بسم الله الرحمن الرحيم

Palestine polytechnic university

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Electrical and Computer Engineering Department

Graduation Project

Non-Invasive Measurement of Blood Glucose Concentration

Project Team

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June, 2009

Abstract

The non-invasive glucose meter is a new technology that can be used to measure the concentration of glucose in blood. This report describes method of non-invasive glucose meter by using optical method.

In this project we design a non invasive glucose meter using three wavelengths (650,880,940 nm) photodiode. we conclude the function between absorbtion of light and blood glucose concentration using a 650 nm wavelength.

ملخص المشروع

الطريقه غير الجراحيه لقياس نسبة السكر في الدم, هي طريقه جديده يمكن استخدامها لقياس تركيز السكر في الدم.

في هذا المشروع قمنا بتصميم طريقة لقياس نسبة السكر في الدم باستخدام ثلاث اطوال موجيه (650 , 880 , 940 نانوميتر), واستنتجنا العلاقه بين نسبة امتصاص الضوء وتركيز الجلوكوز في الدم باستخدام الطول الموجي 650 نانوميتر.

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Chapter one

Introduction

1.1 Introduction

This project is a useful method of determining the concentration of glucose in intravascular blood within a body part of a subject .This device measure blood glucose concentration by non-invasive method includes 4-light source having a wavelength of" 650,880 and 940"nm. Our idea of this device comes from a widespread demand for non-invasive determination of glucose for millions of diabetics all over the world, many of them need several glucose test each day to provide correct insulin control and diet.

1.2 Project Objectives

The main objectives of this project are:

1. To use a new technique for determining blood glucose concentration.
2. Reducing the risks associated with having an open wound in the skin which is not desirable.
3. Reducing the coast of the instruments which are used in invasive techniques, like test strips, lancets and so on …
4. Reducing negative emotions like pain, fear, apprehension, revulsion.

1.3 Importance of the project

The important of this project is that it is a non-invasive method. A non-invasive blood glucose monitor might help many more people with diabetes get their blood glucose concentration, under better control by testing more frequently, without need using strips or wounds.

1.4 Literature Review

This study of this project is depends on some ideas of other projects. The first is the device called SugarTrac meter, the technology was fairly simple, consisting of a single 940 nm near-infrared LED (similar to those used in a television remote control) and a photo detector placed across the earlobe from each other. Using a combination of the pulsatile component of blood flow and some mathematical algorithms, a glucose result could be calculated in as little at 30 seconds.[1]

Figure (1.1). Sugartrac Meter

The second comes from United State patent number 5,910,109" Non-invasive glucose measuring device and method for measuring blood".

" Glucose measuring device for determining the concentration of glucose in intravascular blood within a body part of a subject. The device includes light sources having a wavelength of 650, 880, 940 or 1300 nm to illuminate the fluid. Receptors associated with the light sources for receiving light and generating a transmission signal representing the light transmitted are also provided." [2]

1.5 Estimated costs:

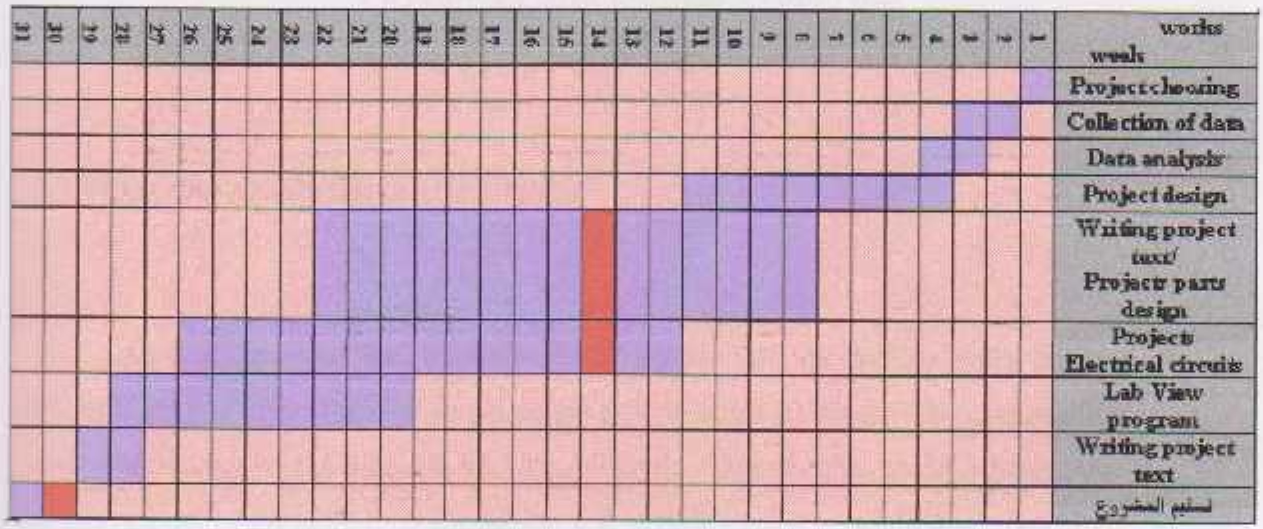
This section lists the overall cost of the project components that are considered in implementing system.

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

Component	Cost
DAQ and chips	300.0$
Diodes	20.0$
Photodiodes	5.0$
Electronics	15.0$
Materials	20.0$
PC	300.0$

The approximated total cost for the project is: 660$.

1.6 Schedule Time:



Red Square in the middle of the table refers to the date of delivery of the introduction of the project in the to the fourteenth week.

Red Square at the end of the table refers to the date of delivery of the project in the thirty week.

Chapter Two

Physiology and Optical Properties

2.1 Properties of skin tissue and blood.

Optical imaging and non-invasive diagnosis of the human body depend strongly on the optical and physical properties of skin and blood. The composition and morphology of the skin are very complicated. Therefore, to build a reasonable optical model of the skin, its composition and structure must be studied in advance.

2.1.1 Composition and Structure of skin tissue.

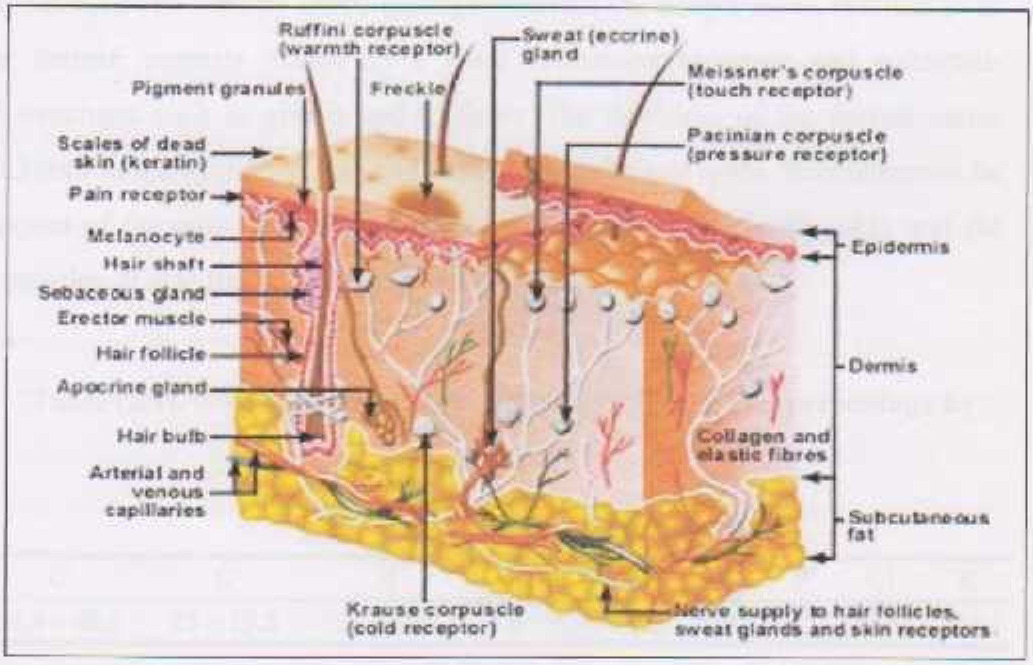


Figure (2.1).Skin Tissue Structure

The structure and properties of skin vary considerably in different parts of the body. A typical structure is shown in Fig (2.1) while Table (2.1) and Table (2.2) list the average elemental composition and the biochemical composition of the skin, respectively.

The skin is usually divided into three layers, namely, the epidermis, dermis, and subcutaneous fat, each with their own sub layers. The outermost layer of the epidermis is composed of a relatively thin, but rough, protective top layer of dead and dry skin cells, known as the stratum corneum or horny layer. The remainder of the epidermis, including the stratum lucidum, stratum granulosum and stratum spinosum, is made up of cells called keratinocytes as well as melanocytes, which are pigment cells responsible for skin pigmentation. The thickness of the epidermis varies from (0.1)mm in the eyelids to nearly (1)mm on the palms and soles. The dermis consists of a variety of cells, fibers, nerves, oil glands, sweat glands, blood vessels and hair roots. Its upper layer is called the papillary dermis and contains the vascular network and sensory nerve endings, whereas the deeper layer, referred to as reticular dermis, consists mainly of a loose connective structure and epithelial-derived structures such as glands and follicles. The thickness of the dermis varies from (0.3)mm in the eyelids to about (3)mm in the palm and soles. Subcutaneous fat is composed of fat cells, which form a cushioning layer between the skin and the deeper muscles. It also has an abundant blood content.

Table (2.1). Average elemental composition of the skin, percentage by mass [3]

O	C	H	N	Na	Mg	P	Cl	K
59.4 ~ 69.5	25 ~ 15.8	10 ~ 10.1	4.6 ~ 3.7	0.2	0.1	0.2	0.3	0.1

Table (2.2). Percentage constituents of adult human skin [3]

Water	Protein	Lipid	Other
58.6 ~ 72.1	22 ~ 27.2	5.2 ~ 13.5	0.7

2.1.2 Optical absorption of skin tissue.

Being composed of water as well as proteins and lipids, the chemical make-up of the skin influences its optical absorption properties. Water absorbs photons at wavelengths longer than the middle infrared range, while proteins are strongly absorbing in the ultraviolet and violet region. Fortunately, the optical absorption capacity of water, proteins and lipids is small in the red and near-infrared region. This region, known as the "tissue optical window", ranges from 600 nm to 2300 nm and allows light to penetrate from a few hundreds of micrometers to a few millimeters into the skin tissue. As a result, it can be exploited for a variety of purposes, including diagnosis, imaging or therapy.[3]

At the shorter wavelengths of the tissue optical window, (600 to 1100)nm, the most important photon absorbing chromophores are blood and melanin. Water becomes dominant at incident wavelengths longer than 1150 nm. The epidermis does not contain any blood and its water content is also much lower that of the dermis. However,the stratum granulosum and stratum spinosum comprise some melanocytes, including melanin, which is involved in skin pigmentation. Because the absorption capacity of melanin is stronger than that of blood and water, it is the dominant source of absorption in the epidermis at shorter near-infrared wavelengths. The volume fraction of melanosomes in the epidermis can vary from (1.3 ~ 6.3)% for light-skinned adults, (11~16)% for well-tanned adults and (18 ~ 43)% for darkly pigmented Africans.

The blood content of the dermis is about (0.2 ~ 5) %, representing the main source of absorption at wavelengths shorter than 1100 nm. If the optical wavelength exceeds the near-infrared range, water content becomes an important consideration in terms of optical absorption. It is a well-known fact that the measured values of absorption coefficient of a tissue are different in vitro and in vivo measurements. This can be explained on a number of grounds. First, soaking the tissue sample in saline prior to an in vitro measurement may alter its optical properties, and increase the amount of reflectance. Also other kinds of tissue treatments, including freezing, drying, heating or deforming, may change the optical properties of the sample. Second, measuring and calibration procedures may introduce an error into the determined values for diffuse reflectance and total transmittance. Third, the use of simplified calculation methods may result in an incorrect interpretation of the measured data, as in the case of internal reflectance at tissue boundaries.

2.1.3 Composition and structure of blood.

Blood is a circulating tissue composed of liquid plasma and cells (red blood cells, white blood cells, platelets), the main function of blood is to supply oxygen, glucose and constitutional elements to tissues and to remove waste products (like carbon dioxide and lactic acid).

The composition of whole blood is shown in Fig.(2.2), the volume fraction of cells in whole blood is about 47% ± 5% in a man and 42% ± 5% in a woman. Of the volume, 99% is erythrocytes, i.e. red blood cells (RBC). Hemoglobin, in turn, accounts for about 30% of an RBC's weight.

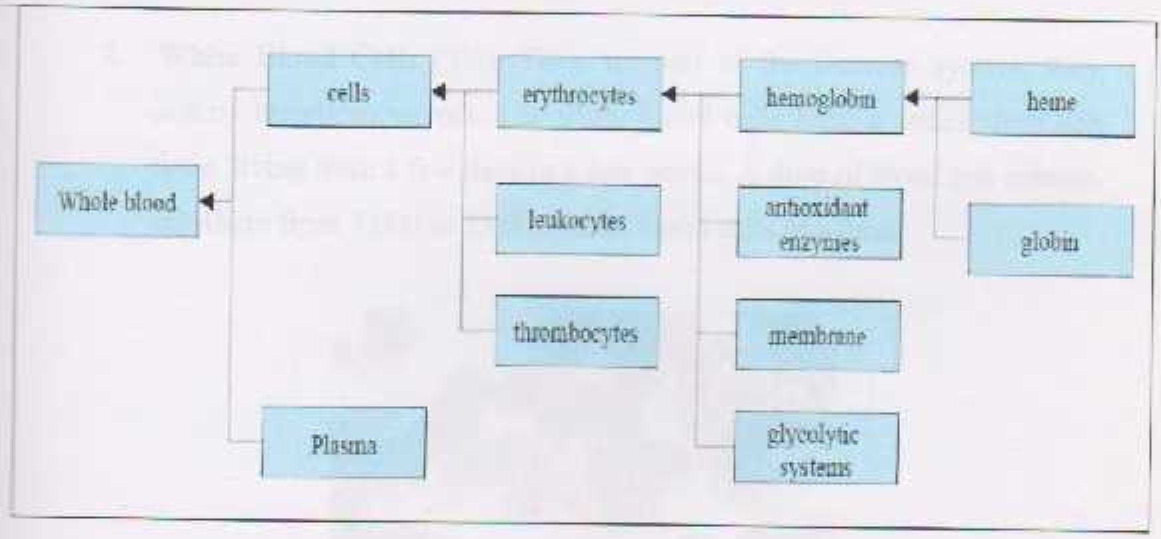


Figure (2.2). Composition of whole blood

2.1.4 Blood Cells:

1. **Red Blood Cells** (96%). They contain the blood's hemoglobin and distribute oxygen women have about 4 to 5 million RBC per micro liter (cubic millimeter) of blood and men about 5 to 6 million.

Figure (2.3). Red Blood Cells

2. **White Blood Cells** (3%). They are part of the immune system, they destroy infections agents. The white blood cells have a rather short life cycle, living from a few days to a few weeks. A drop of blood can contain anywhere from 7,000 to 25,000 white blood cells at a time.

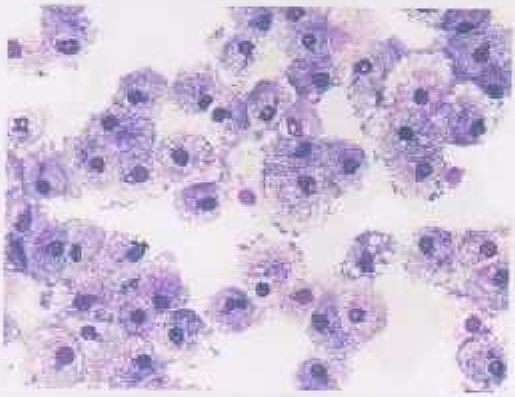


Figure (2.4). White Blood Cells

3. **Platelets** (1%). They are responsible for blood clotting or coagulation. 150,000–400,000 platelets in each micro liter of human blood

Figure (2.5). platelets

2.2 Glucose Structure and properties.

2.2.1 Glucose Structure.

Glucose is an example of a carbohydrate which is commonly encountered. It is also known as blood sugar, and dextrose. Its chemical formula is $C_6H_{12}O_6$, and this empirical formula is shared by other sugars - called **hexoses** - 6 carbon sugars.

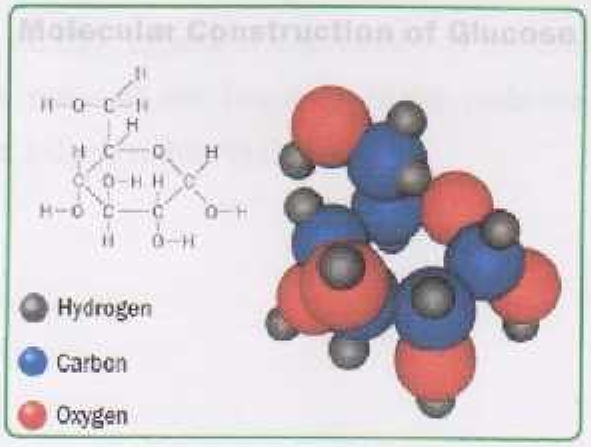


Figure (2.6). Glucose molecule structure

2.2.2 Normal values

Human blood glucose levels normally remain within a remarkably narrow range. In most humans this varies from about 80 mg/dl to perhaps 110 mg/dl (3.9 to 6.0 mmol / liter) except shortly after eating when the blood glucose level rises temporarily (up to maybe 140 mg/dl or a bit more in non-diabetics).

2.2.3 Health effects

If blood sugar levels drop too low, a potentially fatal condition called hypoglycemia develops. Symptoms may include lethargy, impaired mental functioning, irritability, and loss of consciousness. Brain damage is even possible.

If levels remain too high, appetite is suppressed over the short term. Long-term hyperglycemia causes many of the long-term health problems associated with diabetes, including eye, kidney, and nerve damage.

2.2.4 Glucose and Insulin

Glucose in blood stimulates Insulin production. Beta cells measure the blood glucose levels and deliver required amount of Insulin to funnel glucose into the cells. This maintains the blood sugar in the normal range. When there is deficit in the Insulin production, excess Glucose cannot be stored in the liver or muscle tissue. Instead it accumulates in the Blood.

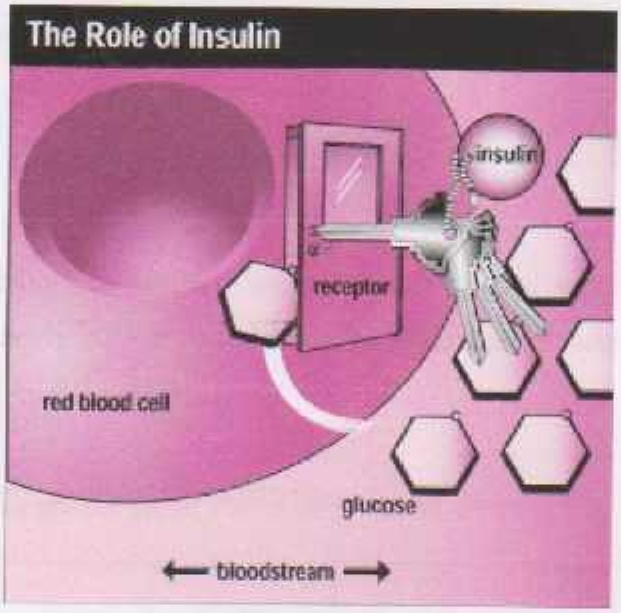


Figure (2.7). Glucose and Insulin

2.3 Diabetes

2.3.1 Types of Diabetes.

There are three types of diabetes: Type 1, Type 2, and Gestational Diabetes.

Type 1 Diabetes:

Also called juvenile diabetes, is usually diagnosed in children and young adults and results from the body's inability to produce insulin, the hormone that enables glucose to enter and fuel cells of the body.

Type 2 Diabetes:

Is the body's failure to properly use insulin, combined with relative insulin deficiency. Approximately 90% of Americans diagnosed with diabetes have type 2.

- **Gestational Diabetes** affects about 4% of all pregnant women.

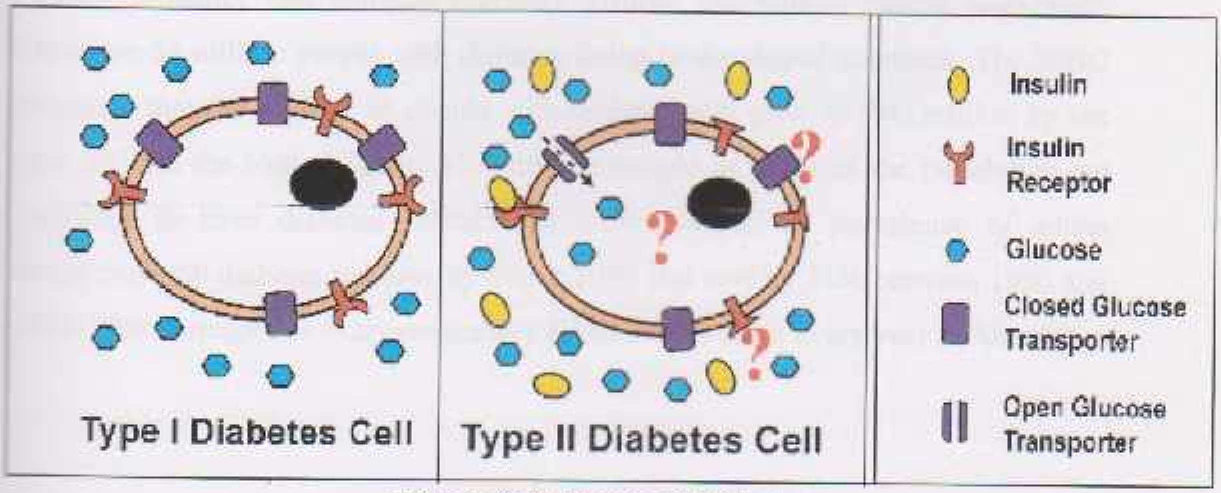


Figure (2.8). Types of Diabetes

2.3.2 Diagnoses of diabetes.

Diabetes is often undiagnosed, because many symptoms appear relatively harmless. Early detection and treatment can decrease the probability of developing the complications of diabetes. For the people diagnosed with diabetes, the challenge is to actively and accurately manage diets and exercise programs, while also actively managing blood sugar to maintain glucose levels within an optimal range. Diabetes have extra reason to be mindful of heart and blood vessel disease, diabetes carries an increased risk for heart attack, stroke, and complications related to poor circulation, two out of three people with diabetes die from heart diseases and stroke.

2.3.3 Diabetes Prevalence and Trends.

Diabetes is an ever more common disease. The World Health Organization (WHO) estimates that diabetes currently afflicts 154 million people worldwide. There are 54 million people with diabetes living in developed countries. The WHO estimates that the number of people with diabetes will grow to 300 million by the year 2025.in the United States, 15.7 million people or 5.9% of the population are estimated to have diabetes. Within the united states, the prevalence of adults diagnosed with diabetes increase by 6% in 1999 and rose by 33% between 1990 and 1998. This corresponds to approximately 800,000 new cases every year in America.

Chapter Three

Theoretical Background

3.1.1 History of Blood Glucose Measurement

Chinese used to test for the disease in ancient times by seeing if ants were attracted to sugar in a patient's urine. Testing urine for glucose as a diagnosis for diabetes has been done for over a century. But Urine testing for glucose has very serious problem which is both; normal and low blood glucose levels result in no glucose in urine, it is never possible to assess low blood levels using urine tests.[1]

In 1964, Ernest Adams of Ames developed a practical test strip for measuring glucose in blood, and it was named Dextrostix which uses a biochemical reaction, with an enzyme called glucose oxidase, which reacted with glucose to produce hydrogen peroxide. The hydrogen peroxide produced a color and the amount of color on the strip after exposing it to a drop of blood was a good measure of the amount of glucose present. This was the first invasive technique. [1]

The first description of a near-infrared glucose measurement that stirred genuine interest seems to be European Patent Application 0160768A1: "Spectrophotometric method and apparatus for the non-invasive determination of glucose in body tissues" by Dähne and Cross, researchers at the Battelle Institute in Switzerland in 1985. [1]

3.1.2 Glucose Measurement

Glucose can be measured in whole blood, serum. Historically, blood glucose values were given in terms of whole blood, but most laboratories now measure and report the serum glucose levels. Because RBC have a higher concentration of protein (eg. hemoglobin) than serum, serum has a higher water content and consequently more dissolved glucose than does whole blood.

Collection of blood in clot tubes for serum chemistry analysis permits the metabolism of glucose in the sample by blood cells until separated by centrifugation. Red blood cells, for instance, do not require insulin to intake glucose from the blood. Higher than normal amounts of white or red blood cell counts can lead to excessive glycolysis in the sample with substantial reduction of glucose level if the sample is not processed quickly. Ambient temperature at which the blood sample is kept prior to centrifuging and separation of Plasma/Serum also affects glucose levels.

At refrigerator temperatures, glucose remains relatively stable for several hours in a blood sample. At room temperature (25°C), a loss of 1 to 2% of total glucose per hour should be expected in whole blood samples. Loss of glucose under these conditions can be prevented by using Fluoride tubes, since fluoride inhibits glycolysis. However, these should only be used when blood will be transported from one hospital laboratory to another for glucose measurement. Red-top serum separator tubes also preserve glucose in samples after being centrifuged isolating the serum from cells.

Particular care should be given to drawing blood samples from the arm opposite the one in which an intravenous line is inserted, to prevent contamination of the sample with intravenous fluids.

Arterial, capillary and venous blood has comparable glucose levels in a fasting individual. After meals venous levels are somewhat lower than capillary or arterial blood; a common estimate is about 10%.

3.1.3 Measurement Techniques

Two major methods that have been used to measure glucose. The first, still in use in some places, is a chemical method exploiting the nonspecific reducing property of glucose in a reaction with an indicator substance that changes color when reduced. Since other blood compounds also have reducing properties (e.g., urea, which can be abnormally high in uremic patients), this technique can produce erroneous readings in some situations (5 to 15 mg/dl has been reported). The more recent technique, using enzymes specific to glucose, are less susceptible to this kind of error. The two most common employed enzymes are glucose oxidase and hexokinase.

In either case, the chemical system is commonly contained on a test strip, to which a blood sample is applied, and which is then inserted into the meter for reading. Test strip shapes and their exact chemical composition vary between meter systems and cannot be interchanged.

3.2.1 Infrared History

The discovery of infrared radiation is ascribed to William Herschel, the astronomer, in the early 19th century. Herschel published his results in 1800 before the Royal Society of London. Herschel used a prism to refract light from the sun and detected the infrared, beyond the red part of the spectrum, through an increase in the temperature recorded on a thermometer. He was surprised at the result and called them "Calorific Rays". The term 'Infrared' did not appear until late in the 19th century. [4]

3.2.2 Introduction to IR (Infra Red).

IR Frequency Range and Spectrum Presentation Infrared radiation spans a section of the electromagnetic spectrum having wave numbers from roughly 13,000 to 10 cm-1, or wavelengths from 0.78 to 1000 µm. It is bound by the red end of the visible region at high frequencies and the microwave region at low frequencies.
IR absorption positions are generally presented as either wave numbers (v) or wavelengths.

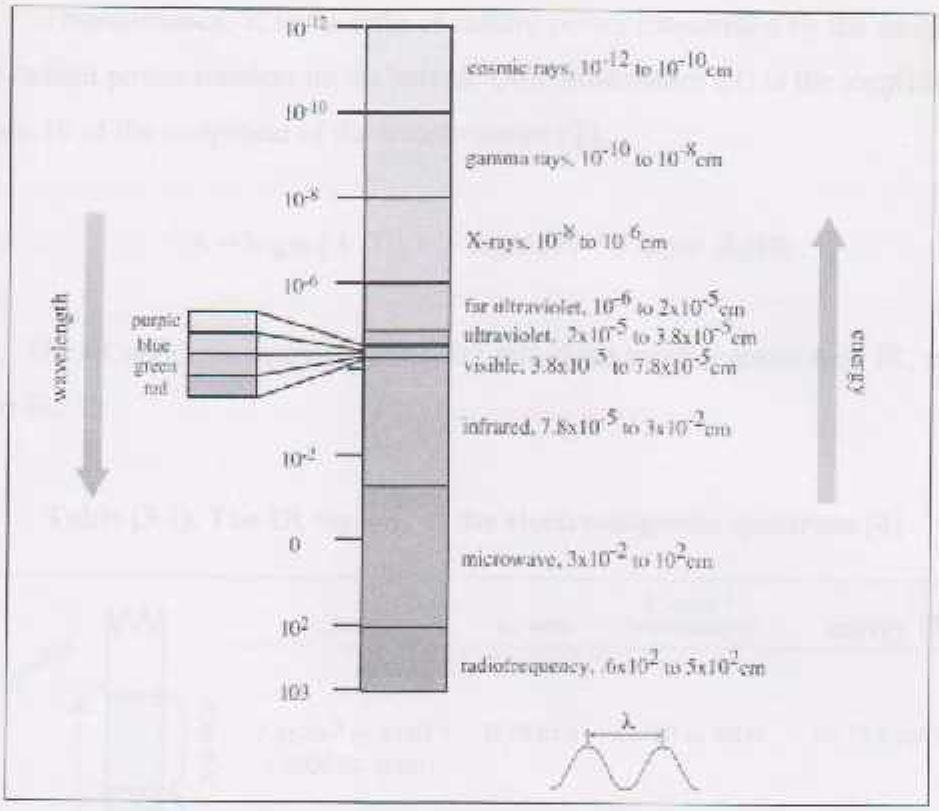


Figure (3.1).The electromagnetic spectrum.

Wave number defines the number of waves per unit length. Thus, wave numbers are directly proportional to frequency, as well as the energy of the IR absorption. The wave number unit (cm-1, reciprocal centimeter) is more commonly used in modern IR instruments that are linear in the cm-1 scale. In the contrast, wavelengths are inversely proportional to frequencies and their associated energy. At present, the recommended unit of wavelength is µm (micrometers), but µ (micron) is used in some older literature. Wave numbers and wavelengths can be inter converted using the following equation:

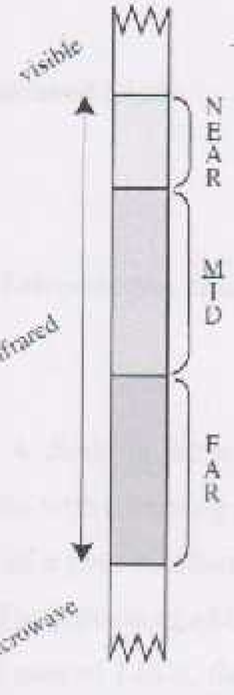
$$V \text{ (in cm}^{-1}) = \mathbf{10000} / \lambda \text{ in } \mu m \quad (3.1)$$

Transmittance, *T*, is the ratio of radiant power transmitted by the sample (*I*) to the radiant power incident on the sample (*I0*). Absorbance (*A*) is the logarithm to the base 10 of the reciprocal of the transmittance (*T*).

$$A = \log_{10}(1/T) = -\log_{10}(T) = -\log_{10}(I/I_0) \qquad (3.2)$$

The IR region is commonly divided into three smaller areas: near IR, mid IR, and far IR.

Table (3.1). The IR regions of the electromagnetic spectrum.[4]



Region	λ, cm	λ, μm	λ, cm⁻¹ (wavenumber)	energy (E)
NEAR	7.8×10^{-5} to 3×10^{-4} (.000078-.0003)	0.78 to 3	12820 to 4000	10-37 Kcal/mole
MID	3×10^{-4} to 3×10^{-3} (.0003-.003)	3 to 30	4000 to 400	1-10 Kcal/mole
FAR	3×10^{-3} to 3×10^{-2} (.003-.03)	30-300	400 to 33	0.1-1 Kcal/mole

recall:
cm = 10^{-2} m
mm = 10^{-3} m
μm = 10^{-6} m

3.2.3 Theory of Infrared Absorption

At temperatures above absolute zero, all the atoms in molecules are in continuous vibration with respect to each other. When the frequency of a specific vibration is equal to the frequency of the IR radiation directed on the molecule, the molecule absorbs the radiation. Each atom has three degrees of freedom, corresponding to motions along any of the three Cartesian
Coordinate axes (x, y, z).

3.3 Infrared Diode

3.3.1 Introduction of infrared diode.

A diode is the simplest sort of semiconductor device. A semiconductor is a material with a varying ability to conduct electrical current. Most semiconductors are made of a poor conductor that has had impurities (atoms of another material) added to it. The process of adding impurities is called doping.
In the case of LEDs, the conductor material is typically aluminum-gallium-arsenide (AlGaAs). In pure aluminum-gallium-arsenide, all of the atoms bond perfectly to their neighbors, leaving no free electrons (negatively-charged particles) to conduct electric current. In doped material, additional atoms change the balance, either adding free electrons or creating holes where electrons can go. Either of these additions makes the material more conductive.

A semiconductor with extra electrons is called N-type material, since it has extra negatively-charged particles. In N-type material, free electrons move from a negatively-charged area to a positively charged area. A semiconductor with extra holes is called P-type material, since it effectively has extra positively-charged particles. Electrons can jump from hole to hole, moving from a negatively-charged area to a positively-charged area. As a result, the holes themselves appear to move from a positively-charged area to a negatively-charged area. A diode comprises a section of N-type material bonded to a section of P-type material, with electrodes on each end. This arrangement conducts electricity in only one direction.

When no voltage is applied to the diode, electrons from the N-type material fill holes from the P-type material along the junction between the layers, forming a depletion zone. In a depletion zone, the semiconductor material is returned to its original insulating state, all of the holes are filled, so there are no free electrons or empty spaces for electrons, and charge can't flow.

To get rid of the depletion zone, electrons must move from the N-type area to the P-type area and holes moving in the reverse direction. To do this, you connect the N-type side of the diode to the negative end of a circuit and the P-type side to the positive end. The free electrons in the N-type material are repelled by the negative electrode and drawn to the positive electrode. The holes in the P-type material move the other way. When the voltage difference between the electrodes is high enough, the electrons in the depletion zone are boosted out of their holes and begin moving freely again. The depletion zone disappears, and charge moves across the diode.

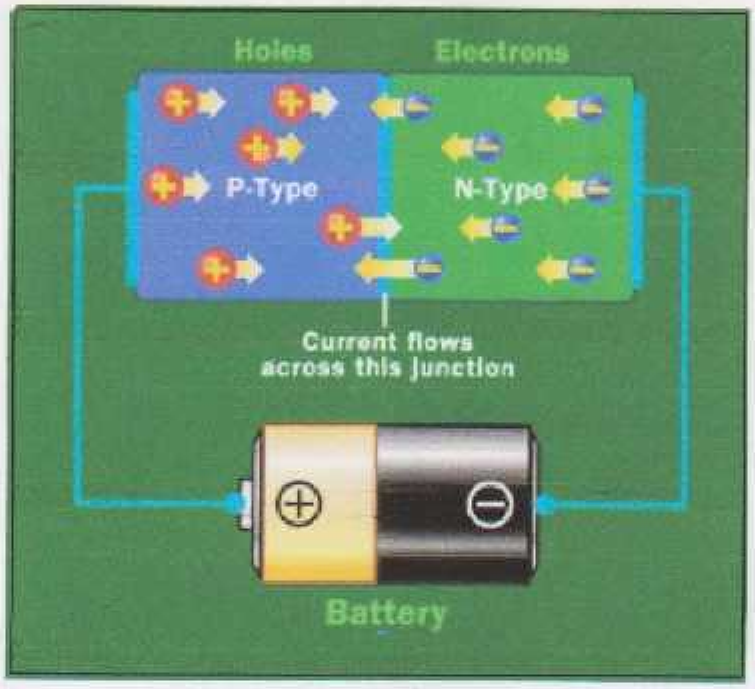


Figure (3.2).When the negative end of the circuit is hooked up to the N-type layer and the positive end is hooked up to P-type layer, electrons and holes start moving and the depletion zone disappears.

If the P-type side connected to the negative end of the circuit and the N-type side connected to the positive end, current will not flow. The negative electrons in the N-type material are attracted to the positive electrode. The positive holes in the P-type material are attracted to the negative electrode. No current flows across the junction because the holes and the electrons are each moving in the wrong direction. The depletion zone increases.

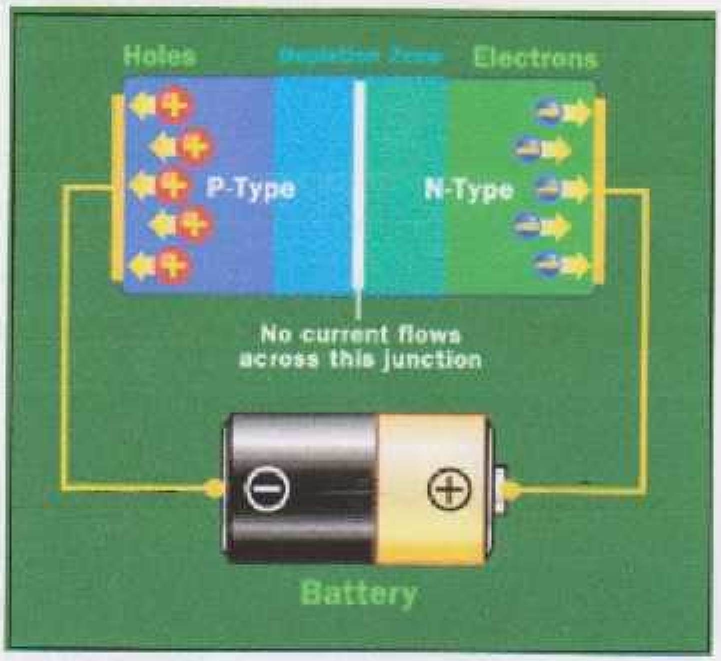


Figure (3.3).When the positive end of the circuit is hooked up to the N-type layer and the negative end is hooked up to the P-type layer, free electrons collect on one end of the diode and holes collect on the other. The depletion zone gets bigger.

3.3.2 How Can Diode Produce Light?

Light is a form of energy that can be released by an atom. It is made up of many small particle-like packets that have energy and momentum but no mass. These particles, called photons, are the most basic units of light.

Photons are released as a result of moving electrons. In an atom, electrons move in orbital around the nucleus. Electrons in different orbital have different amounts of energy. Generally speaking, electrons with greater energy move in orbital farther away from the nucleus.

For an electron to jump from a lower orbital to a higher orbital, something has to boost its energy level. Conversely, an electron releases energy when it drops from a higher orbital to a lower one. This energy is released in the form of a photon. A greater energy drop releases a higher-energy photon, which is characterized by a higher frequency.

As we saw in the last section, free electrons moving across a diode can fall into empty holes from the P-type layer. This involves a drop from the conduction band to a lower orbital, so the electrons release energy in the form of photons. This happens in any diode, photons can be seen when the diode is composed of certain material. The atoms in a standard silicon diode, for example, are arranged in such a way that the electron drops a relatively short distance. As a result, the photon's frequency is so low that it is invisible to the human eye, because it is in the infrared portion of the light spectrum.

3.4 Project Components.

In this section, we provide an 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 (lab view program)

3.4.1 DC Power Source.

This project needs to convert the AC voltage to suitable DC voltage which then applied to the light source.

The circuit of power supply contains:

1. Transformer: is based on two principles: first, that an electric current can produce a magnetic field. 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.

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 out put, it is very inefficient if used for power transfer. Half-wave rectification can be achieved with a single diode.

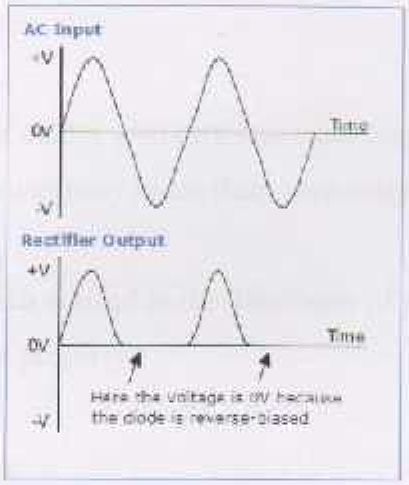


Figure (3.4). Half wave rectifier signal.

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

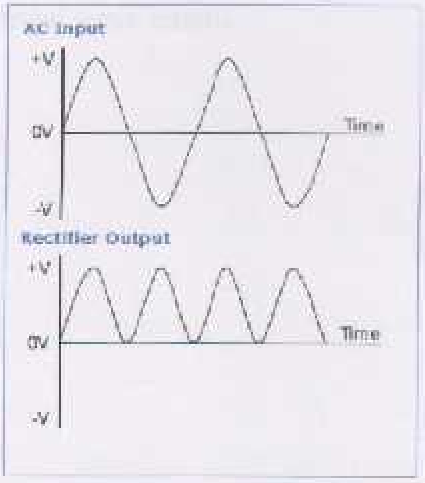


Figure (3.5). Full wave rectifier signal.

3.Regulator:

Designed to automatically maintain a constant voltage level.

3.4.2 Light components.

a. Diodes.

In this project we use four diodes with different wave lengths, which are (940,650,890) nm, there's company made them especially for diabetes measurements.

Currents of the diodes which noticed in the datasheets of each must be carefully chosen to make them work properly.

b. Detectors (photodiode).

A light sensor (photo detector) that allows current to flow in one direction from one side to the other when it absorbs light (photons).

We prefer to use photodiodes with these characteristics:

-each of them absorbs a special wave length.

-~~very high~~ sensitivity

-good stability

-excellent linearity

-low noise

-long lifetime

-low cost

3.4.3 CB 68lp Connecter with parallel port.

To complete this design there is need of a CB68lp connecter to interface between DAQ & the output of photodiode.

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

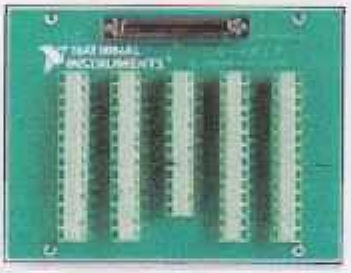


Figure (3.6). CB-681p.

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.

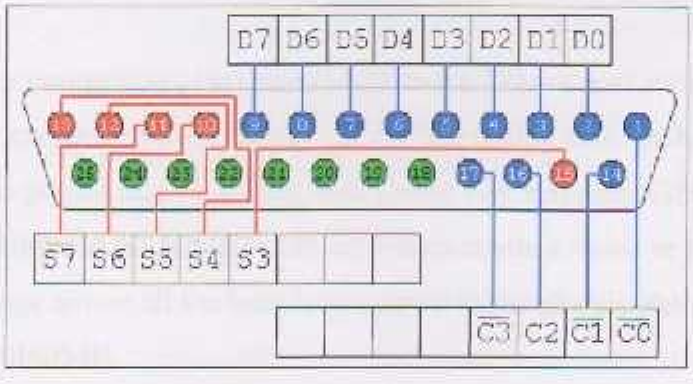


Figure (3.7).Parallel port pins.

3.4.4 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.

Figure (3.8). DAQ (NI 6034E)

As any electrical chip DAQ has cautions for using it. There are:

- The input signal mustn't exceed the highest voltage with which NI6034E can come in contact. (Mustn't exceed 10 v).
- 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 NI6034E device which create a shock or fire hazard, or can damage any or all the boards connected to the chassis, the host computer, and the NI6034E.

3.4.5 PC (Lab View Program).

Lab VIEW (short for Laboratory Virtual Instrumentation Engineering Workbench)

In this project we will deal with a Lab View program to complete the analysis of the signals to reach our aim to measure the Glucose Concentration of human blood.

Using Lab View return to these reasons:

- Lab VIEW is a graphical programming system that is designed for data acquisition, data analysis, and instrument control

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

- Since Lab VIEW is graphical and based on a windows type system it is often much easier to get started than a typical language.

- Lab VIEW 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 controls and indicators are connected to other operators and program structures. Each program structure has a different symbol and each data type has a different color.

Chapter four

Design Concept

4.1 Biosignal Process

Before we start discussing the main block diagram we will discuss the main steps of biosignal process.

Block diagram for the biosignal process is shown in figure (4.1).

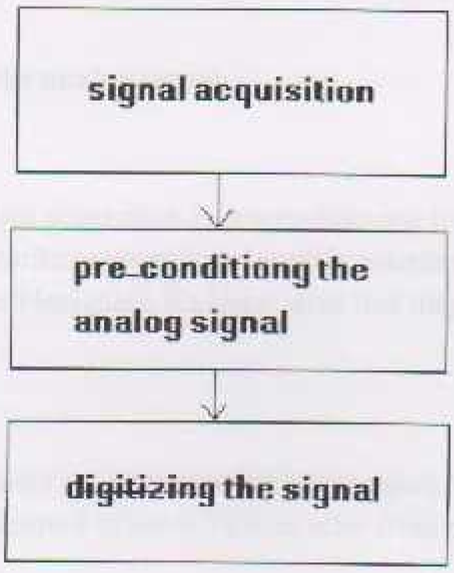


Figure (4.1). Steps of biosignal process.

4.1.1 Signal Acquisition

The first stage of bio-signal process is signal acquisition. Sensors are special devices that are use to provide an interface between signal from biological systems and the instrument detecting them.

Input from sensor: Input from sensor can either come from transducer or electrodes. Electrodes are conductors that provide a current path between the body's potentials and the signal process unit.

Transducers can be used to sensing element to detect physical or chemical quantities, the transducer convert the measured into electrical quantity.

4.1.2 Pre-Conditioning the analog signal.

The next step of data acquisition is preconditioning the analog signal. Due to the fact that biosignals are often very minute, contain interference, and are sometimes hiding by other biosignals, it's imperative that they be amplified and filtered.

Operational amplifiers are used to amplify the signal, while electronic filters are used to minimize the amount of noise. Noises arise from both within the system and from outside sources.

If the noise is at a frequency different from that of the signal, a low pass, high pass or band pass can be used to filter the frequencies.

Low pass filters only passes frequency below a certain pre-determined cutoff frequency while attenuated the high frequencies that above the cutoff frequency.

High pass filters only passes frequency high a certain pre-determined cutoff frequency while attenuated the low frequencies that below the cutoff frequency.

4.1.3 Digitizing the signal

The last step involved in data acquisition is digitizing the signal so that a computer can process it. Analog to Digital Converter (ADC) can be used to convert continuous analog signals to digital signals .High level software such as C++, Pascal, Lap View, and Matlap that are used to control the data acquisition port.

4.2 How system works?

Figure (4.2) is a block diagram of the measurement system. It consists of the optical sensor, sensor electronic, and the signal processing. The optical sensor consists of light source optical detector pre amplifier.Four infrared diodes are used as a light source. The peak wavelength of IR diodes are closed to 650, 880 and 940 nm.

The sources (LED_1 , LED_2 , LED_3 , LED_4) and the detector (PD) are situated in opposite sides, in close contact with the surface of the ear lobe, according to the transmission configuration. Then the signals will be entered to the DAQ in order to be filtered, amplified and processed.

By studying many of United States patents and some other blood glucose meter devices, we conclude that we can measure blood glucose concentration non-invasively using three wavelengths which are: (650,940,880)nm. We use the wavelength (940) nm two times in this project, because many patents show that higher absorption of blood glucose satisfies at this wavelength.

Many of blood samples of people will be taken, in order to measure blood glucose concentration invasively (in hospital laboratory). This result will be compared with the quantity of light absorbed by blood glucose that measured at the ear lobe, in order to find a special algorithm between the blood glucose concentration measured invasively, and the quantity of light absorbed.

The Main Block Diagram :

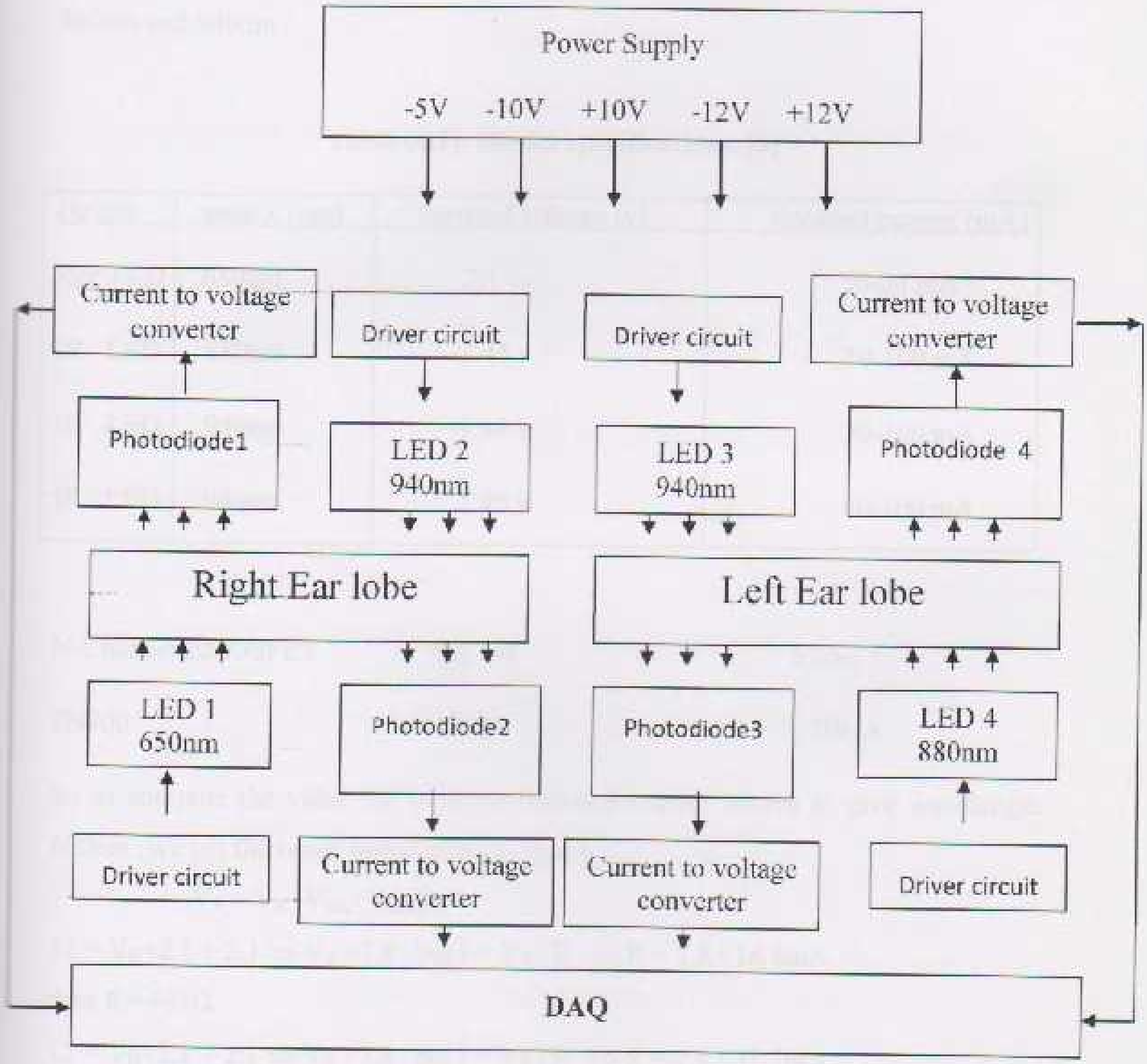


Figure (4.2) Main Block Diagram.

4.3 Detailed description of transmitting and receiving circuits.

4.3.1 Constant current source for driving LED

The circuit of figure (4.3) in which an op-amp is combined with FET that provides an output current fixed for the input current to diodes to give 650nm, 880nm and 940nm .

Table (4.1). Diodes specifications. [6]

Device	peak λ (nm)	Forward voltage [v]	Forward current (mA)
Red LED	650nm	2.1 v	50-20 mA
IR LED	880nm	1.45 v	50-100 mA
IR LED	940nm	1.45 v	50-100 mA
IR LED	940nm	1.45 v	50-100 mA

N-Channel EMOSFET	V_{SD} [v]	$I_{D(ON)}$
2N700	2.1 V	70mA

So to compute the value for R in the constant current source to give wavelength 650nm .We get the range from (16.8-31.7) mA

$$V_S = V_R+V_{DS}+V_{LED}$$

$12 = V_R+2.1 + 2.1 \Rightarrow V_R=7.8$, but $I = V_R \setminus R \Rightarrow R = 7.8 \setminus 16.8mA$

then R= 464Ω.

$12 = V_R+2.1 + 2.1 \Rightarrow V_R=7.8$, but $I = V_R \setminus R \Rightarrow R = 7.8 \setminus 31.7mA$

then R= 246Ω

So to compute the value for R in the constant current source to give wavelength 880nm .

We get the range from (42-77) mA

$$V_S = V_R + V_{DS} + V_{LED} \tag{4}$$

$12 = V_R + 2.1 + 1.45 \Rightarrow V_R = 8.45$, but $I = V_R \backslash R \ \Rightarrow R = 8.45 \backslash 77mA$

then R= 110Ω.

$12 = V_R + 2.1 + 1.45 \Rightarrow V_R = 8.45$, but $I = V_R \backslash R \ \Rightarrow R = 8.45 \backslash 42mA$

then R= 200Ω

So to compute the value for R in the constant current source to give wavelength 940nm .

We get the range from (42-77) mA

$$V_S = V_R + V_{DS} + V_{LED} \tag{4}$$

$12 = V_R + 2.1 + 1.45 \Rightarrow V_R = 8.45$, but $I = V_R \backslash R \ \Rightarrow R = 8.45 \backslash 77mA$

then R= 110Ω.

$12 = V_R + 2.1 + 1.45 \Rightarrow V_R = 8.45$, but $I = V_R \backslash R \ \Rightarrow R = 8.45 \backslash 42mA$

then R= 200Ω

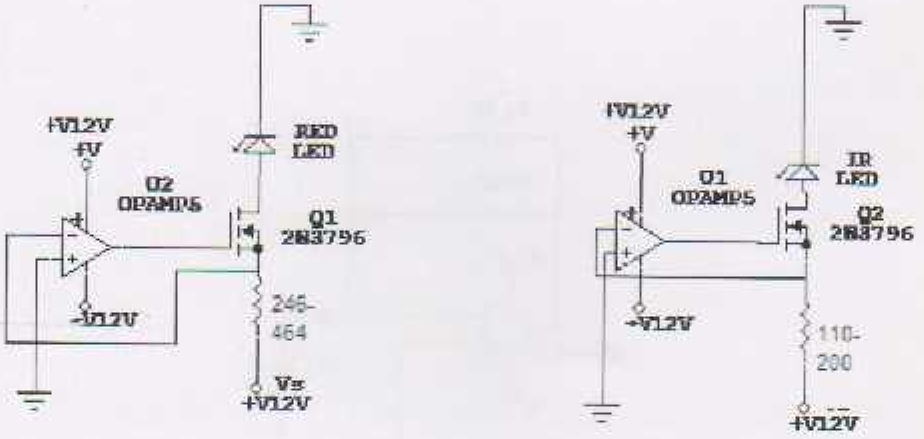


Figure (4.3) Constant current LED Driving

4.3.2 Receiver Circuit.

The simplest solid state optical detector is the photodiode. Photodiode detectors normally operate with reverse bias applied to the pn junction (photoconductive mode). When light falls on the junction region of the photodiode, an electron hole pair is created , under the influence of the junction (or built in) field , the hole is swept towards the p-material and the electron towards the n-material. The resulting light current is seen as a large increase in the reverse current. For the purposes of signal amplification, the photocurrent must be transformed into a voltage with moderate output impedance, this is achieved with the circuit shown in Figure 4.3.4, the op-amp being configured as a current to voltage converter. Because of the high junction resistance of the reverse biased photodiode, the op-amp should be an FET type with very high input impedance. Since the negative input of the op-amp acts like a virtual earth, the output voltage of the circuit is **Vo = *-I Z*.** A large feedback resistance used, 220KΩ. When we choose the photodiode we are limit the wavelength response.

This circuit is worked as a low pas- filter, with **Fc=1/(2*π*R*C)**

Fe= 1/(2*π*220K*33PF)

→Fc = 22 KHZ

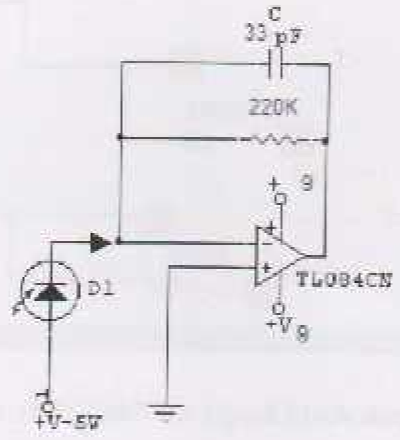


Figure (4.4). Photodiode current to voltage converter circuit.

Chapter Five

Software

5.1 introduction

In our project as mentioned before, we will use a LabView program, to process the output signal from DAQ.

Block diagram applied by LabView program:

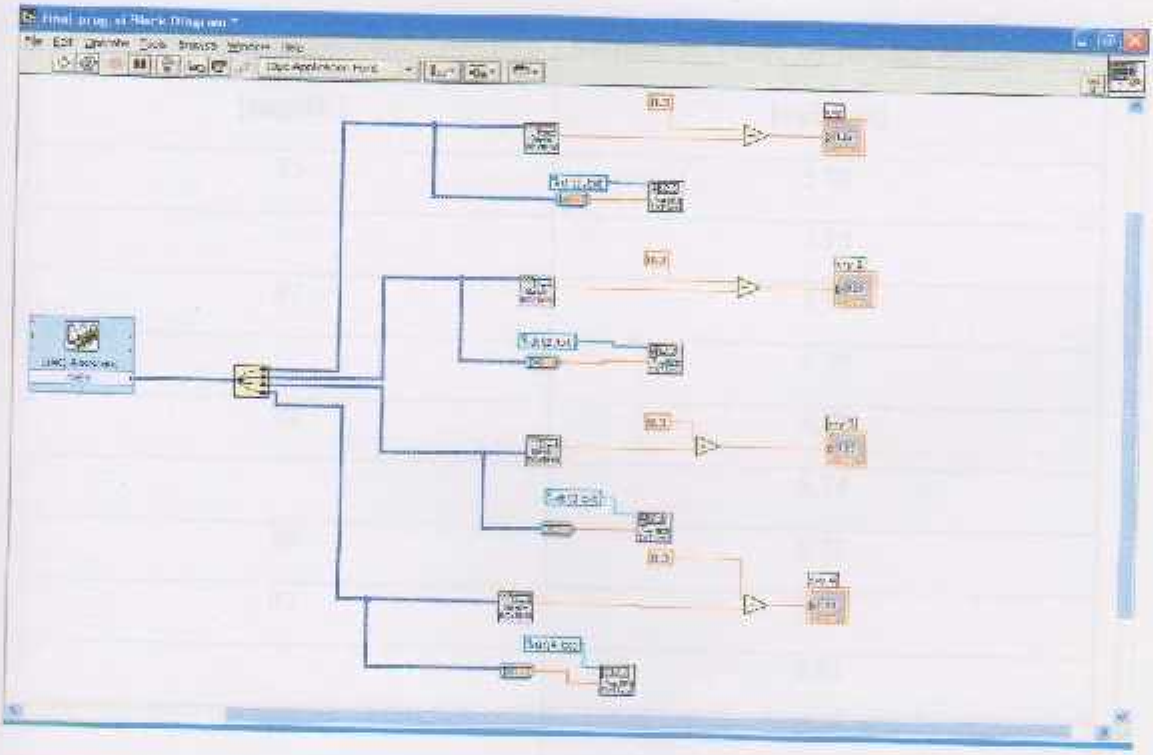


Figure. (5.1) LabView signal block diagram

From this block diagram we take RMS value for each receiver circuit, these values are compared with the exact value which was taken by the invasive glucose meter, in order to find the relation between them.

After studying these results we conclude that the 650 nm photodiode gives more clear relationship with the real values than other photodiodes, so we will depend on this photodiode signals for measuring blood glucose concentration.

5.2 Data and data analysis:

Table (5.1) Measured values of 650nm wavelength

Exact value of glucose concentration [mg/dL]	Measured value by 650nm photodiode [voltage]
85	5.88
	5.95
87	5.97
	5.79
88	5.64
	5.74
89	6.71
92	5.59
	5.61
	6.41
93	6.74
	6.73
94	6.32

	6.45
96	5.83
	5.77
	5.89
97	6.04
	6.00
99	6.20
	6.20
102	5.80
	6.01
106	5.39
	5.47
110	5.12
	5.07
111	5.18
	5.17
114	6.05
	6.06
122	5.15
138	5.02
188	5.01
200	4.65
215	3.68
250	3.54

5.3 Main block diagram of processed signal:

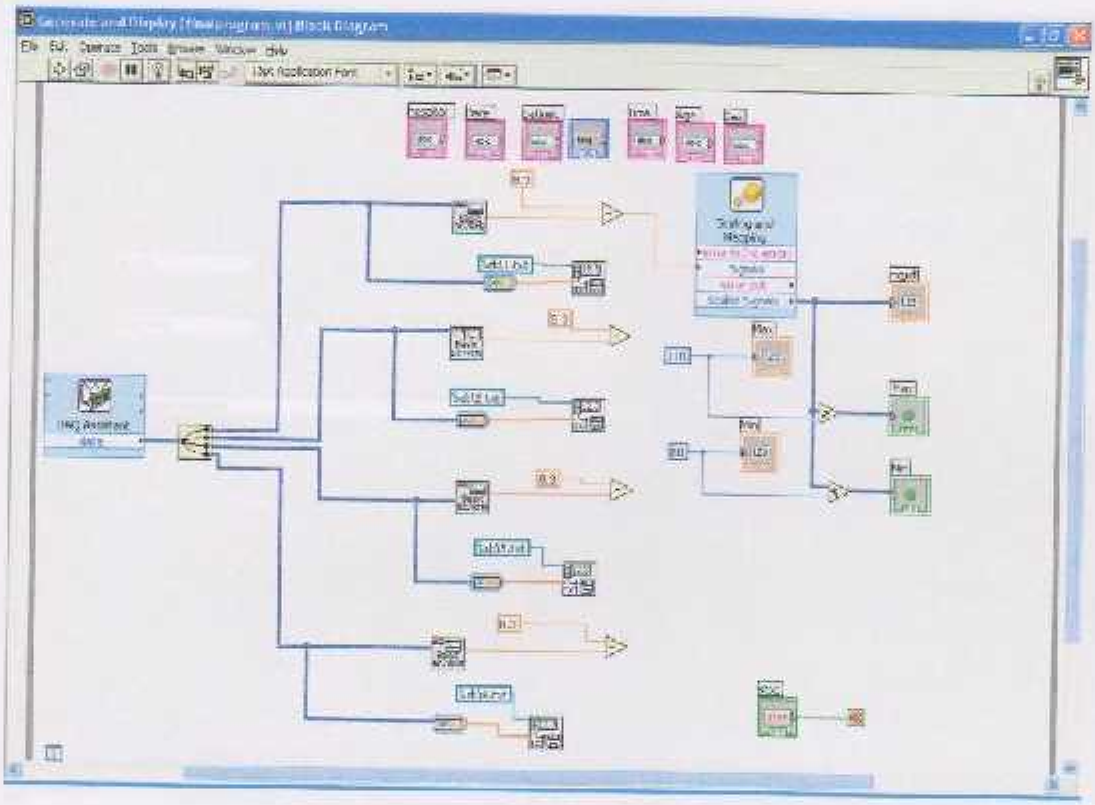


Figure .(5.2)Main block diagram of processed signal

Here we enter the 650nm photodiode signal to scaling and mapping block, to scale the signal and compute the result by comparing it with the stored data in the scaling and mapping block.

Front panel of glucose meter device

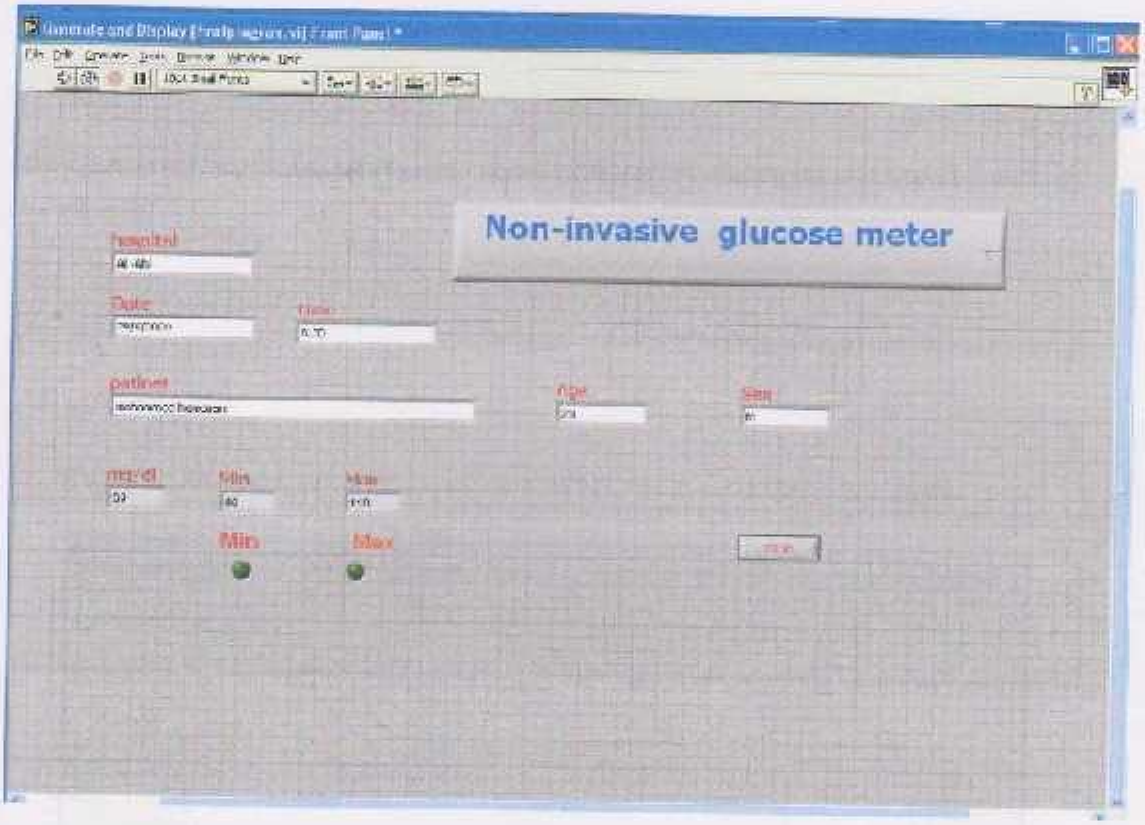


Figure .(5.3)Front panel of glucose meter device

5.4 Mathlab program

The relation between real value and the RMS value of 650 nm photodiode using MATLAB program :

```
>>x(1)=5.92;x(2)=5.85;x(3)=5.69;x(4)=5.6;x(5)=6.73;x(6)=6.3;x(7)=5.8;x(8)=6.2;
x(9)=5.55;x(10)=5.42;x(11)=5.1;x(12)=5.17;x(13)=5.1;x(14)=5.02;x(15)=3.67;
x(16)=3.54;
```

```
>>f(1)=85;f(2)=87;f(3)=88;f(4)=92;f(5)=93;f(6)=94;f(7)=96;f(8)=97;f(9)=102;
f(10)=106;f(11)=110;f(12)=111;f(13)=117;f(14)=138;f(15)=215;f(16)=250;
>>plot(x,f)
>>cftool
```

Correction curve between glucose concentration (exact) and signals come from the circuit:

Relationship given by:

f(x) = 2.145 *x^4 +(-44.34)*x^3 + 359.5 *x^2 + (-1390) *x + 2289

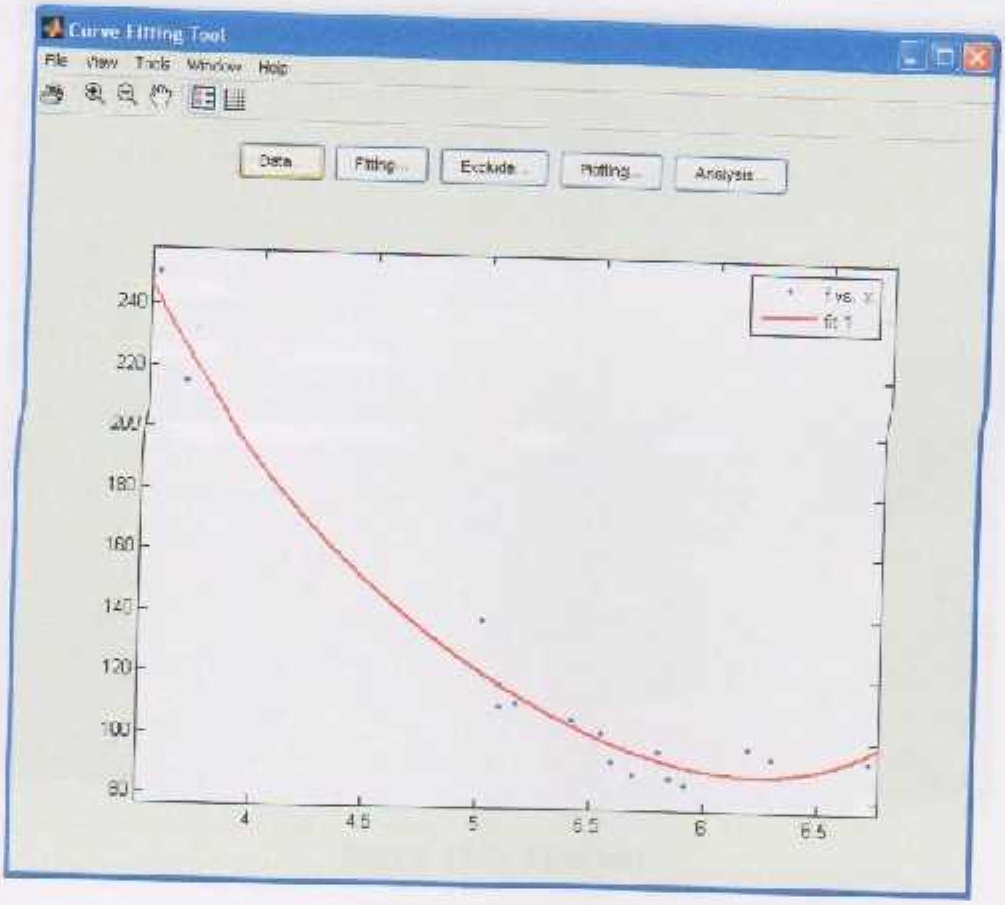


Figure .(5.4)Correction curve between glucose concentration and signals

5.5 System Implementation and Testing.

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

Testing :

In this chapter we are going to explain how the result of glucose concentration calculated.

First sample; hamzeh sawaer sample; as shown in the front panel.

At Laboratory test the glucose value was : 105 mg/dL

At our design the glucose value was : 85 mg/dL.

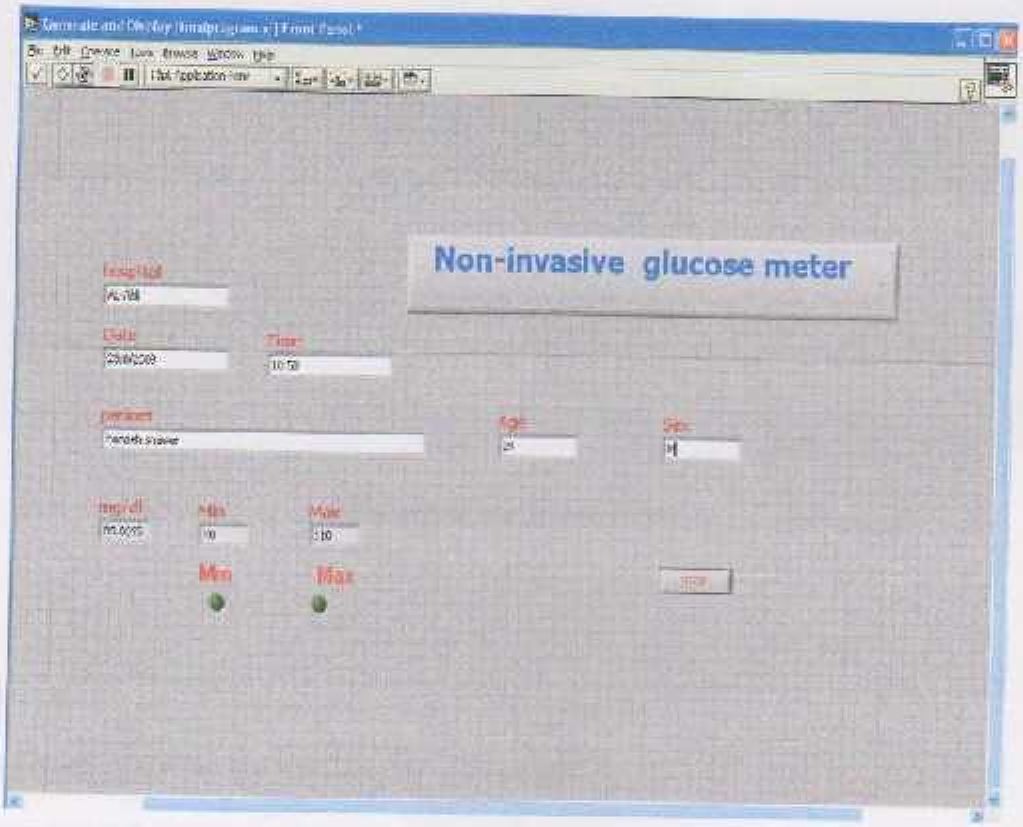


Figure .(5.5) First test

Second sample; salah farhat sample, as shown in the front panel.

At Laboratory test the glucose value was : 110 mg/dL

At our design the glucose value was : 97 mg/dL

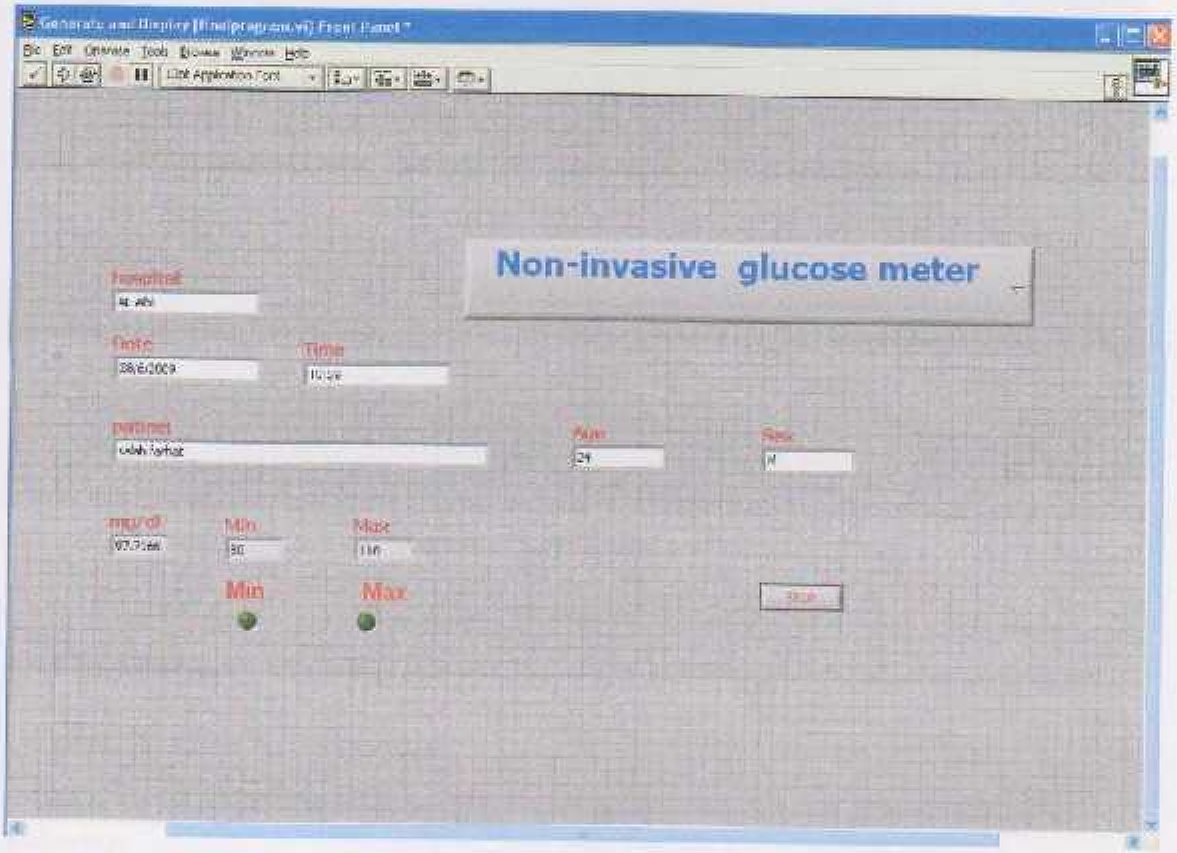


Figure .(5.6) Second test

Third sample; salah farhat sample.as shown in the front panel.

At Laboratory test the glucose value was : 125 mg/dL

At our design the glucose value was : 101 mg/dL

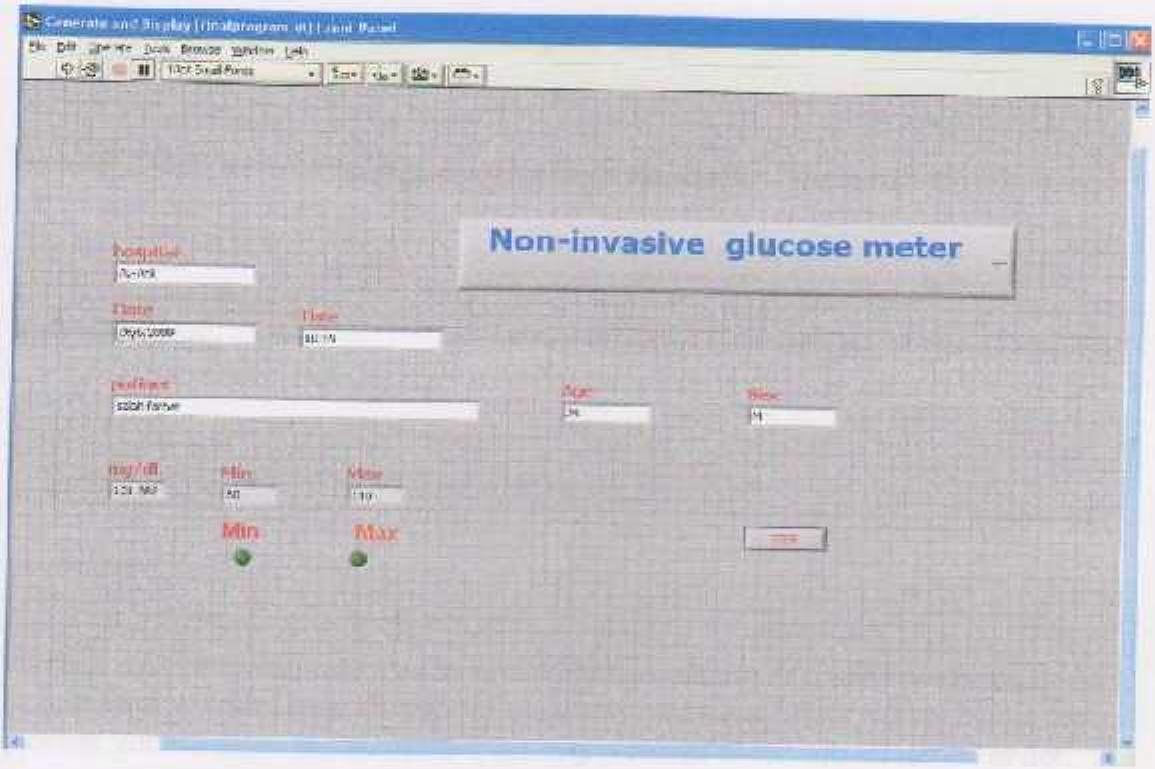


Figure .(5.6) Third test

Error calculations :

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

The error = (real value – measured value) / true value * 100%

Error (1): [(105-85)/105] * 100% = 19%

Error (2): [(110-97)/110] * 100% = 12%

Error (3): [(125-101)/125] * 100% =19%

Average error:

(19% + 12% + 19%) / 3 = 17%

Chapter six

Conclusion and features

6.1 Conclusion:

1. Blood glucose concentration can be measured Non-Invasively depending on an optical absorption method, using transmitter diode with wave length 650nm and photodiode.

2. Lab View software is an excellent program to design a software system which can process, control ,filter and compare if the output results in the normal results or not.

3. MATLAP program can be used for determining the relation (function) between variable values.

4.Non-Invasive blood glucose meter with a good accuracy, is better than Invasive glucose meters with more accuracy. Because; no open wounds, and low costs in Non-Invasive glucose meter.

6.2 Features:

- More samples should be take, in order to give more accuracy.
- The costs can be reduced by applying the function which we included in this project using microprocessor and display.
- The number of sensors which we used can be reduced by using one sensor only (650 nm).
- Power supply can be replaced by 12V battery, this make the device portable.

References

[1] The Pursuit of Noninvasive Glucose: "Hunting the Deceitful Turkey"

By John L. Smith

[2] United State patent number 5,910,109 "Non-invasive glucose measuring device and method for measuring blood".

[3] Pulsed photo acoustic technique and glucose determination in human blood and tissue by Zuomin Zhao

Academic Dissertation to be presented with the assent of

the Faculty of Technology, University of Oulu,

[4] Handbook of Instrumental Techniques for Analytical Chemistry

By Frank A. Settle

Published by Prentice Hall PTR, 1997.

[5] www.wikipedia.org/wiki/diabetes.

[6] diode data sheet

Appendixes

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

Appendix: A

Definitions.

Definitions

Absorance	The ability of a medium to absorb radiation depending on temperature and wavelength.
Amplification	Process of increasing the strength of a signal, current, voltage or power.
Blood	Blood is highly specialized circulating tissue consisting of several types of cells suspended in a fluid medium known as plasma.
Concentration	Is the measure of how much of a given substance there is mixed with another substance
DAQ	Collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to the computer for processing.
Detectors	Any device or instrument used to sense the the presence of a signal, detect the presence of radiation or particles, or convert a signal from one form to another.
Glucose	Glucose is an example of a carbohydrate which chemical formula is $C_6H_{12}O_6$. Human blood glucose levels normally remain within (80-110) mg/dl
Incident light	The light that emanates directly from a light source.
Photodiode	Semiconductor that converts light to an electrical

	signal, used in fiber optic receivers
White blood cells	Cells that help the body fight infections and diseases.

Data

Exact	880nm	940\8 nm	650 nm	940\6 nm
85	5.48	5.74	5.88	4.83
	5.27	5.71	5.95	4.80
87	6.41	5.55	5.97	6.11
	6.44	5.60	5.79	6.13
88	5.29	4.13	5.64	4.85
	5.04	4.05	5.74	4.62
89	6.12	5.85	3.36	5.80
89	4.22	6.45	6.71	6.55
92	3.96	4.02	5.59	3.45
	3.99	4.30	5.61	3.46
	5.89	6.02	6.67	7.18
	5.57	5.80	6.41	7.03
	5.85	6.17	6.68	7.15
93	6.30	5.96	6.74	5.86
	6.09	5.84	6.73	5.72
94	6.66	6.84	6.32	6.36
	6.62	6.78	6.45	6.32
96	5.09	5.32	5.83	4.66
	5.64	4.85	5.77	5.25
	5.13	5.26	5.89	4.71
97	6.30	5.15	6.04	5.80
	6.09	5.05	6.00	5.73
99	6.08	4.98	6.20	5.74
	6.09	4.04	6.20	54.7

100	7.07	4.64		
	7.07	4.67		
102	5.01	6.11	5.27	4.58
	4.92	6.04	6.01	4.50
103	7.06	4.55		5.01
	7.05	4.46		5.12
106	6.06	6.08	5.39	5.72
	6.13	6.25	5.47	5.83
110	5.68	4.85	5.12	5.31
	5.73	5.19	5.07	5.35
111	6.60	6.62	5.18	6.03
	6.57	6.56	5.17	6.26
114	4.48	3.52	6.05	4.15
	4.59	3.44	6.06	4.13
121	5.24	4.87	6.02	4.85
	5.25	4.74	6.15	4.48
122	6.80	6.35	4.02	6.53
131	7.20	5.25		
	7.19	5.15		
132	6.89	4.94		
	6.87	4.81		
138	5.58	6.12	5.02	5.20
171	6.88	5.94		6.15
188	4.76	4.61	5.01	4.19
200	4.63	4.57	4.65	4.17
215	4.60	4.53	3.68	4.15
250	4.63	4.55	3.54	4.15

Appendix: B

Datasheets of Project Components.

Low-Cost E Series Multifunction DAQ – 12 or 16-Bit, 200 kS/s, 16 Analog Inputs

NI E Series – Low-Cost

- 16 analog inputs at up to 200 kS/s, 12 or 16-bit resolution
- Up to 2 analog outputs at 10 kS/s, 12 or 16-bit resolution
- 8 digital I/O lines (TTL/CMOS); two 24-bit counter/timers
- Digital triggering
- 4 analog input signal ranges
- NI-DAQ driver that simplifies configuration and measurements

Families

- NI 6036E
- NI 6034E
- NI 6025E
- NI 6024E
- NI 6023E

Operating Systems

- Windows 2000/NT/XP
- Real-time performance with LabVIEW
- Others such as Linux® and Mac OS X

Recommended Software

- LabVIEW
- LabWindows/CVI
- Measurement Studio
- VI Logger

Other Compatible Software

- Visual Basic, C/C++, and C#

Driver Software (included)

- NI-DAQ 7

Family	Bus	Analog Inputs	Input Resolution	Max Sampling Rate	Input Range	Analog Outputs	Output Resolution	Output Rate	Output Range	Digital I/O	Counter/Timers	Triggers
NI 6036E	PCI, PCMCIA	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	2	16 bits	10 kS/s[1]	±10 V	8	2, 24-bit	Digital
NI 6034E	PCI	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	0	–			8	2, 24-bit	Digital
NI 6025E	PCI, PXI	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	2	12 bits	10 kS/s	±10 V	8	2, 24-bit	Digital
NI 6024E	PCI, PCMCIA	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	2	12 bits	10 kS/s	±10 V	8	2, 24-bit	Digital
NI 6023E	PCI	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	0	–			8	2, 24-bit	Digital

[1] 10 kS/s typical when using the single DMA channel for analog output; 1 kS/s maximum when using the single DMA channel for [illegible] analog input or counter/timer operations. [illegible] PCMCIA DAQCard devices [illegible]

Table 1. Low-Cost E Series Model Guide

Overview and Applications

National Instruments low-cost E Series multifunction data acquisition devices provide full functionality at a price to meet the needs of the budget-conscious user. They are ideal for applications ranging from continuous high-speed data logging to control applications to high-voltage signal or sensor measurements when used with NI signal conditioning. Synchronize the operations of multiple devices using the RTSI bus or PXI trigger bus to easily integrate other hardware such as motion control and machine vision to create an entire measurement and control system.

Highly Accurate Hardware Design

NI low-cost E Series DAQ devices include the following features and technologies:

Temperature Drift Protection Circuitry – Designed with components that minimize the effect of temperature changes on measurements to less than 0.0010% of reading/°C.

Resolution-Improvement Technologies – Carefully designed noise floor maximizes the resolution.

Onboard Self-Calibration – Precise voltage reference included for calibration and measurement accuracy. Self-calibration is completely software controlled, with no potentiometers to adjust.

NI DAQ-STC – Timing and control ASIC designed to provide more flexibility, lower power consumption, and a higher immunity to noise and jitter than off-the-shelf counter/timer chips.

NI MITE – ASIC designed to optimize data transfer for multiple simultaneous operations using bus mastering with one DMA channel, interrupts, or programmed I/O.

NI PGIA – Measurement and instrument class amplifier that guarantees settling times at all gains. Typical commercial off-the-shelf amplifier components do not meet the settling time requirements for high-gain measurement applications.

PFI Lines – Eight programmable function input (PFI) lines that you can use for software-controlled routing of interboard and intraboard digital and timing signals.

RTSI or PXI Trigger Bus – Bus used to share timing and control signals between two or more PCI or PXI devices to synchronize operations.

RSE Mode – In addition to differential and nonreferenced single-ended modes, NI low-cost E Series devices offer the referenced single-ended (RSE) mode for use with floating-signal sources in applications with channel counts higher than eight.

Onboard Temperature Sensor – Included for monitoring the operating temperature of the device to ensure that it is operating within the specified range.

NATIONAL INSTRUMENTS™

Low-Cost E Series Multifunction DAQ – 12 or 16-Bit, 200 kS/s, 16 Analog Inputs

Models		NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	NI 6034E, NI 6035E	NI 6023E, NI 6024E, NI 6025E	PCI-6013, PCI-6014
		Full-Featured E Series				Low-Cost E Series		Basic
Measurement Sensitivity[1] (mV)		0.0023	0.0025	0.006	0.008	0.0036	0.008	0.004
Nominal Range (V)								
Positive FS	Negative FS	Absolute Accuracy (mV)						
10	-10	1.147	4.747	14.369	15.373	7.560	16.530	8.984
5	-5	2.077	1.975	5.163	5.687	1.790	5.270	2.003
2.5	-2.5		1.090	3.605	3.890			
2	-2	0.576	—	—		—	—	—
1	-1	0.422	0.475	1.452	1.556			
0.5	-0.5	0.215	0.249	0.735	0.769	0.285	0.940	0.471
0.25	-0.25		0.127	0.379	0.405			
0.2	-0.2	0.100	—	—		—	—	—
0.1	-0.1	0.087	0.064	0.163	0.176			
0.05	-0.05		0.045	0.081	0.100	0.0611	0.114	[illegible]
10	0	6.896	1.222	6.755	7.283	—	—	—
5	0	1.960	2.118	5.321	4.645			
2	0	0.602	0.850	2.162	2.271			
1	0	0.405	1.478	1.092	1.146			
0.5	0	0.707	0.252	0.550	0.562	—	—	—
0.2	0	0.098	0.111	0.235	0.247	—	—	—
0.1	0	0.058	0.095	0.127	0.136			

Note: Accuracies are valid for measurements following an internal calibration. [illegible] The Absolute Accuracy at Full Scale [illegible] averaging of data.
[1] Smallest detectable voltage change in the input signal at the smallest input range.

Table 2. E Series Analog Input Absolute Accuracy Specifications

Models		NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	NI 6034E, NI 6035E	NI 6023E, NI 6024E, NI 6025E	PCI-6013, PCI-6014
		Full-Featured E Series				Low-Cost E Series		Basic
Nominal Range (V)								
Positive FS	Negative FS	Absolute Accuracy (mV)						
10	-10	1.430	1.435	8.377	8.127	2.???	8.127	[illegible]
10	0	1.270	1.126	5.685	5.685	—	—	—

Table 2. E Series Analog Output Absolute Accuracy Specifications

High-Performance, Easy-to-Use Driver Software

NI-DAQ is the robust driver software that makes it easy to access the functionality of your data acquisition hardware, whether you are a beginning or advanced user. Helpful features include:

Automatic Code Generation – DAQ Assistant is an interactive guide that steps you through configuring, testing, and programming measurement tasks and generates the necessary code automatically for NI LabVIEW, LabWindows/CVI, or Measurement Studio.

Cleaner Code Development – Basic and advanced software functions have been combined into one easy-to-use yet powerful set to help you build cleaner code and move from basic to advanced applications without replacing functions.

High-Performance Driver Engine – Software-timed single-point input typically used in control loops with NI-DAQ achieves rates of up to 50 kHz. NI-DAQ also delivers maximum I/O system throughput with a multithreaded driver.

Test Panels – With NI-DAQ, you can test all of your device functionality before you begin development.

Scaled Channels – Easily scale your voltage data into the proper engineering units using the NI-DAQ Measurement Ready virtual channels by choosing from a list of common sensors and signals or creating your own custom scale.

LabVIEW Integration – All NI-DAQ functions create the waveform data type, which carries acquired data and timing information directly into more than 400 LabVIEW built-in analysis routines for display of results in engineering units on a graph.

For information on applicable hardware for NI-DAQ 7, visit ni.com/dataacquisition.

Visit ni.com/oem for quantity discount information.

Recommended Accessories

Signal conditioning is required for sensor measurements or voltage inputs greater than 10 V. National Instruments SCXI is a versatile, high-performance signal conditioning platform, intended for high-channel-count applications. NI SCC products provide portable, flexible signal conditioning options on a per-channel basis. Both signal conditioning platforms are designed to increase the performance and reliability of your DAQ system, and are up to 10 times more accurate than terminal blocks (please visit **ni.com/sigcon** for more details). Refer to the table below for more information:

Sensor/Signals (>10 V)

System Description	DAQ Device	Signal Conditioning
High performance	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCXI
Low cost, portable	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCC

Signals (<10 V)*

System Description	DAQ Device	Terminal Block	Cable
Shielded	PCI-60xxE	SCB-68	SH6868-EP
Shielded	PXI-60xxE	TB-2705	SH68-68-EP
Shielded	DAQCard-60xxE	SCB-68	SHC68-68-EP
Low-cost	PCI-6025E/PXI-6025E	Two TBX-68s	SH1006868
Low-cost	PCI-60xxE/PXI-60xxE	CB-68LP	R6868
Low-cost	DAQCard-60xxE	CB-68LP	RC68-68

*Terminal blocks do not provide signal conditioning (i.e., filtering, amplification, isolation, etc.), which may be necessary to increase the accuracy of your measurements.

Table 4. Recommended Accessories

Ordering Information

PCI

NI PCI-6036E 778465-01
NI PCI-6034E 778075-01
NI PCI-6025E 777744-01
NI PCI-6024E 777743-01
NI PCI-6023E 777742-01

PCMCIA

NI DAQCard-6036E 778561-01
NI DAQCard-6024E 778269-01

PXI

NI PXI-6025E 777796-01

Includes NI-DAQ driver software.

BUY NOW!

For complete product specifications, pricing, and accessory information, call (800) 813 3693 (U.S.) or go to **ni.com/dataacquisition**.

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We also offer service programs that provide automatic upgrades to your application development environment and higher levels of technical support. Visit **ni.com/ssp**.

Hardware Services

NI Factory Installation Services

NI Factory Installation Services (FIS) is the fastest and easiest way to use your PXI or PXI/SCXI combination systems right out of the box. Trained NI technicians install the software and hardware and configure the system to your specifications. NI extends the standard warranty by one year on hardware components (controllers, chassis, modules) purchased with FIS. To use FIS, simply configure your system online with **ni.com/pxiadvisor**.

Calibration Services

NI recognizes the need to maintain properly calibrated devices for high-accuracy measurements. We provide manual calibration procedures, services to recalibrate your products, and automated calibration software specifically designed for use by metrology laboratories. Visit **ni.com/calibration**.

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NI provides complete repair services for our products. Express repair and advance replacement services are also available. We offer extended warranties to help you meet project life-cycle requirements. Visit **ni.com/services**.

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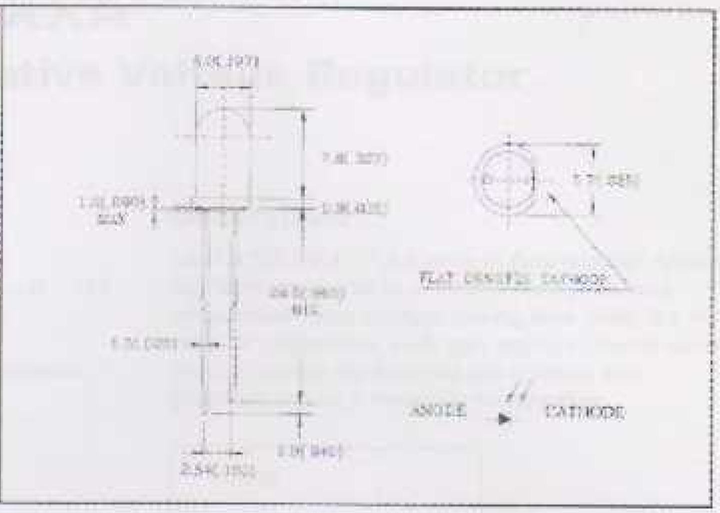
ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH13	26	60	ACH5
ACH6	25	59	AIGND
AIGND	24	58	ACH14
ACH15	23	57	ACH7
DAC0OUT[1]	22	56	AIGND
DAC1OUT[1]	21	55	AOGND
RESERVED	20	54	AOGND
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE[1]
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT[1]
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	7	41	PFI4/GPCTR1_GATE
PFI5/UPDATE[1]	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

[1] Not available on the 6034E

I/O Connector Pin Assignment for the 6034E/6035E

PARA LIGHT

L-51ROPT1XX 5.0mm PHOTODIODE



◆ABSOLUTE MAXIMUN RATING:(Ta=25°C)

Part No.	P_D (mw)	V_{RRM} (V)	Topr	Tstg
L-51ROPT1XX	10	5	-35°C to 85°C	-35°C to 85°C
PARAMETER	Power Dissipation	Reverse break down voltage	Operating Temperature Range	Storage Temperature Range
Lead Soldering Temperature (1.6mm(0.063 inch)From Body) 250°C ±5°C For 3 Seconds				

◆ELECTRO-OPTICAL CHARACTERISTICS:(Ta=25°C)

Part No.	BV_{CEO} (V)			BV_{ECO} (V)			I_{CEO} (nA)			$V_{CE(SAT)}$ (V)			tr, tf (nS)			I_L (mA)			C_{CE} (pF)			λ (nm)		
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
L-51ROPT1C	30			5					100			0.4		[illegible]		1.8	2.4			6.4		400		1050
L-51ROPT1D1	30			5					100			0.4		[illegible]		1.7	2.2			6.4		900	940	
L-51ROPT1D2	30			5					100			0.4		[illegible]		1.7	2.2			6.4		800	870	
TEST CONDITION	I_C=100uA Ee=0mW/cm²			I_E=100uA Ee=0mW/cm²			V_{CE}=20V Ee=0mW/cm²			I_C=2mA Ee=0.1mW/cm²			V_{CE}=5V I_C=1mA RL=1000Ω			V_{CE}=5V Ee=0.1mW/cm²			f=1MHz V_{CE}=3V Ee=0mW/cm²					
PARAMETER	COLLECTOR-EMITTER BREAKDOWN VOLTAGE			EMITTER-COLLECTOR BREAKDOWN VOLTAGE			COLLECTOR DARK CURRENT			COLLECTOR-EMITTER SATURATION VOLTAGE			RISE/FALL TIME			ON STATE COLLECTOR CURRENT			COLLECTOR BASE CAPACITANCE			SPECTRAL SENSITIVITY WAVELENGTH		

D1,D2=BLACK

1.All dimension are in millimeters (inches).

2.Tolerance is ± 0.25 mm (0.01") unless otherwise specified

FAIRCHILD
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KA79XX/KA79XXA

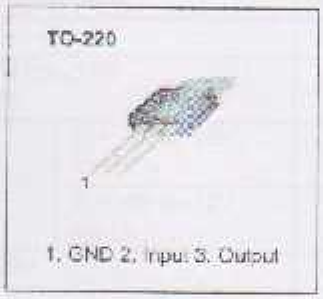
3-Terminal 1A Negative Voltage Regulator

Features

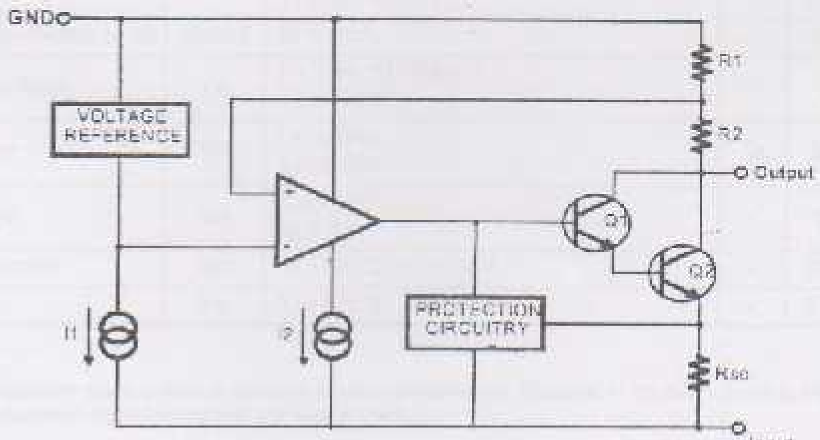
- Output Current in Excess of 1A
- Output Voltages of -5, -6, -8, -9, -10, -12, -15, -18 , -24V
- Internal Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating area Compensation

Description

The KA79XX/KA79XXA series of three-terminal negative regulators are available in TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection, making it essentially indestructible.



Internal Block Digram



Rev. 1.0.0

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage	V_I	-35	V
Thermal Resistance Junction-Cases Junction-Air	$R_{\theta JC}$ $R_{\theta JA}$	5 65	°C/ W
Operating Temperature Range	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	- 65 ~ +150	°C

Electrical Characteristics (KA7905)

(V_I = -10V, I_O = 500mA, 0°C ≤T_J≤ +125°C, C_I =2.2μF, C_O =1μF, unless otherwise specified.)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J=+25°C		- 4.8	- 5.0	- 5.2	V
		I_O = 5mA to 1A, P_O ≤15W V_I = -7V to -20V		- 4.75	-5.0	- 5.25	
Line Regulation (Note1)	ΔV_O	T_J=+25°C	V_I = -7V to -20V I_O=1A	-	5	50	mV
			V_I = -8V to -12V I_O=1A	-	2	25	
		V_I = -7.5V to -25V		-	7	50	
		V_I= -8V to -12V I_O=1A		-	7	50	
Load Regulation (Note1)	ΔV_O	T_J = +25°C I_O = 5mA to 1.5A		-	10	100	mV
		T_J =+25°C I_O = 250mA to 750mA		-	3	50	
Quiescent Current	I_Q	T_J =+25°C		-	3	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	0.05	0.5	mA
		V_I = -8V to -25V		-	0.1	0.8	
Temperature Coefficient of V_D	$\Delta V_O/\Delta T$	I_O = 5mA		-	- 0.4	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	40	-	μV
Ripple Rejection	RR	f = 120Hz ΔV_I = 10V		54	60	-	dB
Dropout Voltage	V_D	T_J=+25°C I_O = 1A		-	2	-	V
Short Circuit Current	I_{SC}	T_J =+25°C, V_I = -35V		-	300	-	mA
Peak Current	I_{PK}	T_J =+25°C		-	2.2	-	A

Note

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (KA7905A)

(V_I = -10V, I_O = 500mA, 0°C ≤ T_J ≤ +125°C, C_I =2.2µF, C_O =1µF, unless otherwise specified.)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J=+25°C		- 4.9	- 5.0	- 5.1	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I = -7V to -20V		- 4.8	-5.0	- 5.2	
Line Regulation (Note1)	ΔV_O	T_J=+25°C	V_I = -7V to -20V I_O=1A	-	5	50	mV
			V_I = -8V to -12V I_O=1A	-	2	25	
		T_J=+25°C V_I = -7.5V to -25V		-	7	50	
		V_I= -8V to -12V I_O=1A		-	7	50	
Load Regulation (Note1)	ΔV_O	I_O = 5mA to 1.5A		-	10	100	mV
		T_J =+25°C I_O = 250mA to 750mA		-	3	50	
Quiescent Current	I_Q	T_J =+25°C		-	3	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	0.05	0.5	mA
		V_I = -8V to -25V		-	0.1	0.8	
Temperature Coefficient of V_D	$\Delta V_O/\Delta T$	I_O = 5mA		-	- 0.4	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	40	-	µV
Ripple Rejection	RR	f = 120Hz ΔV_I = 10V		54	60	-	dB
Dropout Voltage	V_D	T_J=+25°C I_O = 1A		-	2	-	V
Short Circuit Current	I_{SC}	T_J =+25°C, V_I = -35V		-	300	-	mA
Peak Current	I_{PK}	T_J =+25°C		-	2.2	-	A

Note

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (KA7909)

(V_I = -14V, I_O = 500mA, 0°C ≤ T_J ≤ +125°C, C_I = 2.2μF, C_O = 1μF, unless otherwise specifed.)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J=+25°C		-8.7	-9.0	-9.3	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I = -1.5V to -23V		-8.6	-9.0	-9.4	
Line Regulation (Note1)	ΔV_O	T_J=+25°C	V_I = -10.5V to -25V	-	10	180	mV
			V_I = -11V to -17V	-	5	90	
Load Regulation (Note1)	ΔV_O	T_J=+25°C I_O = 5mA to 1.5A		-	12	180	mV
		T_J=+25°C I_O = 250mA to 750mA		-	4	90	
Quiescent Current	I_Q	T_J=+25°C		-	3	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	0.05	0.5	mA
		V_I = -11.5V to -25V		-	0.1	1	
Temperature Coefficient of V_D	$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.6	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	175	-	μV
Ripple Rejection	RR	f = 120Hz ΔV_I = 10V		54	60	-	dB
Dropout Voltage	V_D	T_J=+25°C I_O = 1A		-	2	-	V
Short Circuit Current	I_{SC}	T_J=+25°C, V_I = -35V		-	300	-	mA
Peak Current	I_{PK}	T_J=+25°C		-	2.2	-	A

Note

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Electrical Characteristics (KA7912)

(V_I = -18V, I_O = 500mA, 0°C ≤ T_J ≤ +125°C, C_I =2.2μF, C_O =1μF, unless otherwise specified.)

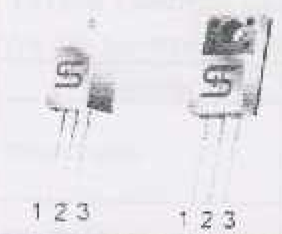
Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J=+25°C		-11.5	-12	-12.5	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I = -15.5V to -27V		-11.4	-12	-12.6	
Line Regulation (Note1)	ΔV_O	T_J=+25°C	V_I = -14.5V to -30V	-	12	240	mV
			V_I= -16V to -22V	-	6	120	
Load Regulation (Note1)	ΔV_O	T_J=+25°C I_O = 5mA to 1.5A		-	12	240	mV
		T_J =+25°C I_O = 250mA to 750mA		-	4	120	
Quiescent Current	I_Q	T_J =+25°C		-	3	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	0.05	0.5	mA
		V_I = -15V to -30V		-	0.1	1	
Temperature Coefficient of V_D	$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.8	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25°C		-	200	-	μV
Ripple Rejection	RR	f = 120Hz ΔV_I = 10V		54	60	-	dB
Dropout Voltage	V_D	T_J=+25°C I_O = 1A		-	2	-	V
Short Circuit Current	I_{SC}	T_J =+25°C, V_I = -35V		-	300	-	mA
Peak Current	I_{PK}	T_J =+25°C		-	2.2	-	A

Note

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

TS7800 series

3-Terminal Fixed Positive Voltage Regulator



Pin assignment
1. Input
2. Ground
3. Output

(Heatsink surface connected to Pin 2)

Voltage Range 5V to 24V
Output Current up to 1A

General Description

These voltage regulators are monolithic integrated circuits designed as fixed-voltage regulators for a wide variety of applications including local, on-card regulation. These regulators employ internal current limiting, thermal shutdown, and safe-area compensation. With adequate heatsink they can deliver output currents up to 1 ampere.

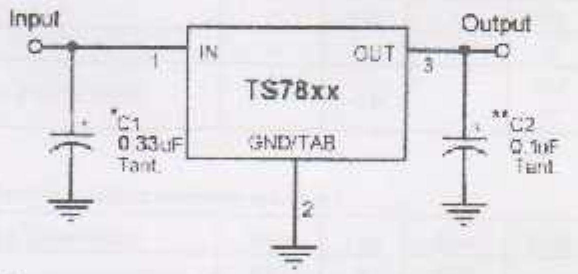
Although designed primarily as a fixed voltage regulator, these devices can be used with external components to obtain adjustable voltages and currents.

This series is offered in 3-pin TO-220, ITO-220 package.

Features

- Output current up to 1A
- No external components required
- Internal thermal overload protection
- Internal short-circuit current limiting
- Output transistor safe-area compensation
- Output voltage offered in 4% tolerance

Standard Application



A common ground is required between the input and the output voltages. The input voltage must remain typically 2.0V above the output voltage even during the low point on the Input ripple voltage.

XX = these two digits of the type number indicate voltage.

* = Cin is required if regulator is located an appreciable distance from power supply filter.

** = Co is not needed for stability; however, it does improve transient response.

Ordering Information

Part No.	Operating Temp. (Ambient)	Package
TS78xxCZ	-20 ~ +85°C	TO-220
TS78xxCI		ITO-220

Note: Where xx denotes voltage option.

Absolute Maximum Rating

Input Voltage		Vin *	35	V
Input Voltage		Vin **	40	V
Power Dissipation	TO-220	Without heatsink	2	W
	TO-220	Pt ***	15	
	ITO-220	Without heatsink	10	
Operating Junction Temperature Range		T_J	0 ~ +150	°C
Storage Temperature Range		T_{STG}	-65 ~ +150	°C

Note : * TS7805 to TS7818
** TS7824
*** Follow the derating curve

TSC

TS7808 Electrical Characteristics

(Vin=14V, Iout=500mA, 0°C≤Tj≤125°C, Cin=0.33uF, Cout=0.1uF; unless otherwise specified.)

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
Output Voltage	Vout	Tj=25°C		7.69	8	8.32	V
		10.5V≤Vin≤23V, 10mA≤Iout≤1A, PD≤15W		7.61	8	8.40	
Line Regulation	REGline	Tj=25°C	10.5V≤Vin≤25V	--	6	160	mV
			11V≤Vin≤17V	--	2	80	
Load Regulation	REGload	Tj=25°C	10mA≤Iout≤1A	--	12	160	
			250mA≤Iout≤750mA	--	4	80	
Quiescent Current	Iq	Iout=0, Tj=25°C		--	4.3	8	mA
Quiescent Current Change	ΔIq	10.5V≤Vin≤25V		--	--	1	
		10mA≤Iout≤1A		--	--	0.5	
Output Noise Voltage	Vn	10Hz≤f≤100KHz, Tj=25°C		--	52	--	uV
Ripple Rejection Ratio	RR	f=120Hz, 11V≤Vin≤21V		56	72	--	dB
Voltage Drop	Vdrop	Iout=1.0A, Tj=25°C		--	2	--	V
Output Resistance	Rout	f=1KHz		--	16	--	mΩ
Output Short Circuit Current	Ios	Tj=25°C		--	450	--	mA
Peak Output Current	Io peak	Tj=25°C		--	2.2	--	A
Temperature Coefficient of Output Voltage	ΔVout/ΔTj	Iout=10mA, 0°C≤Tj≤125°C		--	0.8	--	mV/°C

TS7809 Electrical Characteristics

(Vin=15V, Iout=500mA, 0°C≤Tj≤125°C, Cin=0.33uF, Cout=0.1uF; unless otherwise specified.)

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
Output Voltage	Vout	Tj=25°C		8.65	9	9.36	V
		11.5V≤Vin≤23V, 10mA≤Iout≤1A, PD≤15W		8.57	9	9.45	
Line Regulation	REGline	Tj=25°C	11.5V≤Vin≤26V	--	6	180	mV
			12V≤Vin≤17V	--	2	90	
Load Regulation	REGload	Tj=25°C	10mA≤Iout≤1A	--	12	180	
			250mA≤Iout≤750mA	--	4	90	
Quiescent Current	Iq	Iout=0, Tj=25°C		--	4.3	8	mA
Quiescent Current Change	ΔIq	11.5V≤Vin≤26V		--	--	1	
		10mA≤Iout≤1A		--	--	0.5	
Output Noise Voltage	Vn	10Hz≤f≤100KHz, Tj=25°C		--	52	--	uV
Ripple Rejection Ratio	RR	f=120Hz, 12V≤Vin≤22V		55	72	--	dB
Voltage Drop	Vdrop	Iout=1.0A, Tj=25°C		--	2	--	V
Output Resistance	Rout	f=1KHz		--	16	--	mΩ
Output Short Circuit Current	Ios	Tj=25°C		--	450	--	mA
Peak Output Current	Io peak	Tj=25°C		--	2.2	--	A
Temperature Coefficient of Output Voltage	ΔVout/ΔTj	Iout=10mA, 0°C≤Tj≤125°C		--	-1	--	mV/°C

- Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible, and thermal effects must be taken into account separately.
- This specification applies only for DC power dissipation permitted by absolute maximum ratings.

TSC

TS7810 Electrical Characteristics

(Vin=16V, Iout=500mA, 0°C≤Tj≤125°C, Cin=0.33uF, Cout=0.1uF; unless otherwise specified.)

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
Output Voltage	Vout	Tj=25°C		9.6	10	10.4	V
		12.5V≤Vin≤25V, 10mA≤Iout≤1A, PD≤15W		9.5	10	10.5	
Line Regulation	REGline	Tj=25°C	12.5V≤Vin≤28V	--	7	200	mV
			13V≤Vin≤17V	--	2	100	
Load Regulation	REGload	Tj=25°C	10mA≤Iout≤1A	--	12	200	
			250mA≤Iout≤750mA	--	4	100	
Quiescent Current	Iq	Iout=0, Tj=25°C		--	4.3	8	mA
Quiescent Current Change	ΔIq	12.5V≤Vin≤28V		--	--	1	
		10mA≤Iout≤1A		--	--	0.5	
Output Noise Voltage	Vn	10Hz≤f≤100KHz, Tj=25°C		--	70	--	uV
Ripple Rejection Ratio	RR	f=120Hz, 13V≤Vin≤23V		55	71	--	dB
Voltage Drop	Vdrop	Iout=1.0A, Tj=25°C		--	2	--	V
Output Resistance	Rout	f=1KHz		--	18	--	mΩ
Output Short Circuit Current	Ios	Tj=25°C		--	400	--	mA
Peak Output Current	Io peak	Tj=25°C		--	2.2	--	A
Temperature Coefficient of Output Voltage	ΔVout/ ΔTj	Iout=10mA, 0°C≤Tj≤125°C		--	-1	--	mV/ °C

TS7812 Electrical Characteristics

(Vin=19V, Iout=500mA, 0°C≤Tj≤125°C, Cin=0.33uF, Cout=0.1uF; unless otherwise specified.)

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
Output Voltage	Vout	Tj=25°C		11.53	12	12.48	V
		14.5V≤Vin≤27V, 10mA≤Iout≤1A, PD ≤15W		11.42	12	12.60	
Line Regulation	REGline	Tj=25°C	14.5V≤Vin≤30V	--	10	240	mV
			16V≤Vin≤19V	--	3	120	
Load Regulation	REGload	Tj=25°C	10mA≤Iout≤1A	--	12	240	
			250mA≤Iout≤750mA	--	4	120	
Quiescent Current	Iq	Tj=25°C, Iout=0		--	4.3	8	mA
Quiescent Current Change	ΔIq	14.5V≤Vin≤30V		--	--	1	
		10mA≤Iout≤1A		--	--	0.5	
Output Noise Voltage	Vn	10Hz≤f≤100KHz, Tj=25°C		--	75	--	uV
Ripple Rejection Ratio	RR	f=120Hz, 15V≤Vin≤25V		55	71	--	dB
Voltage Drop	Vdrop	Iout=1.0A, Tj=25°C		--	2	--	V
Output Resistance	Rout	f=1KHz		--	18	--	mΩ
Output Short Circuit Current	Ios	Tj=25°C		--	350	--	mA
Peak Output Current	Io peak	Tj=25°C		--	2.2	--	A
Temperature Coefficient of Output Voltage	ΔVout/ ΔTj	Iout=10mA, 0°C≤Tj≤125°C		--	-1	--	mV/ °C

- Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as *possible, and thermal effects must be taken into account separately.*
- This specification applies only for DC power dissipation permitted by absolute maximum ratings.

Marubeni

L890-_ _AU Infrared LED Lamp

This series of L890-_ _AU is a GaAlAs LED mounted on a lead frame and encapsulated in various types of epoxy lens which offer different design settings.
On forward bias, it emits a high power radiation of typical 30mW with a peak wavelength at 880nm.

1) Specifications

(1) Chip material	AlGaAs	(4) Package	Clear epoxy resin
(2) Chip Size	0.4mm*0.4mm	(5) Lead frame	Soldered
(3) Peak wavelength	880nm		

2) Absolute Maximum Ratings

Item	Symbol	Maximum Rated Value	Unit	Ambient Temperature
Power Dissipation	PD	150	mW	Ta=25°C
Forward Current	IF	100	mA	Ta=25°C
Pulse Forward Current	IFP	500	mA	Ta=25°C
Reverse Voltage	VR	5	V	Ta=25°C
Operating Temperature	TOPR	-30 ~ +85	°C	Ta=25°C
Storage Temperature	TSTG	-30 ~ +100	°C	
Soldering Temperature	TSOL	260	°C	

3) Electro-Optical Characteristics [Ta=25°C]

Item	Symbol	Condition	Minimum	Typical	Maximum	Unit
Forward Voltage	VF	IF=50mA DC		1.45	1.7	V
		IF=100mA, tp=20ms		1.65	1.95	
Reverse Current	IR	VR=5V			10	uA
Total Radiated Power	PO	IF=50mA DC	10.0	15.0		mW
		IF=100mA, tp=20ms		30.0		
Peak Wavelength	λP	IF=50mA DC		880		nm
Half Width	Δλ	IF=50mA DC		75		nm
Rise Time	tr	IF=50mA DC		800		ns
Fall Time	tf	IF=50mA DC		400		ns

4) Characteristics of Radiant Intensity [Ta=25°C]

Type	Viewing Half Angle	Radiant Intensity IF=100mA,tp=20ms unit: mW/sr			Outer Dimension	
		Minimum	Typical	Maximum	Dimension	Figure
L890-01AU	±10°		120		Φ5	1
L890-02AU	±5°		140		Φ5	2
L890-03AU	±15°		100		Φ5	3
L890-04AU	±20°		60		Φ5	4
L890-05AU	±40°		16		Φ5	5
L890-06AU	±6°		160		Φ5	6
L890-09AU	±25°(Long) ±15°(Short)		100		Φ5 Oval	7
L890-33AU	±15°		40		Φ3	9
L890-36AU	±30°		30		Φ3	10

‡ Radiant Intensity is measured by Tektronix J-16.
‡ Total Radiated Power is measured by Photodyne #500.

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L940-_ _AU Infrared LED Lamp

This series of L940-_ _AU is a GaAs LED mounted on a lead frame and encapsulated in various types of epoxy lens which offer different design settings.
On forward bias, it emits a high power radiation of typical 30mW with a peak wavelength at 940nm.

1) Specifications

(1) Chip material	GaAs	(4) Package	Clear epoxy resin
(2) Chip Size	0.4mm*0.4mm	(5) Lead frame	Soldered
(3) Peak wavelength	940nm		

2) Absolute Maximum Ratings

Item	Symbol	Maximum Rated Value	Unit	Ambient Temperature
Power Dissipation	PD	140	mW	Ta=25°C
Forward Current	IF	100	mA	Ta=25°C
Pulse Forward Current	IFP	1000	mA	Ta=25°C
Reverse Voltage	VR	5	V	Ta=25°C
Operating Temperature	TOPR	-30 ~ +85	°C	Ta=25°C
Storage Temperature	TSTG	-30 ~ +100	°C	
Soldering Temperature	TSOL	250	°C	

3) Electro-Optical Characteristics [Ta=25°C]

Item	Symbol	Condition	Minimum	Typical	Maximum	Unit
Forward Voltage	VF	IF=50mA DC		1.30	1.45	V
		IF=100mA, tp=20ms		1.40	1.65	
Reverse Current	IR	VR=5V			10	uA
Total Radiated Power	PO	IF=50mA DC	14.0	18.0		mW
		IF=100mA, tp=20ms		36.0		
Peak Wavelength	λP	IF=50mA DC		940		nm
Half Width	Δλ	IF=50mA DC		50		nm
Rise Time	tr	IF=50mA DC		1000		ns
Fall Time	tf	IF=50mA DC		500		ns

4) Characteristics of Radiant Intensity [Ta=25°C]

Type	Viewing Half Angle	Radiant Intensity IF=100mA,tp=20ms unit: mW/sr			Outer Dimension	
		Minimum	Typical	Maximum	Dimension	Figure
L940-01AU	±10°		120		Φ5	1
L940-02AU	±5°		130		Φ5	2
L940-03AU	±15°		90		Φ5	3
L940-04AU	±20°		40		Φ5	4
L940-05AU	±40°				Φ5	5
L940-06AU	±7°		150		Φ5	6
L940-09AU	±25°(Long) ±15°(Short)		70		Φ5 Oval	7
L940-33AU	±15°		40		Φ3	9
L940-36AU	±30°		22		Φ3	10

± Radiant Intensity is measured by Tektronix J-16.
± Total Radiated Power is measured by Photodyne #500.

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Marubeni

L645-_ _V High Bright Red LED Lamp

This series of L645-_ _V is an InGaAlP LED mounted on a lead frame with a clear epoxy lens. On forward bias, it emits a band of visible light that peaks 645nm.

1) Specifications

(1) Chip material	InGaAlP
(2) Peak wavelength	645nm typ.
(3) Package	Clear epoxy resin
(4) Lead frame	Soldered

2) Absolute Maximum Ratings

Item	Symbol	Maximum Rated Value	Unit	Ambient Temperature
Power Dissipation	P_D	120	mW	Ta=25°C
Forward Current	I_F	50	mA	Ta=25°C
Reverse Voltage	V_R	5	V	Ta=25°C
Operating Temperature	T_{OPR}	-30 ~ +85	°C	Ta=25°C
Storage Temperature	T_{STG}	-30 ~ +100	°C	
Soldering Temperature	T_{SOL}	260	°C	

3) Electro-Optical Characteristics [Ta=25°C]

Item	Symbol	Condition	Minimum	Typical	Maximum	Unit
Forward Voltage	V_F	I_F=20mA		2.0	2.3	V
Reverse Current	I_R	V_R=5V			10	uA
Total Radiated Power	P_O	I_F=20mA		2.5		mW
Peak Wavelength	λ_P	I_F=20mA	635	645	655	nm
Half Width	$\Delta\lambda$	I_F=20mA		20		nm

4) Characteristics of Brightness [Ta=25°C]

Type	Viewing Half Angle	Brightness IF=20mA unit: mcd			Outer Dimension	
		Minimum	Typical	Maximum	Dimension	Figure
L645-01V	±9°		2000		Φ5	1
L645-02V	±3°		3000		Φ5	2
L645-03V	±12°		1500		Φ5	3
L645-04V	±15°		600		Φ5	4
L645-05V	±30°		100		Φ5	5
L645-06V	±3°		5000		Φ5	6
L645-09V	±25°(Long) ±15°(Short)		600		Φ5 Oval	7
L645-10V	±5°		8000		Φ10	8
L645-33V	±16°		500		Φ3	9
L645-36V	±40°		250		Φ3	10

‡ Brightness is measured by Tektronix J-16.
‡ Total Radiated Power is measured by Photodyne #500.

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FAIRCHILD
SEMICONDUCTOR™

November 1995

2N7000 / 2N7002 / NDS7002A
N-Channel Enhancement Mode Field Effect Transistor

General Description

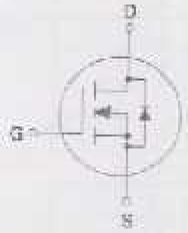
These N-Channel enhancement mode field effect transistors are produced using Fairchild's proprietary, high cell density, DMOS technology. These products have been designed to minimize on-state resistance while provide rugged, reliable, and fast switching performance. They can be used in most applications requiring up to 400mA DC and can deliver pulsed currents up to 2A. These products are particularly suited for low voltage, low current applications such as small servo motor control, power MOSFET gate drivers, and other switching applications.

Features

- High density cell design for low $R_{DS(ON)}$.
- Voltage controlled small signal switch.
- Rugged and reliable.
- High saturation current capability.

TO-92
2N7000

SOT-23
(TO-236AB)
2N7002/NDS7002A



Absolute Maximum Ratings T_A = 25°C unless otherwise noted

Symbol	Parameter	2N7000	2N7002	NDS7002A	Units
V_{DSS}	Drain-Source Voltage		60		V
V_{DGR}	Drain-Gate Voltage (R_{GS} ≤ 1 MΩ)		60		V
V_{GSS}	Gate-Source Voltage - Continuous		±20		V
	- Non Repetitive (tp < 50µs)		±40		
I_D	Maximum Drain Current - Continuous	200	115	280	mA
	- Pulsed	500	800	1500	
P_D	Maximum Power Dissipation	400	200	300	mW
	Derated above 25°C	3.2	1.6	2.4	mW/°C
T_J, T_{STG}	Operating and Storage Temperature Range	-55 to 150		-65 to 150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16" from Case for 10 Seconds		300		°C
THERMAL CHARACTERISTICS					
$R_{θJA}$	Thermal Resistance, Junction-to-Ambient	312.5	625	417	°C/W

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Conditions		Type	Min	Typ	Max	Units
OFF CHARACTERISTICS								
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0 V, I_D = 10 µA		All	60			V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 48 V, V_{GS} = 0 V		2N7000			1	µA
			T_J=125°C				1	mA
		V_{DS} = 60 V, V_{GS} = 0 V		2N7002 NDS7002A			1	µA
			T_J=125°C				0.5	mA
I_{GSSF}	Gate - Body Leakage, Forward	V_{GS} = 15 V, V_{DS} = 0 V		2N7000			10	nA
		V_{GS} = 20 V, V_{DS} = 0 V		2N7002 NDS7002A			100	nA
I_{GSSR}	Gate - Body Leakage, Reverse	V_{GS} = -15 V, V_{DS} = 0 V		2N7000			-10	nA
		V_{GS} = -20 V, V_{DS} = 0 V		2N7002 NDS7002A			-100	nA
ON CHARACTERISTICS (Note 1)								
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 1 mA		2N7000	0.8	2.1	3	V
		V_{DS} = V_{GS}, I_D = 250 µA		2N7002 NDS7002A	1	2.1	2.5	
$R_{DS(ON)}$	Static Drain-Source On-Resistance	V_{GS} = 10 V, I_D = 500 mA		2N7000		1.2	5	Ω
			T_J=125°C			1.9	9	
		V_{GS} = 4.5 V, I_D = 75 mA				1.8	5.3	
		V_{GS} = 10 V, I_D = 500 mA		2N7002		1.2	7.5	
			T_J=100°C			1.7	13.5	
		V_{GS} = 5.0 V, I_D = 50 mA				1.7	7.5	
			T_J=100C			2.4	13.5	
		V_{GS} = 10 V, I_D = 500 mA		NDS7002A		1.2	2	
			T_J=125°C			2	3.5	
		V_{GS} = 5.0 V, I_D = 50 mA				1.7	3	
			T_J=125°C			2.8	5	
$V_{DS(ON)}$	Drain-Source On-Voltage	V_{GS} = 10 V, I_D = 500 mA		2N7000		0.6	2.5	V
		V_{GS} = 4.5 V, I_D = 75 mA				0.14	0.4	
		V_{GS} = 10 V, I_D = 500mA		2N7002		0.6	3.75	
		V_{GS} = 5.0 V, I_D = 50 mA				0.09	1.5	
		V_{GS} = 10 V, I_D = 500mA		NDS7002A		0.6	1	
		V_{GS} = 5.0 V, I_D = 50 mA				0.09	0.15	

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Conditions	Type	Min	Typ	Max	Units
ON CHARACTERISTICS Continued (Note 1)							
$I_{D(on)}$	On-State Drain Current	V_{GS} = 4.5 V, V_{DS} = 10 V	2N7000	75	600		mA
		V_{GS} = 10 V, V_{DS} ≥ 2 $V_{DS(on)}$	2N7002	500	2700		
		V_{GS} = 10 V, V_{DS} ≥ 2 $V_{DS(on)}$	NDS7002A	500	2700		
g_{FS}	Forward Transconductance	V_{DS} = 10 V, I_D = 200 mA	2N7000	100	320		mS
		V_{DS} ≥ 2 $V_{DS(on)}$, I_D = 200 mA	2N7002	80	320		
		V_{DS} ≥ 2 $V_{DS(on)}$, I_D = 200 mA	NDS7002A	80	320		
DYNAMIC CHARACTERISTICS							
C_{iss}	Input Capacitance	V_{DS} = 25 V, V_{GS} = 0 V, f = 1.0 MHz	All		20	50	pF
C_{oss}	Output Capacitance		All		11	25	pF
C_{rss}	Reverse Transfer Capacitance		All		4	5	pF
t_{on}	Turn-On Time	V_{DD} = 15 V, R_L = 25 Ω, I_D = 500 mA, V_{GS} = 10 V, R_{GEN} = 25	2N7000			10	ns
		V_{DD} = 30 V, R_L = 150 Ω, I_D = 200 mA, V_{GS} = 10 V, R_{GEN} = 25 Ω	2N700 NDS7002A			20	
t_{off}	Turn-Off Time	V_{DD} = 15 V, R_L = 25 Ω, I_D = 500 mA, V_{GS} = 10 V, R_{GEN} = 25	2N7000			10	ns
		V_{DD} = 30 V, R_L = 150 Ω, I_D = 200 mA, V_{GS} = 10 V, R_{GEN} = 25 Ω	2N700 NDS7002A			20	
DRAIN-SOURCE DIODE CHARACTERISTICS AND MAXIMUM RATINGS							
I_S	Maximum Continuous Drain-Source Diode Forward Current		2N7002			115	mA
			NDS7002A			280	
I_{SM}	Maximum Pulsed Drain-Source Diode Forward Current		2N7002			0.8	A
			NDS7002A			1.5	
V_{SD}	Drain-Source Diode Forward Voltage	V_{GS} = 0 V, I_S = 115 mA (Note 1)	2N7002		0.88	1.5	V
		V_{GS} = 0 V, I_S = 400 mA (Note 1)	NDS7002A		0.88	1.2	

Note:
1. Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%

Typical Electrical Characteristics

2N7000 / 2N7002 / NDS7002A

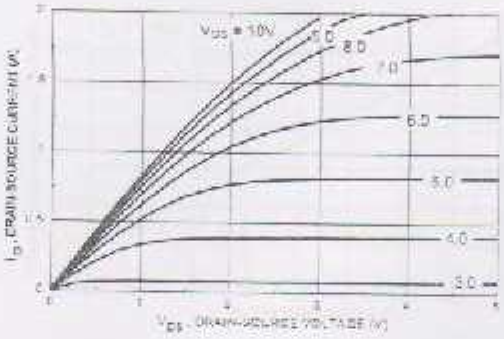


Figure 1. On-Region Characteristics

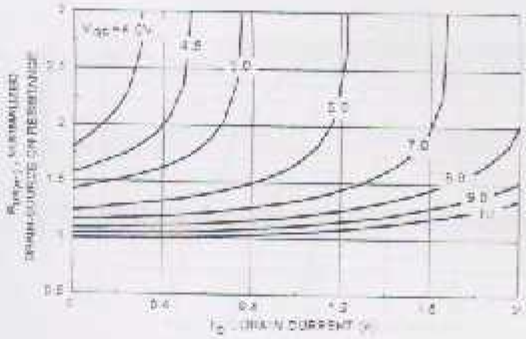


Figure 2. On-Resistance Variation with Gate Voltage and Drain Current

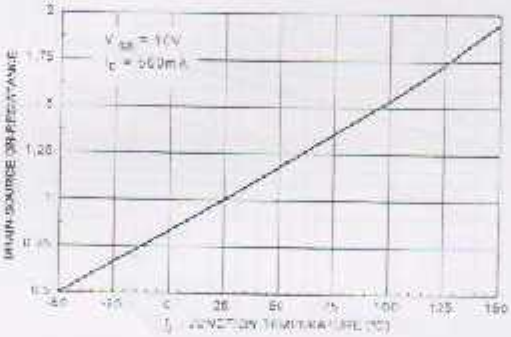


Figure 3. On-Resistance Variation with Temperature

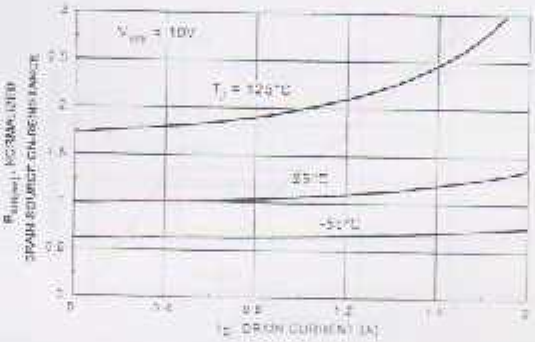


Figure 4. On-Resistance Variation with Drain Current and Temperature

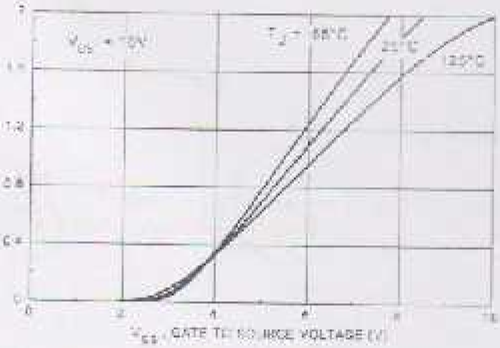


Figure 5. Transfer Characteristics

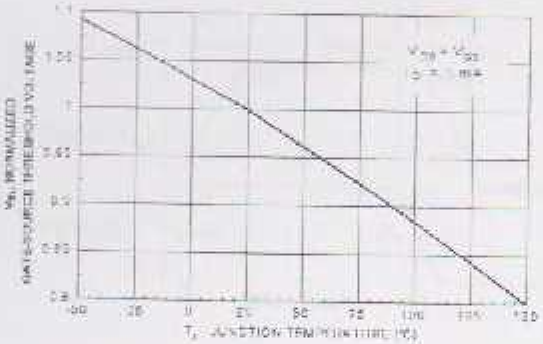


Figure 6. Gate Threshold Variation with Temperature

Typical Electrical Characteristics (continued)

2N7000 / 2N7002 /NDS7002A

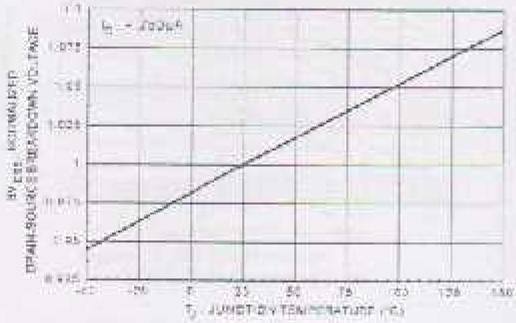


Figure 7. Breakdown Voltage Variation with Temperature

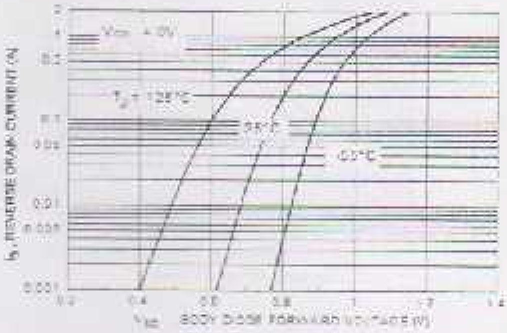


Figure 8. Body Diode Forward Voltage Variation with

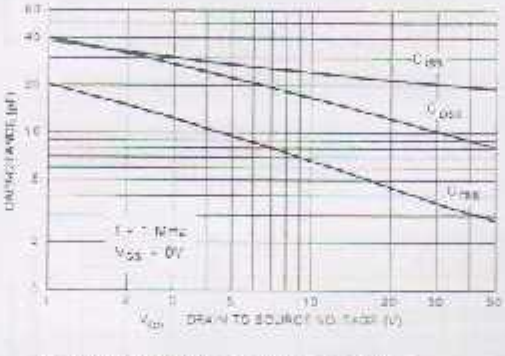


Figure 9. Capacitance Characteristics

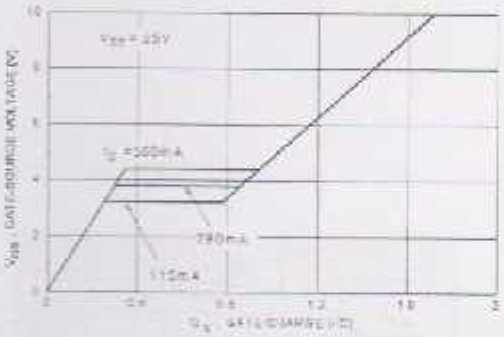


Figure 10. Gate Charge Characteristics

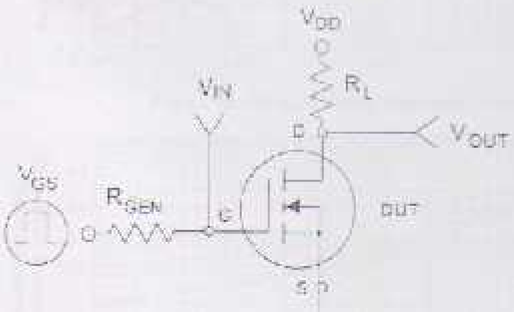


Figure 11.

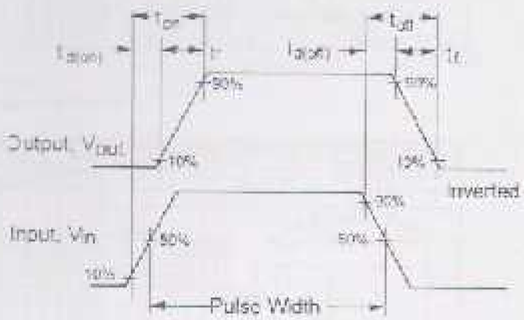


Figure 12. Switching Waveforms

Typical Electrical Characteristics (continued)

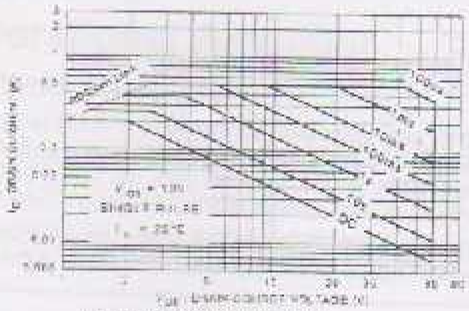


Figure 13. 2N7000 Maximum Safe Operating Area

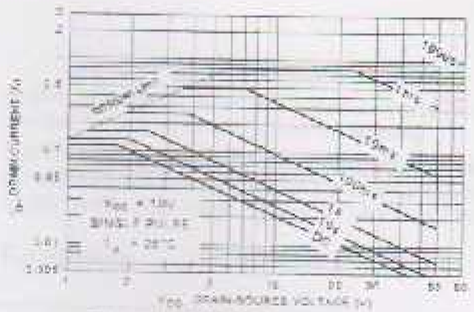


Figure 14. 2N7002 Maximum Safe Operating Area

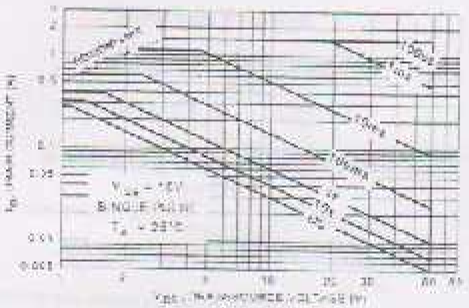


Figure 15. NDS7000A Maximum Safe Operating Area

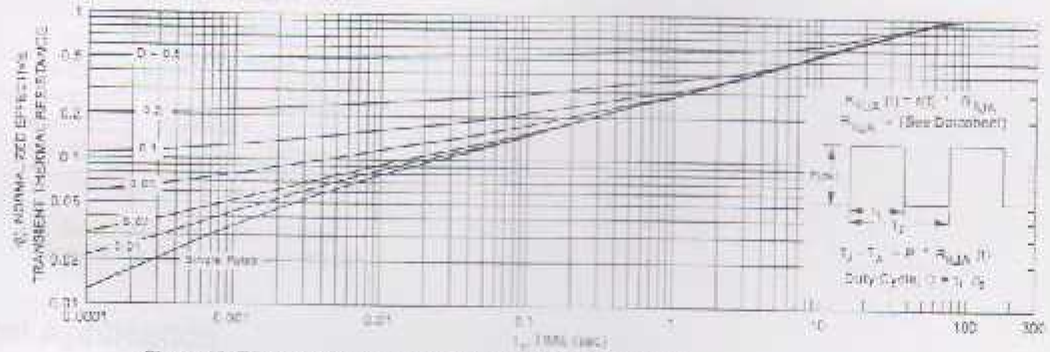


Figure 16. TO-92, 2N7000 Transient Thermal Response Curve

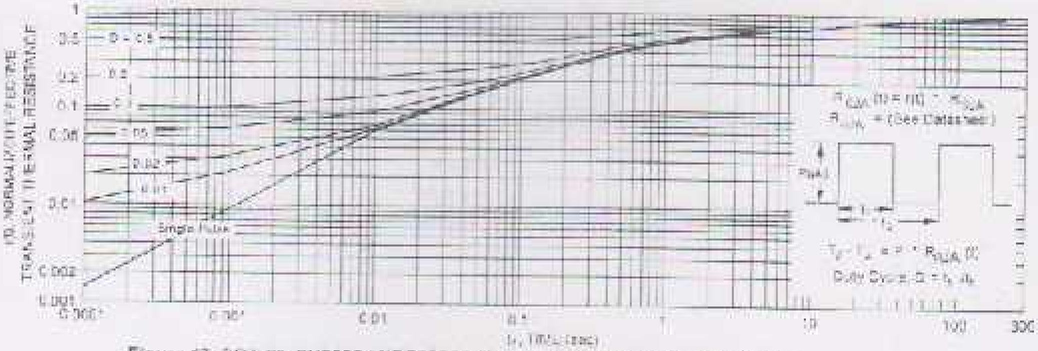


Figure 17. SOT-23, 2N7002 / NDS7002A Transient Thermal Response Curve

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

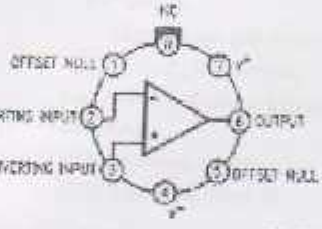
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Features

Connection Diagrams

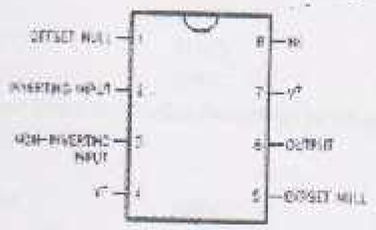
Metal Can Package



Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1), LM741AH/883 or LM741CH
See NS Package Number H08C

Dual-In-Line or S.O. Package



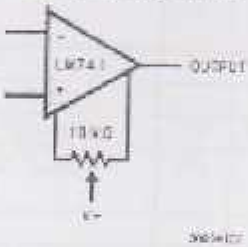
Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak

Order Number LM741W/883
See NS Package Number W10A

Typical Application

Offset Nulling Circuit



Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−63°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
N-Package (10 seconds)	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering

surface mount devices.

	LM741A	LM741	LM741C
ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$, $R_S \le 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$T_A = 25°C$, $R_S \le 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \le T_A \le T_{AMAX}$, $R_S \le 50\Omega$			4.0							mV
	$T_{AMIN} \le T_A \le T_{AMAX}$, $R_S \le 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \le T_A \le T_{AMAX}$				±12	±13					V

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $R_L \geq 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25°C$	10	25	35		25			25		mA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50\Omega$, $V_{CM} = \pm 12V$	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		µs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/µs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 2: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Electrical Characteristics (Note 5) (Continued)

Note 3: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100°C/W	100°C/W	170°C/W	195°C/W
θ_{jC} (Junction to Case)	N/A	N/A	25°C/W	N/A

Note 4: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

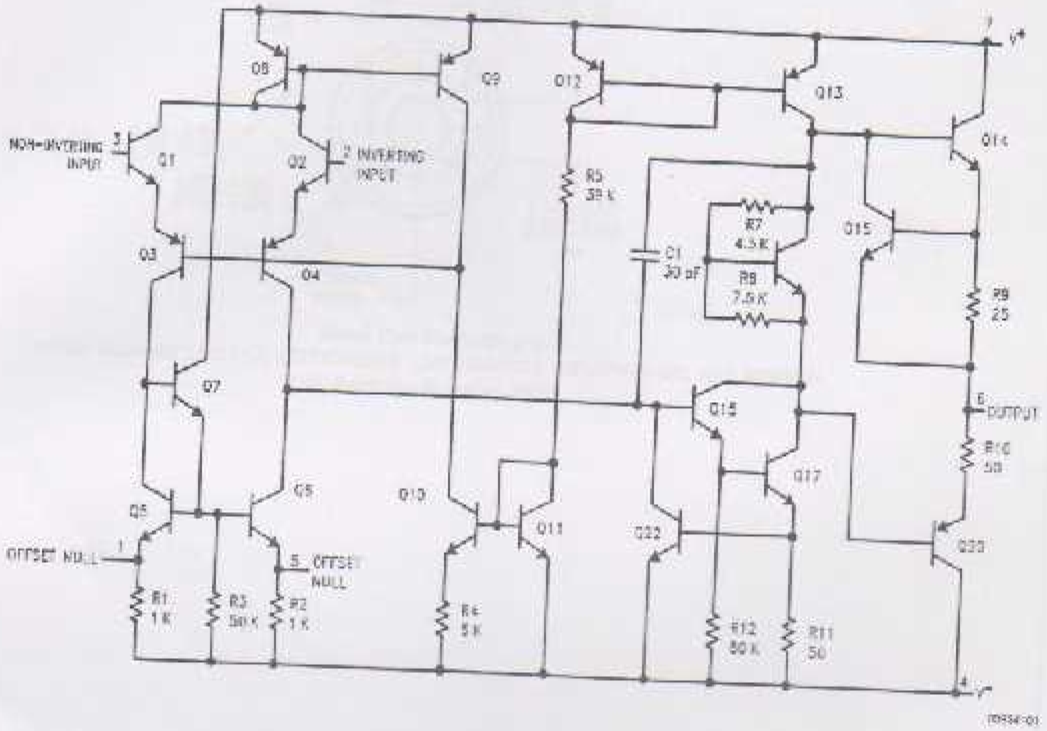
Note 5: Unless otherwise specified, these specifications apply for $V_S = \pm 15V$, $-55°C \le T_A \le +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \le T_A \le +70°C$.

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(µs).

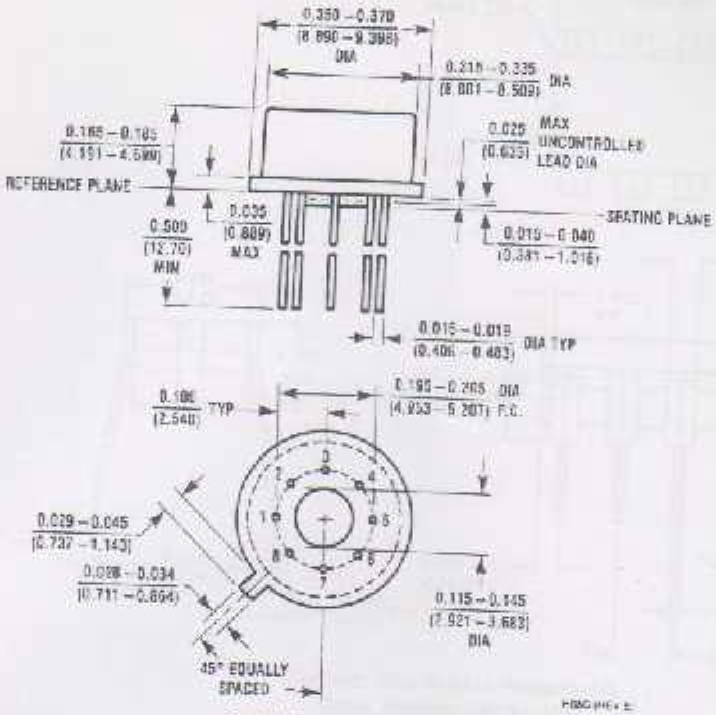
Note 7: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 8: Human body model, 1.5 kΩ in series with 100 pF.

Schematic Diagram

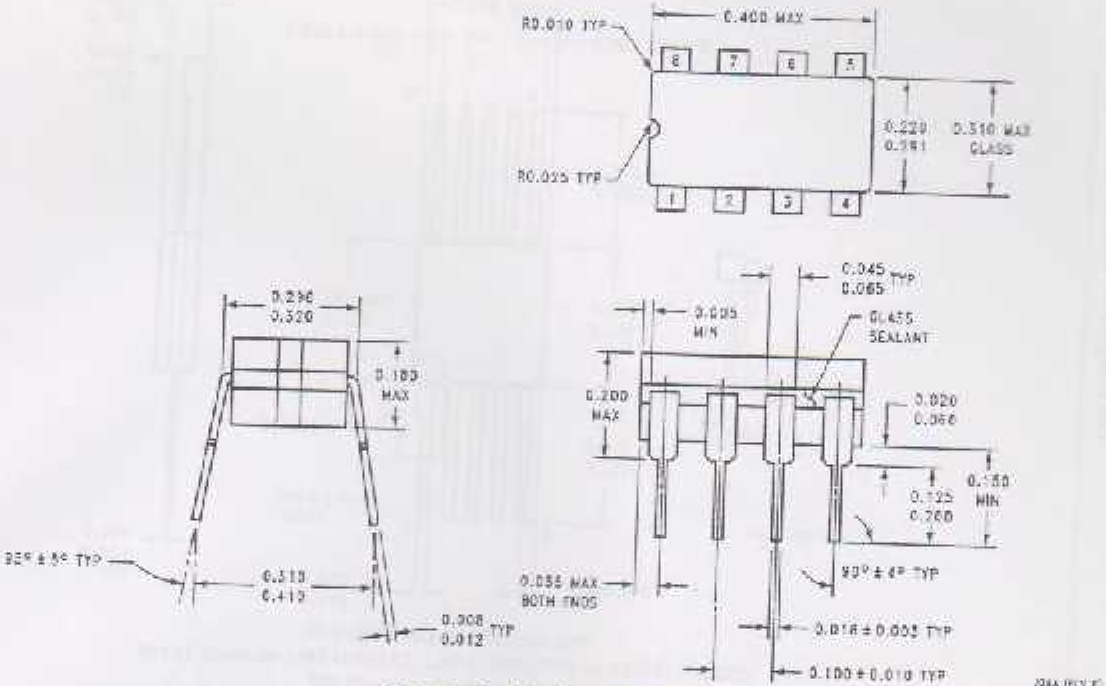


Physical Dimensions inches (millimeters) unless otherwise noted

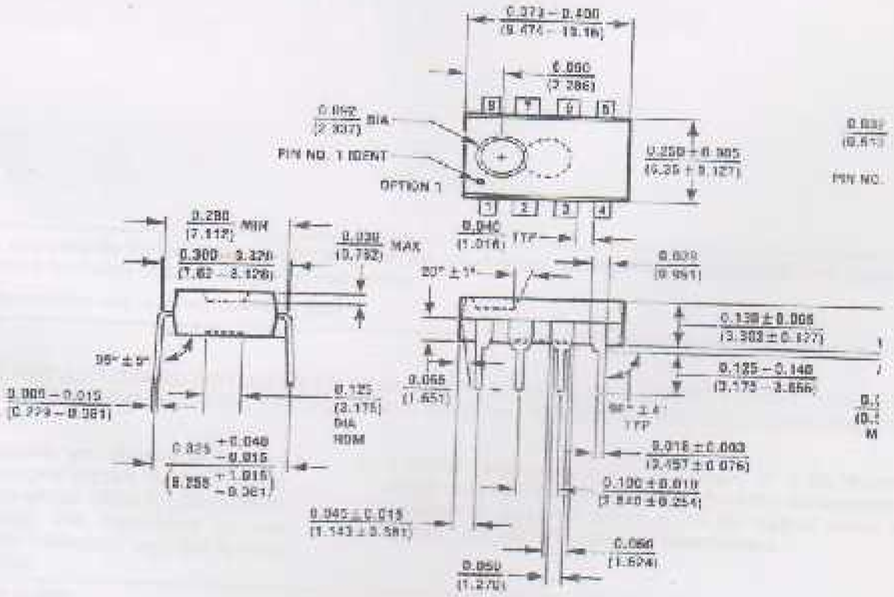


Metal Can Package (H)
Order Number LM741H, LM741H/883, LM741AH/883, LM741AH-MIL or LM741CH
NS Package Number H08C

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

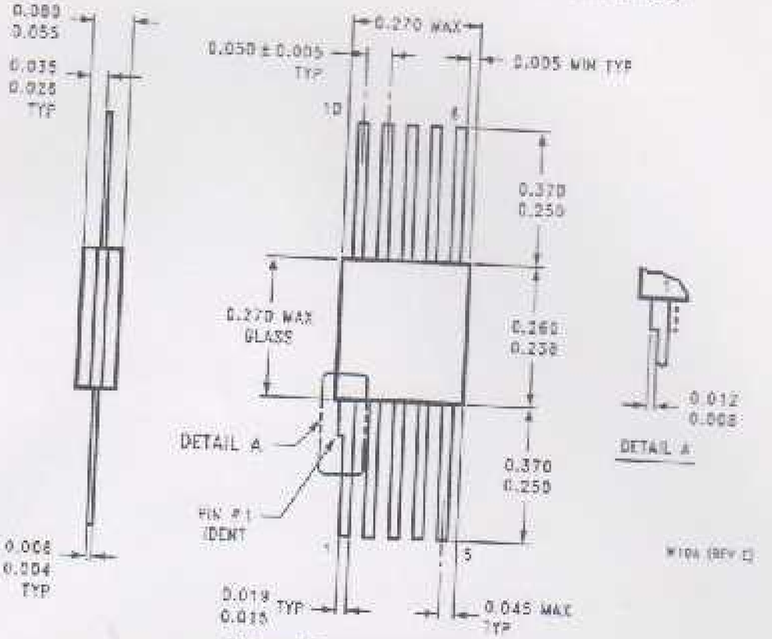


Ceramic Dual-In-Line Package (J)
Order Number LM741J/883
NS Package Number J08A



Dual-In-Line Package (N)
Order Number LM741CN
NS Package Number N08E

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



10-Lead Ceramic Flatpak (W)
Order Number LM741W/883, LM741WG-MPR or LM741WG/883
NS Package Number W10A

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