$

$$\text{The error (2)} = \frac{\text{true value - read value}}{truevlaue} \times 100\% = \frac{11.30-10.77}{11.30} \times 100\% = 4.6\%.$$

$$\text{The error (3)} = \left|\frac{\text{true value - read value}}{truevlaue}\right| \times 100\% = \left|\frac{11.5-11.9}{11.5}\right| \times 100\% = 3.4\%.$$

$$\text{The error (4)} = \left|\frac{\text{true value - read value}}{truevlaue}\right| \times 100\% = \left|\frac{13.5-14.5}{13.5}\right| \times 100\% = 7.4\%.$$

→Average error ($\overline{E}$):

$$\overline{E}(\%) = (\sum_{1}^{4} E)/4 = (4.8+4.6+3.4+7.4)/4 = 5.05.\%$$

6.3. Project Safety

Project safety is an important point to the operator; and to the device it self from the other hand, to integrate the blood test without any hazard; the project team described it in the following points:

1. To prevent electrical hazard; don't touch the lamp wires.
2. Don't did the blood test unless you wearing the medical gloves; because the sample has the cyanide solution which is TOXIC.

3. Prevent the optical filter from touch by hand; it may prevent its work correctly.
4. Don't turn the project ON unless you check the connection of DAQ with computer.

6.4. Project Maintenance:

This design needs maintenance as any medical instrumentation; the main points to maintain the integrity of the work are:

1. Always check the lamp voltage; prevent it to be less than 12v.
2. Change the lamp at the end of it expected life hour.
3. Change the cuvette when needed; keep it clean after every test.
4. Always check the DAQ connection.

Chapter 7

Conclusion and Future work

7.1 Conclusion.

7.2 Recommendations & Future work.

Chapter Seven

Conclusion and Future work

7.1 Conclusion

Our project conclusions consist on our study and design:

1. Our project designed to measuring the value of hemoglobin concentration; using suitable filter for the desired wave length (530 nm) which we need.

2. LabView software program is an excellent program to process the second part of our design (Beer's law); to have accurate output; & this program allow us to design an alarm circuit to compare if the output in the normal range or not; this gives the operator diagnosis about the patient status.

3. In our project the operator must follow the flowchart to have accurate result & success the aim of alarms.

7.2 Recommendation & Future Work

1. Our project was for one test sample (hemoglobin); in the future projects the students can develop it for more than one sample (sugar, electrolyte) by using wheel filter.

2. To enhance the reading concentration in the future projects, they can use photomultiplier instead of photo detector and enhance the dark room building.

3. We recommend to the electrical department to support the future projects to enhance projects quality.

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Appendices

- **Appendix A: Definitions**
- **Appendix B: Datasheets of Project Components**

Appendix: A

Definitions

Definitions

Absorbance	The ability of a medium to absorb radiation depending on temperature and wavelength. Expressed as the negative common logarithm of the transmittance.
Amplification	Process of increasing the strength of a signal, current, voltage or power
Anemic	Low red blood cell count.
Beer's law	Describes the dependence of intensity of light (electromagnetic radiation) transmitted through a sample. A = a * b * C, where A = absorbance, which is unit less, b = cell thickness in distance units and C = concentration in any valid concentration units.
Blank	A solution prepared exactly like your samples and standards except that the concentration of analytic is zero
Blood	Blood is a highly specialized circulating tissue consisting of several types of cells suspended in a fluid medium known as plasma.
Bone marrow	The soft material that fills the cavities of the bones.
Cuvette	A cuvette is a kind of laboratory glassware, usually a small square tube, sealed at one end, made of plastic, glass, or optical grade quartz and designed to hold samples for spectroscopic experiments. The best cuvettes are as clear as possible, without impurities that might affect a spectroscopic reading
Cytosol	The fluid portion of a cells cytoplasm
DAQ	Collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing; (2) Collecting and measuring the same kinds of electrical signals with A/D and/or DIO boards plugged into a PC, and possibly generating control signals with D/A

	and/or DIO boards in the same PC
Deciliter	A fluid measurement that is equal to one-tenth of a liter, or 100 cubic centimeters
Detectors	Any device or instrument used to sense the presence of a signal, detect the presence of radiation or particles, or convert a signal from one form to another.
Filters	A device which selectively transmits light having certain properties (often, a particular range of wavelengths, that is, range of colors of light, or polarizations), while blocking the remainder. They are commonly used in photography, in many optical instruments, and to color stage lighting.
Hemoglobin	The substance inside red blood cells that binds to oxygen and carries it from the lungs to the tissues
Incident light	The light that emanates directly from a light source
Mitochondria	Normal structures responsible for energy production in cells. Mitochondria are located in the cytoplasm outside the nucleus of the cell. They consist of two sets of membranes, a smooth continuous outer coat and an inner membrane arranged in tubules or in folds that form plate-like double membranes.
Plasma	The yellow fluid portion of the blood in which the red cells, white cells, and platelets are suspended. Like other blood components, it can be separated out from the whole blood for use in component therapy. Plasma contains many clotting proteins.
Platelet	An irregular, disc-shaped element in the blood that assists in blood clotting. During normal blood clotting, the platelets clump together (aggregate). Although platelets are often classed as blood cells, they are actually fragments of large bone marrow cells called megakaryocytic.

Photodiode	semiconductor that converts light to an electrical signal, used in fiber optic receivers
Reagent	compound involved in a chemical or biochemical reaction, especially one used in chemical analysis to produce a characteristic reaction in order to determine the presence of another compound
Red blood cells	are the most common type of blood cell and the vertebrate body's principal means of delivering oxygen from the lungs or gills to body tissues via the blood.
Transmittance	concentration is the measure of how much of a given substance there is mixed with another substance
Tumors	a general term for abnormal new growth initiated when a resting cell starts dividing.
Wavelength	Distance from one wave peak to another
White Blood Cell	Cells that help the body fight infections and disease. Also called white blood cells. White blood cells include lymphocytes, granulocytes, macrophages, and others

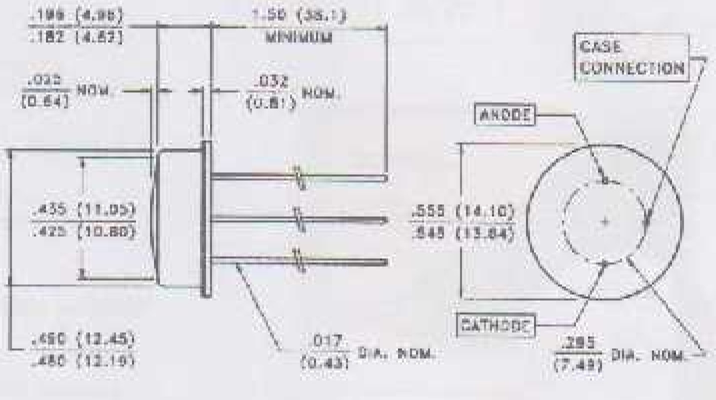
Appendix: B

Datasheets of Project Components

VTB Process Photodiodes

VTB6061UV

PACKAGE DIMENSIONS inch (mm)



CASE 15 TO-8 HERMETIC
CHIP ACTIVE AREA: .058 in^2 (37.7 mm^2)

Large area planar silicon photodiode in a dual lead TO-8 package with a UV transmitting "flat" window. Cathode is common to the case. These diodes have very high shunt resistance and have good blue response.

ABSOLUTE MAXIMUM RATINGS

Storage Temperature:	-40°C to 110°C
Operating Temperature:	-40°C to 110°C

ELECTRO-OPTICAL CHARACTERISTICS @ 25°C (See also VTB curves, pages 21-22)

SYMBOL	CHARACTERISTIC	TEST CONDITIONS	VTB6061UV			UNITS
			Min.	Typ.	Max.	
I_{SC}	Short Circuit Current	H = 100 fc, 2850 K	260	350		μA
TC I_{SC}	I_{SC} Temperature Coefficient	2850 K		.12	.23	%/°C
V_{OC}	Open Circuit Voltage	H = 100 fc, 2850 K		490		mV
TC V_{OC}	V_{OC} Temperature Coefficient	2850 K		-2.0		mV/°C
I_D	Dark Current	H = 0, VR = 2.0 V			2.0	nA
R_{SH}	Shunt Resistance	H = 0, V = 10 mV		.10		GΩ
TC R_{SH}	R_{SH} Temperature Coefficient	H = 0, V = 10 mV		-8.0		%/°C
C_J	Junction Capacitance	H = 0, V = 0		8.0		nF
S_R	Sensitivity	365 nm		.10		A/W
S_R	Sensitivity	220 nm	.04			A/W
λ_{range}	Spectral Application Range		200		1100	nm
λ_p	Spectral Response - Peak			920		nm
V_{BR}	Breakdown Voltage		2	40		V
$\theta_{1/2}$	Angular Resp. - 50% Resp. Pt.			±55		Degrees
NEP	Noise Equivalent Power		5.7×10^{-14} (Typ.)			W/$\sqrt{Hz}$
D*	Specific Detectivity		1.1×10^{13} (Typ.)			cm$\sqrt{Hz}$ / W

Low-Cost E Series Multifunction DAQ 16-Bit, 200 kS/s, 16 Analog Inputs

NI 6034E, NI 6036E

- 16 analog inputs at 200 kS/s, 16-bit resolution
- Up to 2 analog outputs, 16-bit resolution
- 8 digital I/O lines (5 V TTL/CMOS); two 24-bit counter/timers
- Digital triggering
- 4 analog input signal ranges
- NI-DAQ driver simplifies configuration and measurements

Models
NI 6034E
- NI PCI-6034E

NI 6036E
- NI PCI-6036E
- NI DAQCard-6036E ***NEW!***

Operating Systems
- Windows 2000/NT/XP/Me/9x
- Mac OS 9*

Recommended Software
- LabVIEW
- LabWindows/CVI
- Measurement Studio for Visual Basic
- VI Logger

Other Compatible Software
- Visual Basic
- C/C++

Driver Software (included)
- NI-DAQ

Calibration Certificate Included

*See ordering information

Overview and Applications

NI 6034E and NI 6036E devices use E Series technology to deliver high performance, reliable data acquisition capabilities. These devices enable a broad variety of applications including:

- Continuous high-speed data logging at up to 200 kS/s
- Externally timed and/or triggered data acquisition
- High-voltage and sensor measurements when used with NI signal conditioning
- High channel-count synchronization with RTSI

Features

NI 6034E and NI 6036E devices feature the NI-PGIA, an instrumentation-class amplifier that guarantees settling times at all gains. Typical commercial off-the-shelf amplifier components don't meet the settling time requirements for high-gain measurement applications. Without the NI-PGIA, 16-bit devices with a 100X gain can have an effective resolution of 12 bits. The NI 6034E and NI 6036E devices also offer resolution improvement technologies such as dithering to reduce quantization error. This technology permits NI 16-bit multifunction DAQ devices to perform with an effective input resolution of at least 16-bits. These devices offer several methods in which to connect your signals including differential for eight analog input channels and maximum noise elimination, as well as referenced and nonreferenced single-ended for 16 analog input channels.

NI 6034E and NI 6036E devices feature digital triggering, two 24-bit 20 MHz counter/timers, and eight digital I/O lines compatible with both 5 V TTL and CMOS. NI 6036E devices also feature two 16-bit analog outputs.

INFO CODES

For more information, or to order products online visit ni.com/info and enter:

pci6034e
pci6036e
daqcard6036e

BUY ONLINE!

Family	Bus	Analog Inputs	Resolution	Sampling Rate S/s	Input Range	Analog Outputs	Resolution	Output Rate	Output Range	Digital I/O	Counter/ Timers	Triggers
NI 6034E	PCI	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	–	–	–	–	8	2, 24-bit	Digital
NI 6036E	PCI/PCMCIA	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	2	16 bits	10 kS/s¹	±10 V	8	2, 24-bit	Digital

¹10 kS/s maximum when using the single DMA channel for analog output. kS/s system dependent when using the single DMA channel for either analog input or counter/timer operations.

Table 1. NI 6036E and NI 6034E Channel, Speed, and Resolution Specifications

Low-Cost E Series Multifunction DAQ 16-Bit, 200 kS/s, 16 Analog Inputs

Nominal Range (V)		Absolute Accuracy								Relative Accuracy	
		% of Reading		Offset	Noise + Quantization (µV)		Temp	Absolute Accuracy		Resolution (µV)	
Positive FS	Negative FS	24 Hrs	1 Year	(µV)	Single Pt.	Averaged	Drift (%/°C)	at Full Scale (mV)		Single Pt.	Averaged
10.0	-10.0	0.0648	0.0688	1591.4	885.0	77.90	0.0010	8.553		1025.20	102.50
5.0	-5.0	0.0146	0.0188	803.2	442.5	38.90	0.0005	1.787		512.60	51.26
0.5	-0.5	0.0648	0.0688	99.5	53.4	4.76	0.0010	0.443		82.73	8.27
0.05	-0.05	0.0648	0.0688	28.9	28.4	2.57	0.0010	0.068		33.60	3.38

Note: Accuracies are valid for measurements following an internal E Series Calibration. Averaged numbers assume dithering and averaging of 100 single-channel readings. Measurement accuracies are listed for operational temperatures within ±1 °C of internal calibration temperature and ±10 °C of external or factory-calibration temperature. One-year calibration interval recommended. The Absolute Accuracy at Full Scale calculations were performed for a maximum range input voltage (for example, 10 V for the ±10 V range) after one year, assuming 100 pt averaging of data.

Table 2. NI PCI-6034E and NI PCI-6036E Analog Input Accuracy Specifications

Nominal Range (V)		Absolute Accuracy							Relative Accuracy	
		% of Reading		Offset	Noise + Quantization (mV)		Temp	Absolute Accuracy	Resolution (mV)	
Positive FS	Negative FS	24 Hrs	1 Year	(mV)	Single Pt.	Averaged	Drift (%/°C)	at Full Scale (mV)	Single Pt.	Averaged
10	-10	0.0077	0.0914	2.93	0.60	0.079	0.0010	12.154	1.03	0.10
5	-5	0.0272	0.0314	1.48	0.44	0.039	0.0005	3.087	0.51	0.051
0.5	-0.5	0.0372	0.0514	0.197	0.053	0.005	0.0010	0.629	0.083	0.009
0.05	-0.05	0.0872	0.0514	0.039	0.026	0.003	0.0010	0.084	0.034	0.003

Note: Accuracies are valid for measurements following an internal E Series Calibration. Averaged numbers assume dithering and averaging of 100 single-channel readings. Measurement accuracies are listed for operational temperatures within ±1 °C of internal calibration temperature and ±10 °C of external or factory-calibration temperature. One-year calibration interval recommended. The Absolute Accuracy at Full Scale calculations were performed for a maximum range input voltage (for example, 10 V for the ±10 V range) after one year, assuming 100 pt averaging of data.

Table 3. NI DAQCard-6036E Analog Input Accuracy Specifications

Family	Nominal	Absolute Accuracy					Absolute
		% of Reading				Temp	Accuracy at
	Range (V) FS	24 Hrs	90 Days	1 Year	Offset (mV)	Drift (%/°C)	Full Scale (mV)
NI PCI-6036E	±10	0.009	0.011	0.013	1.1	0.0005	2.417
NI DAQCard-6036E	±10	0.009	0.011	0.013	1.22	0.0005	2.547

Note: Temp Drift applies only if ambient is greater than ±10 °C of previous external calibration.

Table 4. NI PCI-6036E and NI DAQCard-6036E Analog Output Accuracy Specifications

Low-Cost E Series Multifunction DAQ
16-Bit, 200 kS/s, 16 Analog Inputs

Driver Software

NI-DAQ is the robust driver software included with all National Instruments data acquisition and signal conditioning products. This easy-to-use software tightly integrates the full functionality of your DAQ hardware to LabVIEW, LabWindows/CVI, and Measurement Studio for Visual Basic. High-performance features include multidevice synchronization, networked measurements, and DMA data management. Bundled with NI-DAQ, the Measurement & Automation Explorer utility simplifies the configuration of your measurement hardware with device test panels, interactive measurements, and scaled I/O channels. NI-DAQ also provides numerous example programs for LabVIEW and other application development environments to get you started with your application quickly.

Services and Support/Training

As a complement to your data acquisition and signal conditioning product, consider:

- **Technical Support –** Included in hardware/software purchase through applications engineers worldwide. Web resources with more than 1000 example programs and more than 7000 Knowledge Bases, and Premier Support – *ni.com/support*
- **NI Factory Installation Services (FIS) –** Software and hardware installed in PXI and PXI/SCXI systems, tested and ready to use – *ni.com/advisor*
- **Calibration –** Includes NIST-traceable basic calibration certificate, services for ANSI/NCSL-Z540 and periodic calibration – *ni.com/calibration*
- **Extended Warranty –** Meet project life-cycle requirements and maintain optimal performance in a cost-effective way – *ni.com/services*
- **Data Acquisition Training –** Instructor-led courses – *ni.com/training*
- **Professional Services –** Feasibility, consulting, and integration through our Alliance Program members – *ni.com/alliance*

For more information on NI services and support, visit *ni.com/services*

Related Products

For related products, please refer to:

- SCXI Signal Conditioning
- SCC Signal Conditioning
- Analog Output Multifunction DAQ
- High-speed Digital I/O

Tech Tip

Learn how to reduce your development time and system costs. Visit *ni.com/info* and enter **mready** to download an interactive white paper on the benefits of Measurement Ready DAQ – measurement quality, software integration, and solutions support.

For more information, visit *ni.com/info* and enter: mready

Ordering Information

NI PCI-6034E[1] 778075-01
NI PCI-6036E 778465-01
NI DAQCard-6036E 778561-01

Includes NI-DAQ driver software

[1] Compatible with Mac OS 9

Recommended Configurations

Family	DAQ Devices	Accessory	Cable
NI 6034E	NI PCI-6034E	CB-68LP (777145-01)	R6868 (182482-01)
NI 6036E	NI PCI-6036E	CB-68LP (777145-01)	R6868 (182482-01)
NI 6036E	NI DAQCard-6036E	CB-68LP (777145-01)	RC6868 (187252-01)

16-Bit E Series Multifunction DAQ Specifications

Specifications – 16-Bit E Series NI 6052E and NI 603xE

These specifications are typical for 25 °C unless otherwise noted.

Analog Input

Accuracy specifications .... See tables in E Series product pages

Input Characteristics

Number of channels

6052E 6030E 6032E 6034E 6036E	16 single-ended or 8 differential (software selectable per channel)
6031E 6033E	64 single-ended or 32 differential (software selectable per channel)

Resolution .... 16 bits, 1 in 65,536

Maximum sampling rate

6052E	333 kS/s
6034E 6036E	200 kS/s
6030E 6031E 6032E 6033E	100 kS/s

Streaming-to-disk rate (system dependent)[1]

6052E	333 kS/s
6034E 6036E	200 kS/s
6030E 6031E 6032E 6033E	100 kS/s

[1]Streaming-to-disk rates do not apply to RT Series devices.

Input signal ranges

Device	Range Software Selectable	Bipolar Input Range	Unipolar Input Range
6052E	20 V	±10 V	–
	10 V	±5 V	0 to 10 V
	5 V	±2.5 V	0 to 5 V
	2 V	±1 V	0 to 2 V
	1 V	±500 mV	0 to 1 V
	500 mV	±250 mV	0 to 500 mV
	200 mV	±100 mV	0 to 200 mV
	100 mV	±50 mV	0 to 100 mV
6030E 6031E 6032E 6033E	20 V	±10 V	–
	10 V	±5 V	0 to 10 V
	5 V	–	0 to 5 V
	4 V	±2 V	–
	2 V	±1 V	0 to 2 V
	1 V	±500 mV	0 to 1 V
	500 mV	–	0 to 500 mV
	400 mV	±200 mV	–
	200 mV	±100 mV	0 to 200 mV
	100 mV	–	0 to 100 mV
6034E 6036E	20 V	±10 V	–
	10 V	±5 V	–
	1 V	±500 mV	–
	100 mV	±50 mV	–

Input coupling .... DC

Maximum working voltage
(signal + common mode) .... Each input should remain within ±11 V of ground

Overvoltage protection
Powered on .... ±25 V
Powered off .... ±15 V

Inputs protected

6052E 6030E 6032E 6034E 6036E	ACH<0..15>, AISENSE
6031E 6033E	ACH<0..63>, AISENSE, AISENSE2

FIFO buffer size .... 512 samples; 1024 samples for DAQCard

Data transfers
PCI, PXI .... DMA, interrupts, programmed I/O
DAQCard .... Interrupts, programmed I/O

DMA modes
PCI, PXI .... Scatter-gather (single transfer, demand transfer)

Configuration memory size .... 512 words

Transfer Characteristics

Relative accuracy (dithered)

Device	Typical	Maximum
6052E 6034E PCI-6036E	±1.5 LSB	±3 LSB
6030E 6031E 6032E 6033E	±0.75 LSB	±1 LSB
DAQCard-6036E	±2.0 LSB	±4 LSB

DNL

Device	Typical	Maximum
6052E 603xE (except DAQCard-6036E)	±0.5 LSB	±1 LSB
DAQCard-6036E	+4, -0.5 LSB	+4, -2 LSB

No missing codes .... 16 bits, guaranteed

Amplifier Characteristics

Input impedance

Device	Normal Powered On	Powered Off	Overload
6052E 603xE	100 GΩ in parallel with 100 pF	820 Ω	820 Ω

Input bias and offset current

Device	Bias Current	Offset Current
6052E 6034E PCI-6036E	±200 pA	±100 pA
6030E 6031E 6032E 6033E	±1 nA	±2 nA
DAQCard-6036E	±200 pA	±100 pA

16-Bit E Series Multifunction DAQ Specifications

Specifications – 16-Bit NI 6052E and NI 603xE (continued)

CMRR, DC to 60 Hz

Device	Range	CMRR Bipolar (dB)	CMRR Unipolar (dB)
6052E	20 V	92	–
	10 V	97	87
	5 V	101	101
	2 V	101	104
	100 mV to 1 V	105	105
6030E 6031E 6032E 6033E	20 V	92	–
	10 V	97	92
	5 V	–	97
	4 V	101	–
	2 V	104	101
	1 V	105	104
	100 mV to 500 mV	105	105
6034E 6036E	20 V	92	–
	10 V	92	–
	1 V	96	–
	100 mV	96	–

Dynamic Characteristics

Bandwidth

Device	Range	Small Signal (-3 dB)
6052E	All ranges	400 kHz
6030E 6031E 6032E 6033E	All ranges	255 kHz
6034E 6036E	All ranges	413 kHz

System noise (LSB, including quantization)

Device	Range	Bipolar	Unipolar
6052E	2 to 20 V	0.55	0.95
	1 V	1.1	1.1
	500 mV	1.3	1.3
	200 mV	2.7	2.7
	100 mV	5.0	5.0
6030E 6031E 6032E 6033E	2 to 20 V	0.6	0.8
	1 V	0.7	0.8
	400 to 500 mV	1.1	1.1
	200 mV	2.0	2.0
	100 mV		3.8
6034E 6036E	10 to 20 V	0.6	–
	1 V	1.0	–
	100 mV	8.2	–

Settling time to full-scale step

Device	Range	Accuracy ±0.00076% (±0.5 LSB)	±0.0015% (±1 LSB)	±0.0031% (±2 LSB)	±0.0061% (±4 LSB)	±0.024% (±16 LSB)
6052E	2 to 20 V	–	10 µs max	5 µs max	4 µs max	3 µs max
	1 V	–	15 µs max	5 µs max	4 µs max	3 µs max
	200 to 500 mV	–	15 µs max	10 µs max	4 µs max	3 µs max
	100 mV	–	15 µs typical	10 µs typical	4 µs max	3 µs max
6030E 6032E	All	40 µs max	20 µs max	–	10 µs max	–
6031E 6033E	All	50 µs max	25 µs max	–	10 µs max	–
6034E 6036E	1 to 10 V	–	–	5 µs max	–	–
	200 mV	–	–	–	5 µs typical	–

Crosstalk

Device	Adjacent Channels	All Other Channels
6052E 603xE	-75 dB	-90 dB

Analog Output

Output Characteristics

Number of channels

6052E 6030E 6031E 6036E 6032F	2 voltage outputs
6032E 6034E	None

Resolution

6052E 6036E 6030E 6031E	16 bits, 1 in 65,536

Maximum update rate

6052E	333 kS/s
6036E	10 kS/s, system dependent
6030E 6031E	100 kS/s

Type of DAC .... Double buffered, multiplying

FIFO buffer size

6052E 6030E 6031E	2,048 samples
6036E	None

Data transfers
PCI, PXI .... DMA, interrupts, programmed I/O
DAQCard .... Interrupts, programmed I/O
DMA modes
PCI, PXI .... Scatter-gather (single transfer, demand transfer)

Transfer Characteristics

Relative accuracy

6052E	±0.35 LSB typical, ±1 LSB max
6030E 6031E	±0.5 LSB typical, ±1 LSB max
6036E	±2 LSB max

DNL .... ±1.0 LSB max
Monotonicity

6052E 6036E 6030E 6031E	16 bits, guaranteed

Voltage Output

Ranges

6052E	±10 V, 0 to 10 V, ±EXTREF, 0 to EXTREF; software selectable
6030E 6031E	±10 V, 0 to 10 V; software selectable
6036E	±10 V

Output coupling .... DC
Output impedance .... 0.1 Ω max
Current drive .... ±5 mA max
Protection .... Short-circuit to ground
Power-on state

6052E 6030E 6031E	0 V (±20 mV)
PCI-6036E	0 V (±44 mV)
DAQCard-6036E	0 V (±60 mV)

16-Bit E Series Multifunction DAQ Specifications

Specifications – 16-Bit NI 6052E and NI 603xE (continued)

External reference input (6052E only)
- Range .... ±11 V
- Overvoltage protection .... ±25 V powered on, ±15 V powered off
- Input impedance .... 10 kΩ
- Bandwidth (-3 dB) .... 3 kHz
- Slew rate .... 0.5 V/µs

Dynamic Characteristics

Settling time and slew rate

Device	Settling Time for Full-Scale Step	Slew Rate
6052E	3.5 µs to ±1 LSB accuracy	15 V/µs
6030E 6031E	10 µs to ±1 LSB accuracy	5 V/µs
PCI-6036E	10 µs to ±4.0 LSB accuracy	15 V/µs
DAQCard-6036E	10 µs to ±0.5 LSB	5 V/µs

Noise

6052E 6030E 6031E	60 μV_{rms}, DC to 1 MHz
PCI-6036E	110 μV_{rms}, DC to 400 kHz
DAQCard-6036E	160 μV_{rms}, DC to 400 kHz

Glitch energy (at mid-scale transition)

Device	Magnitude	Duration
6052E	±10 mV	1 µs
6030E 6031E	N/A	N/A
PCI-6036E	±10 mV	1 µs

Digital I/O

- Number of channels .... 8 input/output
- Compatibility .... 5 V/TTL/CMOS
- Power-on state .... Input (high impedance)
- Data transfers .... Programmed I/O

Digital logic levels

Level	Minimum	Maximum
Input low voltage	0 V	0.8 V
Input high voltage	2 V	5 V
Output low voltage (Iout = 24 mA)	–	0.4 V
Output high voltage (Iout = 13 mA)	4.35 V	–

Timing I/O

General-Purpose Up/Down Counter/Timers

- Number of channels 2
- Resolution .... 24 bits (1 in 16,777,216)
- Compatibility .... 5 V/TTL/CMOS

Digital logic levels

Level	Minimum	Max
Input low voltage	0.0 V	0.8 V
Input high voltage	2.0 V	5.0 V
Output low voltage (Iout = 5 mA)	–	0.4 V
Output high voltage (Iout = 3.5 mA)	4.35 V	–

- Base clocks available .... 20 MHz and 100 kHz
- Base clock accuracy .... ±0.01%
- Maximum source frequency .... 20 MHz
- External source selections .... PFI <0..9>, RTSI <0..6>, analog trigger; software selectable
- External gate selections .... PFI <0..9>, RTSI <0..6>, analog trigger; software selectable
- Minimum source pulse duration .... 10 ns
- Minimum gate pulse duration .... 10 ns, edge-detect mode
- Data transfers
  - PCI, PXI .... DMA, interrupts, programmed I/O
  - DAQCard .... Interrupts, programmed I/O
- DMA modes
  - PCI, PXI .... Scatter-gather (single transfer, demand transfer)

Frequency Scaler

- Number of channels 1
- Resolution .... 4 bits
- Compatibility .... 5 V/TTL

Digital logic levels

Level	Minimum	Max
Input low voltage	0.0 V	0.8 V
Input high voltage	2.0 V	5.0 V
Output low voltage (Iout = 5 mA)	–	0.4 V
Output high voltage (Iout = 3.5 mA)	4.35 V	–

- Base clocks available .... 10 MHz, 100 kHz
- Base clock accuracy .... ±0.01%
- Data transfers .... Programmed I/O

Triggers

Analog Triggers

Number of triggers

6052E 6030E 6031E 6032E 6033E	1
6034E 6036E	None

Purpose
- Analog input .... Start and stop trigger, gate, clock
- Analog output .... Start trigger, gate, clock
- General-purpose counter/timers .... Source, gate

Source

6052E 6030E 6032E	ACH<0..15>, PFI0/TRIG1
6031E 6033E	ACH<0..63>, PFI0/TRIG1

Level
- Internal source, ACH<0..15/63> .... ±Full-scale
- External source, PFI0/TRIG1 .... ±10 V

- Slope .... Positive or negative; software-selectable
- Resolution .... 12 bits, 1 in 4,096
- Hysteresis .... Programmable

Bandwidth (-3 dB)

Device	Internal Source ACH<0..15/63>	External Source PFI0/TRIG1
6052E	700 kHz	700 kHz
6030E, 6031E, 6032E, 6033E	255 kHz	4 MHz

- Accuracy .... ±1% of full-scale range max

Digital Triggers (all devices)

- Number of triggers 2

Purpose
- Analog input .... Start and stop trigger, gate, clock
- Analog output .... Start trigger, gate, clock
- General-purpose counter/timers .... Source, gate

- Source .... PFI <0..9>, RTSI <0..6>
- Slope .... Positive or negative; software selectable
- Compatibility .... 5 V/TTL
- Response .... Rising or falling edge
- Pulse width .... 10 ns minimum

16-Bit E Series Multifunction DAQ Specifications

Specifications – 16-Bit NI 6052E and NI 603xE (continued)

External Input for Digital or Analog Trigger (PFI0/TRIG1)

Impedance .... 10 kΩ
Coupling .... DC
Protection
  Digital trigger .... -0.5 to (Vcc + 0.5) V
  Analog trigger
    On/Off/Disabled .... ±35 V

Calibration

Recommended warm-up time .... 15 minutes; 30 minutes for DAQCard
Calibration interval .... 1 year
Onboard calibration reference
  DC Level

6052E 6030E 6031E 6032E 6033E	5.000 V (±1.0 mV)	Over full operating temperature, actual value stored in EEPROM
6034E 6036E	5.000 V (±3.5 mV)	

Temperature coefficient

6052E 6030E 6031E 6032E 6033E	±0.6 ppm/°C max
6012E 6034E 6036E	±5.0 ppm/°C max

Long-term stability

6052E 6030E 6031E 6032E 6033E	±6.0 ppm/√1000 h
6034E 6036E	±15.0 ppm/√1000 h

RTSI (PCI only)

Trigger lines 7

PXI Trigger Bus (PXI only)

Trigger lines 6
Star Trigger 1

Bus Interface

PCI, PXI .... Master, slave
DAQCard .... Slave

Power Requirements[1]

Device	+5 VDC (±5%)	Power Available at I/O Connector
6052E	1.3 A	+4.65 to +5.25 VDC, 1 A
603xE (PCI, PXI), except 6034E	1.5 A	+4.65 to +5.25 VDC, 1 A
6034E PCI-6036E	0.9 A	+4.65 to +5.25 VDC, 1 A
DAQCard-6036E	300 mA	+4.65 to +5.25 VDC, 0.75 A

Physical[1]

Dimensions (not including connectors)

PCI .... 17.5 by 10.6 cm (6.9 by 4.2 in.)
PXI .... 16.0 by 10.0 cm (6.3 by 3.9 in.)
DAQCard .... Type II PC Card

I/O connectors

6052E 6030E 6032E 6034E PCI-6036E	68-pin male SCSI-II type
6031E 6033E	100-pin female 0.050 D-type
DAQCard-6036E	68-position VHDCI female

Environment

Operating temperature .... 0 to 55 °C; DAQCards should not exceed 55 °C while in PCMCIA slot
Storage temperature .... -20 to 70 °C
Relative humidity .... 10 to 90%, noncondensing

Certifications and Compliances

CE Mark Compliance CE

[1] See RT Series devices for RT Series power requirements and physical parameters.