Palestine Polytechnic University

Collage of Engineering and Technology
Electrical and Computer Engineering Department

Graduation Project
Glucose measurement by using photometric method

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June 2009

جامعة بوليتكنك فلسطين
الخليل – فلسطين
كلية الهندسة و التكنولوجيا
دائرة الهندسة الكهربائية والحاسوب

اسم المشروع

قياس السكر في الدم باستخدام الطريقة الضوئية

أسماء الطلبة

نداء فراش غدير القصراوي نسرين رمضان

بناء على نظام كلية الهندسة والتكنولوجيا واشراف ومتابعة **المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة** تم تقديم هذا المشروع الى دائرة الهندسة الكهربائية والحاسوب .**وذلك للوفاء بمتطلبات** درجة البكالوريوس في الهندسة تخصص هندسه الأجهزة الطبية.

توقيع المشرف

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توقيع اللجنه الممتحنه

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توقيع رئيس الدائره

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الاهداء

عندما يعيش الإنسان في وسط **الظلم والمعاناة**
وتنسكب الدموع غزيرة في دنيا **الآلام**
وتقف العين بكل ما **ترى من مجازر شامخة**
وينجز عملا ما ليكون **بإذن الله في القمة** يهديه ويقدمه **إلى** اعز من لديه بالوجود

إلى المعلم الأول عليه الصلاة والسلام

إلى نبض روحي المتألقة بالعطاء..... والدي الحبيب
إلى تلك الوردة المفتحة..... أمي الغالية

إلى أهل فلسطين **الصمود**
إلى إخوتي
أخواتي
أهلي جميعا
إلى زملائي وزميلاتي

إلى كل من ساهم في إنجاح ودعم مسيرتنا التعليمية

نهدي عملنا المتواضع هذا
ونسأل الله أن يجعله في ميزان حسناتنا يوم القيامة

Acknowledgment

We would like to thank Palestine Polytechnic University, Collage of Engineering and Technology, and Electrical and Computer Engineering department.

Also thanks to our parents for their support and love.

We would like to thank every body shared in this success of our project; thanks to Dr.Ramzi AL-Qawassmi, for his suggestions and supervision during the establishment process of the project and for the reviewing of the report.

Thank to assistant Eng-Ashraf Abu-Aresh, Eng-Feda' Jaafreh.

Abstract

Diabetes become the update disease, the number of people who are suffering from this sickness is increased. As a result of that the observation of the blood is extremely necessary .

It is extremely necessary to design equipment that measure the blood sugar depending on the optical characteristics of the blood, Optical method can easily carried and used without referring to the clinics or hospitals, and it is easy to repeat the measurement.

The idea of the project is to design and build glucose meter that can measure a user's blood sugar .The device consisted of main parts: light source (Halogen lamp), filter, tube for blood sample, photocell, and amplification circuit.

The filter allows the visible light of wave length of 530nm to pass and goes through the blood sample. The photocell converts the optical signal to current. The C/V converter converts the current into voltage. And the microcontroller converts the analog signal to digital after it has been amplified, and displays it on a liquid crystal display.

After finishing the construction of pieces and testing, all of the components are put together in one package.

خلاصة المشروع

لقد أصبح مرض السكري من امراض العصر الحديث وازداد عدد الاشخاص الذين يعانون من ارتفاع سكر الدم ، وباتت مراقبة السكر لدى هؤلاء المرضى من الضروريات الملحة لذلك اقترح فريق العمل تصميم (جهاز لفحص السكري) ليكون قادرا على إعطاء تركيز الجلوكوز في الدم.

ومع تطور التكنولوجيا وصعوبه استخدام اجهزه قياس فحص السكر العاديه من قبل المرضى ، و الحاجه لمراجعه الطبيب . أصبح من الضروري توفر جهاز طبي لا يعتمد على الطريقه الكيميائيه ، التي تحوي صعوبات كبيره في الحصول على هذه المواد بالاضافه الى صعوبه استخدامها.
لذا كان من الضروري تصميم جهاز لقياس نسبه السكر في الدم اكثر عمليا واقل تكلفه و وبدون الحاجه الى تلك المواد الكيميائية, أيضا كان الحافز لهذا المشروع مستندا على الرغبة في اكتساب الخبرة وتعميق فهم الأجهزة المخبرية الطبية,والرغبة بتطبيق هذا التصميم لقياس تركيز الجلوكوز بالدم لمختلف فئات الأعمار.

يتميز جهاز قياس السكر الضوئي باحتوائه على الاجزاء الرئيسيه التاليه :مصدر ضوئي،وفلتر (يمرر الضوء المرئي ذو الطول الموجي ٥٣٠ نانوميتر) ووعاء زجاجي يحتوي على العينه المراد فحصها .بالاضافه إلى خليه ضوئية وأخيرا شاشه عرض.

ويمر المشروع بهذه المراحل: المرحلة الأولى: يقوم الطبيب المخبري بأخذ العينة من المريض ووضعها في المكان المخصص لها من الجهاز، المرحلة الثانية بعد وضع العينة في المكان المخصص لها من الجهاز لتكون متوسطه لمسار الضوء,يتم اختراق الضوء للعينة من خلال مصدر الضوء ويمر هذا الضوء على فلتر ضوئي (350nm) لحجب الأطول الأخرى من الاختراق،وبعد اختراق شعاع الضوء للعينة يسقط على مجس ضوئي ليقوم بتحسس كمية الضوء النافذة من العينة وبالتالي تغير الجهد تبعا لتركيز الجلوكوز في العينة، المرحلة الثالثة تتمثل في معالجة هذه الإشارة الكهربائية لتصبح جاهزة لعرضها على شاشة عرض رقميه.

وبعد الانتهاء من تركيب القطع وتجريبها ,توضع جميعها في صندوق صغير سهل الحمل يمكن المريض من مراقبه السكر في دمه.

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ATP	Adenosine Triphosphate
CSF	Cerebrospinal Fluid
LCD	Liquid Crystal Display
ADC	Analog to Digital Convertor
NADP	Nicotinamide-Adenine Dinucleotide Phosphate
C/V	Current to voltage converter
G%	Glucose concentration

Chapter

1 Introduction

1.1 Introduction.

1.2 Project objectives.

1.3 Project importance.

1.4 Project content.

1.5 Time plan.

1.6 Cost.

Chapter one

Introduction

1.1 Introduction

There are more than one method for measuring the glucose of the blood, The first one was to convert the sugar in blood into PH, this idea was easy to apply, but there was one problem, that is the materials used to convert the sugar into PH is a secrets of companies and they didn't allow to give their secrets to anyone, and the other method, which was called chemical method. In which we used a chemical materials and chemical reactions, this method also was easy; but we faced a problem in the chemical materials; that materials not available; and we have to recommend for it and that will take along time; in addition it may be not found.

Finally, we decided to use the optical method; this method was easy and available, and there are no problems in applying it.

Our final project is to design and build glucose devices that can measure a user's blood sugar by using photometric method. The devise consisted of main parts: light source (halogen lamp), filter, and tube for blood sample, photocell, and processing circuit .

The filter allows the visible light of wave length of 535nm to pass and go through the blood sample. The photocell converts the optical signal to current. The current to voltage converter is used to produce voltage signal. Microcontroller is used to control the operation when start and when stoped, also used to convert the analog signal to digital signal, and displays it on a LCD display. All of the components are put together in one package.

It is undeniable that nowadays people are more aware of the health conditions. One of the most widely used methods to test the health conditions of an individual is to measure his blood sugar. We, as ones of those who are concerned about their health, decide to work on this subject matter because we would like to build something that is useful and useable in real life.

1.2 Project objectives:

The main objectives of this project are:

1. To study the physiology of the blood sugar. To design glucose measurement device by using light absorption property.
2. To increase our conception and to get greater depth of understanding the laboratory instrumentation.
3. To design glucose measurement device by using light absorption property
4. To be used as an instructional purpose in the biomedical laboratory in our university.

1.3 Project importance:

It is undeniable that nowadays people are more aware of the health conditions. One of the most widely used methods to test the health conditions of an individual is to measure his blood sugar.

Our project is important, because it adds a new technique to the medical measurement systems through the safe glucometer instrument for blood sugar.

The importance of the device comes from the following:

* It is safe.
* Simple to use.
* Test can be repeated.
* The patient doesn't require special preparation.

1.4 project content:

Our report is divided into five chapters; these chapters are described as follows:

Chapter one: Introduction.

Chapter two: Physiological background.

Chapter three: Measurement of glucose in blood.

Chapter four: Project conceptual design.

Chapter five: Detailed Technical Project Design.

Chapter six : Software.

Chapter seven: System results.

Chapter eight: Conclusions and recommendations.

1.5 Time plane

Table 1.1
Time scheduling

Time (week)	Activity
5	Study blood sugar physiology
7	Study blood sugar measurements
8	Literature review
10	Design theory
12	Theoretical report ready
13	Discussion for project
16	Design the schematic block diagram

1.6 Cost

There are many electronic chips and electrical equipments have to be provided as shown in table below:

Table 1.2
Hardware cost

Component	Cost(Dolores)
Light source & filter	125$
Light detector	1.25$
Processing circuit	1.25$
Microcontroller	17.5$
LCD	10$
Transformer	8.75$
TOTAL	163.75$

Chapter

2 Physiological Background

2.1 Introduction.

2.2 Regulation of Glucose.

2.3 Reasons of monitoring glucose.

2.4 What is diabetes?

2.5 Diabetes Statistics.

Chapter two

Physiological Background

2.1 Introduction

Glucose is a form of simple sugar, which is a carbohydrate. Our cells need it for energy. Glucose is important for cellular respiration. Chemically, glucose is made up of six carbon atoms, twelve hydrogen atoms, and six oxygen atoms. Naturally, glucose can be found in plants and is one of the products needed for photosynthesis. Glucose is found in fungi and starchy plants. Animals synthesize glucose in the liver and kidneys. Commercially, glucose is found in food products such as corn, rice, wheat products, andpotatoes.

Glucose is an energy source for the body. It is the main source of energy for the brain, and when glucose levels are low, person's mental abilities may be impaired. Since glucose is distributed through our bodies by our blood streams, where it meet and reacts with insulin, ingesting too much glucose will overwhelm the body. When the body's glucose level is too high, the body becomes hyperglycemic which means you have too much sugar and too little insulin. Hypoglycemia and diabetes are disorders that that result when the body cannot regulate glucose and/ or insulin levels, and can happen after years of consuming too much glucose. People who consume too little glucose (usually by not eating enough food in general) become hyperglycemic. This results in low energy levels and can lead to fainting [1].

2.2 Regulation of Glucose

The human body wants blood glucose (blood sugar) maintained in a very narrow range. Insulin and glucagon are the hormones which make this happen. Both insulin and glucagon are secreted from the pancreas, and thus are referred to as pancreatic endocrine hormones. Figure 2.2 shows the intimate relationship both insulin and glucagon have to each other. Note that the pancreas serves as the central player in this scheme. It is the production of insulin and glucagon by the pancreas which ultimately determines if a patient has diabetes, hypoglycemia, or some other sugar problem.

Insulin and glucagon are hormones secreted by islet cells within the pancreas. They are both secreted in response to blood sugar levels, but in opposite fashion.

Insulin is normally secreted by the beta cells (a type of islet cells) of the pancreas. Although there is always a low level of insulin secreted by the pancreas, the amount secreted into the blood increases as the blood glucose rises. Similarly, as blood glucose falls, the amount of insulin secreted by the pancreatic islets goes down. insulin has an effect on a number of cells, including muscle, red blood cells, and fat cells .In response to insulin, these cells absorb glucose out of the blood, having the net effect of lowering the high blood glucose levels into the normal range.

Glucagon is secreted by the alpha cells of the pancreatic islets in much the same manner as insulin...except in the opposite direction. If blood glucose is high, then no glucagon is secreted. When blood glucose goes low, however, (such as between meals, and during exercise), more and more glucagon is secreted. Like insulin, glucagon has an effect on many cells of the body, but most notably the liver. The effect of glucagon is to make the liver release the glucose it has stored in its cells into the blood stream, with the net effect of increasing blood glucose. Glucagon also induces the liver (and some other cells such as muscle) to make glucose out of building blocks obtained from other nutrients found in the body (e.g., protein).

Our bodies desire blood glucose to be maintained between 70 mg/dl and 110 mg/dl (mg/dl means milligrams of glucose in 100 milliliters of blood). Below 70 is termed "hypoglycemia". Above 110 can be normal if you have eaten within 2 to 3 hours. Even after you have eaten, however, your glucose should be below 180. Above 180 is termed "hyperglycemia" (too much glucose in the blood). If you have two blood sugar measurements above 200 after drinking a sugar-water drink (glucose tolerance test), then you are diagnosed with diabetes [2] .

Table 2.1

Blood Sugar Range [10]

Elevated Blood Sugar Range	**Risk of Complications**
Above 800mg/dl	Life threatening acute risk
400 mg/dl – 800 mg/dl	Very high risk
250 mg/dl – 400 mg/dl	High risk
180 mg/dl – 250 mg/dl	Moderate risk
110 mg/dl – 180 mg/dl	Low risk
70 mg/dl – 110 mg/dl	Normal rang

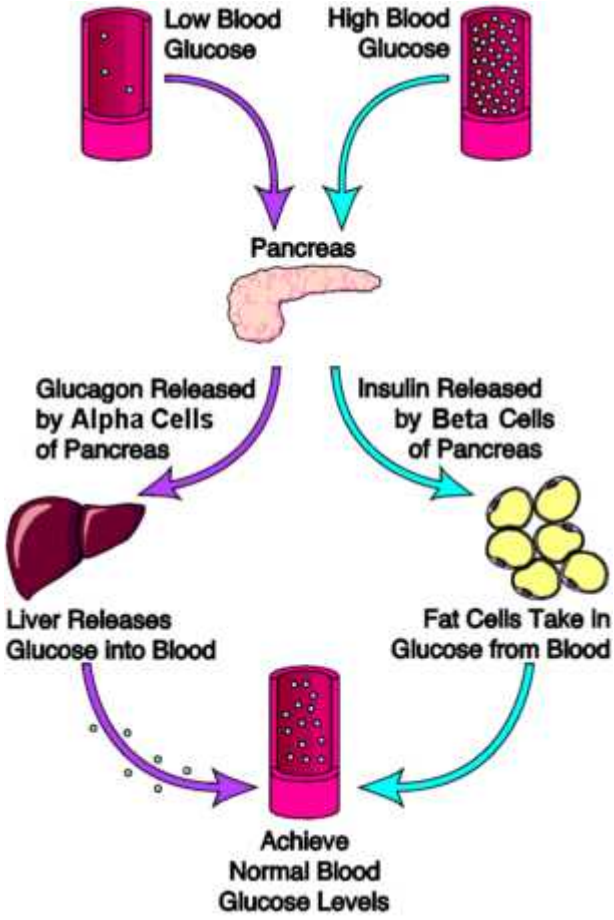


Fig 2.1: Roles of insulin and glucagon [13]

2.3 Reasons of monitoring glucose

1. Monitoring shows you what your blood glucose is doing at the best of times, while you are feeling good and in your usual routine. This allows you to interpret the readings under more unusual circumstances. It also lets you to catch any changes in your glucose as time goes by.
2. It shows you how your blood glucose varies over the course of the day, indicating trends.
3. It shows you what happens to your blood glucose when there is a change in physical activity, such as playing sports.
4. It shows you what is happening to your blood glucose in times of illness.

5. It shows you what happens to your glucose when there is a change in medication (for diabetes or any other illness), and where further changes need to be made.
6. If recorded properly, it shows your doctor all of the above so that he can better advise you about your diabetes medications.

2.3.1 Testing Blood Sugar

Testing the blood before meals and after offers different information. As a general rule, readings taken before meals indicate how low your glucose can get. Testing after meals shows you how high the blood glucose went, due to the absorption of the food. It should be done 2 hours after eating. Both pre-meal and post-meal testing supply important information. The most common mistake people make in testing is always testing at the same time of day [3].

2.4 What is diabetes?

Diabetes is a group of diseases marked by high levels of blood glucose, also called blood sugar, resulting from defects in insulin production, insulin action, or both, Diabetes can cause serious health complications including heart disease, blindness, kidney failure, and lower-extremity amputations.

But people with diabetes can take steps to control the disease and lower the risk of complications.

2.5.1 The symptoms of diabetes

People who think they might have diabetes must visit a physician for diagnosis. They might have SOME or NONE of the following symptoms:

- Frequent urination
- Excessive thirst
- Unexplained weight loss
- Extreme hunger
- Sudden vision changes
- Tingling or numbness in hands or feet
- Feeling very tired much of the time
- Very dry skin
- Sores that are slow to heal
- More infections than usual.

2.5.2 Types of Diabetes

Type 1 diabetes was previously called insulin-dependent diabetes mellitus (IDDM) or juvenile-onset diabetes. Type 1 diabetes develops when the body's immune system destroys pancreatic beta cells, the only cells in the body that make the hormone insulin that regulates blood glucose. To survive, people with type 1 diabetes must have insulin delivered by injection or a pump. This form of diabetes usually strikes children and young adults, although disease onset can occur at any age. In adults, type 1 diabetes accounts for 5 to 10 percent of all diagnosed cases of diabetes. Risk factors for type 1 diabetes may be autoimmune, genetic, or environmental. No known way to prevent type 1 diabetes exists. Several clinical trials for the prevention of type 1 diabetes are currently in progress or are being planned.

Type 2 diabetes was previously called non-insulin-dependent diabetes mellitus (NIDDM) or adult-onset diabetes. In adults, type 2 diabetes accounts for about 90 to 95 percent of all diagnosed cases of diabetes. It usually begins as insulin resistance, a disorder in which the cells do not use insulin properly. As the need for insulin rises, the pancreas gradually loses its ability to produce it. Type 2 diabetes is associated with older age, obesity, family history of diabetes, history of gestational diabetes, impaired glucose metabolism and physical inactivity.

Gestational diabetes is a form of glucose intolerance diagnosed during pregnancy. It is also more common among obese women and women with a family history of diabetes. During pregnancy, gestational diabetes requires treatment to normalize maternal blood glucose levels to avoid complications in the infant. Immediately after pregnancy, 5 to 10 percent of women with gestational diabetes are found to have diabetes, usually type 2. Women who have had gestational diabetes have a 40 to 60 percent chance of developing diabetes in the next 5 to 10 years.

Other types of diabetes result from specific genetic conditions, such as maturity-onset diabetes of youth; surgery; medications; infections; pancreatic disease; and other illnesses. Such types of diabetes account for 1 to 5 percent of all diagnosed cases.

2.5.3 The treatment of diabetes

Healthy eating, physical activity, and insulin injections are the basic therapies for type 1 diabetes. The amount of insulin taken must be balanced with food intake and daily activities. Blood glucose levels must be closely monitored through frequent blood glucose testing.

Healthy eating, physical activity, and blood glucose testing are the basic therapies for type 2 diabetes. In addition, many people with type 2 diabetes require oral medication, insulin, or both to control their blood glucose levels.

People with diabetes must take responsibility for their day-to-day care, and keep blood glucose levels from going too low or too high.

People with diabetes should see a health care provider who will monitor their diabetes control and help them learn to manage their diabetes. In addition, people with diabetes may see endocrinologists, who may specialize in diabetes care; ophthalmologists for eye examinations; podiatrists for routine foot care; and dietitians and diabetes educators who teach the skills needed for daily diabetes management

2.4 Diabetes Statistics:

1. Diabetes currently affects 246 million people worldwide and is expected to affect 380 million by 2025.
2. In 2007, the five countries with the largest numbers of people with diabetes are India (40.9 million), China (39.8 million), the United States (19.2 million), Russia (9.6 million) and Germany (7.4 million).
3. In 2007, the five countries with the highest diabetes prevalence in the adult population are Nauru (30.7%), United Arab Emirates (19.5%), Saudi Arabia (16.7%), Bahrain (15.2%), and Kuwait (14.4%).
4. Each year a further 7 million people develop diabetes.
5. Each year 3.8 million deaths are attributable to diabetes. An even greater number die from cardiovascular disease made worse by diabetes-related lipid disorders and hypertension.
6. Every 10 seconds a person dies from diabetes-related causes.
7. Every 10 seconds two people develop diabetes.
8. Diabetes is the fourth leading cause of global death by disease.
9. Up to 80% of type 2 diabetes is preventable by adopting a healthy diet and increasing physical activity.
10. Diabetes is the largest cause of kidney failure in developed countries and is responsible for huge dialysis costs.
11. Type 2 diabetes has become the most frequent condition in people with kidney failure in countries of the Western world. The reported incidence varies between 30% and 40% in countries such as Germany and the USA.
12. Diabetic retinopathy is the leading cause of vision loss in adults of working age (20 to 65 years) in industrialized countries.
13. On average, people with type 2 diabetes will die 5-10 years before people without diabetes, mostly due to cardiovascular disease.
14. Cardiovascular disease is the major cause of death in diabetes, accounting for some 50% of all diabetes fatalities, and much disability [4].

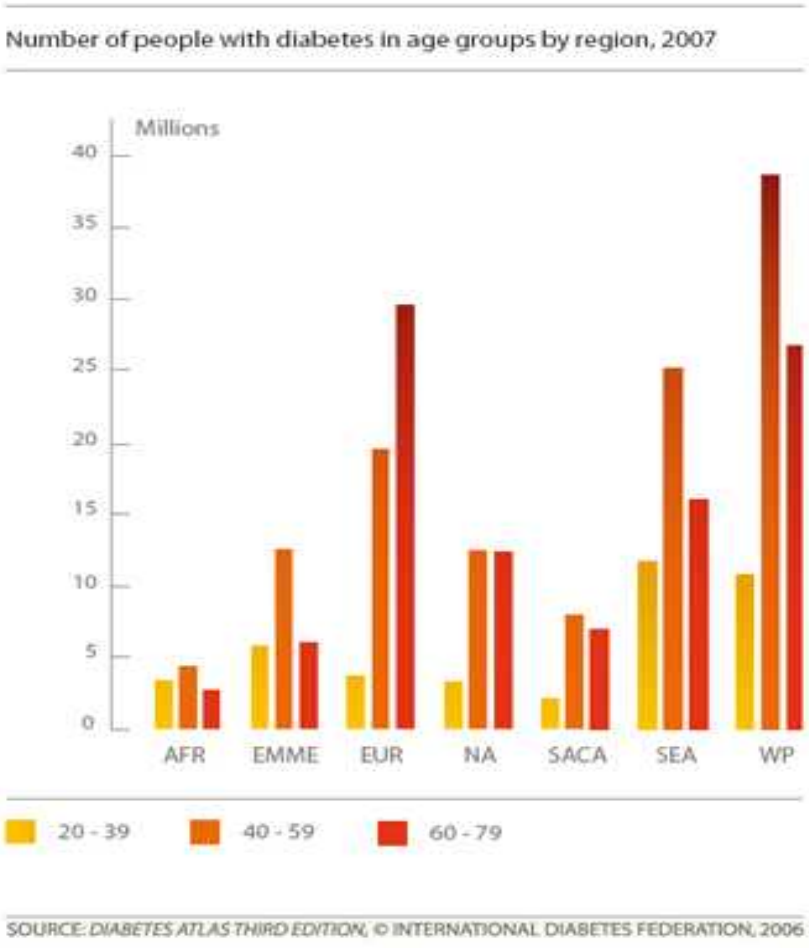


Fig2.2:Number of people with diabetes in age groups,2007.(AFR : Africa , EMM : Eastern Mediterranean and Middle East , EUR : Europe , NA : North America, SACA: South and Central America, SEA: South East Asia ,WP :Western Poland [11] .

Chapter

3 Measurement of Glucose in Blood

3.1 Introduction.

3.2 Methods of measuring blood glucose.

3.3 Reference intervals.

3.4 The use of the spectrophotometer and Beer's Law.

Chapter three

Measurement of Glucose in Blood

3.1 Introduction

Many analytical procedures are used to measure blood glucose levels. In the past, analyses were often performed with relatively nonspecific methods that resulted in falsely elevated values. Almost all commonly used techniques are now enzymatic methods.

In individuals with a normal hematocrit, fasting whole blood glucose concentration is approximately 12% to 15% lower than plasma glucose. Although the glucose concentration in the water phase of red blood cells and plasma is similar (the erythrocyte plasma membrane is freely permeable to glucose), the water content of plasma (93%) is approximately 12% higher than that of whole blood. In most clinical laboratories, plasma or serum is used for the majority of glucose determinations, whereas most methods for self-monitoring of glucose use whole blood. During fasting, capillary blood glucose level is only about 2 to 5 mg/dl higher than that of venous blood. After glucose load, however, capillary blood glucose concentrations are 20 to 70 mg/dl (mean 30 mg/dl) greater than concurrently drawn venous blood samples.

3.2 Methods of measuring blood glucose:

3.2.1 Hexokinase Methods

Principle: Glucose is phosphorylated by ATP in the presence of hexokinase and Mg^{2+}. The glucose-6-phosphate formed is oxidized by glucose-6-phosphate dehydrogenase (G-6-PD) to 6-phosphogluconate in the presence of nicotinamide-adenine dinucleotide phosphate ($NADP^{+}$). The amount of NADPH produced is directly proportional to the amount of glucose in the sample and is measured by

absorbance at 340 nm. G-6-PD derived from yeast is used in the assay with $NADP^+$ as the cofactor. Nicotinamide-adenine dinucleotide (NAD^+) is the cofactor if bacterial G-6- PD is used, and the NADH produced is also measured at 340 nm.

Glucose + ATP $\xrightarrow{\text{hexokinase}}$ **glucose-6-phosphate + ADP**

Glueose-6-phosphate + $NADP^+$ $\xrightarrow{\text{G-6-PD}}$ **6-phosphogluconate + NADPH + H+**

(Or NAD^+) **(Or NADH)**

A generally accepted reference method based on this principle has been developed and validated. Serum or plasma is deproteinated by the addition of solutions of barium hydroxide ($Ba[OH]_2$) and zinc sulfate ($ZnSO_4$). The clear supernatant is mixed with a reagent containing ATP, NAD+, hexokinase, and G-6-PD; the mixture is incubated at 25 °C until the reaction is complete; and the NADH is measured. Calibrators and blanks are carried through the entire procedure, including the deproteination step.

Although highly accurate and precise, the reference method is too exacting and time consuming for routine use in a clinical laboratory. An alternative approach is to apply the reaction directly to serum or plasma and to use a specimen blank to correct for interfering substances that absorb at 340 nm.

Either serum or plasma may be used. NaF, with an anticoagulant such as EDTA, heparin, oxalate, or citrate, may be used. Hemolyzed specimens containing more than 0.5 g of hemoglobin per deciliter are unsatisfactory because phosphate esters and enzymes released from red blood cells interfere with the assay. Other sources of interference include drugs, bilirubin, and lipemia (triglyceride level ≥500 mg/dL causes a positive interference).

Absorbances of sample or calibrator reaction mixtures are measured after the reactions have continued to the point of completion (equilibrium reaction). Although glucose concentrations may be calculated directly, based on the molar absorptivity of NADPH or NADH, inclusion of a set of calibrators is recommended to detect possible

deterioration of enzymes, ATP, $NADP^+$, or NAD^+. All of which are unstable. Reagents may also contain substances that react with the coenzymes.

Presence of these substances can be evaluated by measuring the increase in absorbance observed in a reagent blank. The highest calibrator provides a check on linearity of response and the adequacy of the enzyme reagent. The procedure is linear from 0 to 500 mg/dL. Glucose concentrations that exceed 500 mg/dL should be diluted with isotonic saline and reassayed.

Hexokinase procedures in which indicator reactions produce colored products are also available, enabling absorbance to be measured in the visible range. An oxidation-reduction system containing phenazine methosulfate and a substituted tetrazolium compound.

2- (p-iodophenyl) -3-p- nitrophenyl -5-phenyltetrazoliurn chloride (INT), is reacted with NADPH formed in the reaction. The reduced INT is colored with maximum absorbance at 520 nm.

3.2.2 Glucose Oxidase Methods

Principle: The enzyme glucose oxidase catalyzes the oxidation of glucose to gluconic acid and hydrogen peroxide (H_2O_2):

$$\text{Glucose} + 2\,H_2O + 0_2 \xrightarrow{\text{glucose oxidase}} \text{gluconic acid} + 2\,H_2O_2$$

Addition of the enzyme peroxidase and a chromogenic oxygen acceptor, such as o-dianisidine, results in the formation of a colored compound that can be measured:

$$\underset{\text{(Colorless)}}{\text{o-Dianisidine} + H_2O_2} \xrightarrow{\text{peroxidase}} \underset{\text{(Colored)}}{\text{oxidized o-dianisidine} + H_2O}$$

Glucose oxidase is highly specific for β-D-glucose Since 36% and 64% of glucose in solution are in the α- and β-forms, respectively, complete reaction requires

mutarotation of the α - to β- form. Some commercial preparations of glucose oxidase contain an enzyme, mutarotase, which accelerates this reaction. Otherwise, extended incubation time allows spontaneous conversion.

The second step, involving peroxidase, is much less specific than the glucose oxidase reaction. Various substances, such as uric acid, ascorbic acid, bilirubin, hemoglobin, tetracycline, and glutathione, inhibit the reaction (presumably by competing with the chromogen for H_2O_2, producing lower values. Some glucose oxidase preparations contain catalase as a contaminant; catalase activity decomposes peroxide and decreases the final color obtained. Calibrators and unknowns should be analyzed simultaneously under conditions in which the rate of oxidation is proportional to glucose concentration.

Modifications: Some instruments use a polarographic oxygen electrode that measures the rate of oxygen consumption after the sample is added to a solution containing glucose oxidase. Because this measurement involves only the first reaction shown earlier, interferences encountered in the peroxidase step are eliminated. To prevent formation of oxygen from H_2O_2 by catalase present in some preparations of glucose oxidase, H,O, is removed by two additional reactions:

$$H_2O_2 + C_2H_2OH \xrightarrow{\text{catalase}} CH_3CHO + 2\,H_2O$$

ethanol — acetaldehyde

$$H_2O_2 + 2\,H^+ + 2I^- \xrightarrow{\text{molybdate}} I_2 + 2H_2O$$

The latter reaction is effective even when catalase activity has diminished on storage of reagents. The procedure can be applied directly to urine, serum, plasma, or CSF. However, this approach cannot be used for the determination of glucose in whole blood because blood cells consume oxygen.

3.2.3 Glucose Dehydrogenase Methods

Principle: The enzyme glucose dehydrogenase (β-D- glucose:NAD oxidoreductase) catalyzes the oxidation of glucose to gluconolactone:

$$\text{Glucose} + NAD^{+} \xrightarrow{\text{glucose dehydrogenase}} \text{D-glucono-}\delta\text{-lactone} + NADH + H^{+}$$

Mutarotase is added to shorten the time necessary to reach equilibrium. The amount of NADH generated is proportional to the glucose concentration. The reaction appears to be highly specific for glucose, shows no interference from common anticoagulants and substances normally found in serum, and provides results in close agreement with hexokinase procedures.

3.3 Reference intervals

Although glucose can be assayed by a number of different analytical procedures, reference intervals do not vary significantly among methods. The following values should apply to virtually all currently used glucose assays.

Sample	Fasting Glucose (mg/dl)
Plasma/serum	
Children	70-105
Premature neonates	25-80
Term neonates	30-90
Whole blood	60-95
CSF	40-75 (60% of plasma value)
Urine	
Random	< 30 mg/dl
24-hr	<500mg/24hr

Plasma glucose levels show no sex difference. Plasma glucose values increase with age: approximately 2 mg/dl per decade for fasting levels; 4 mg/dl per decade for postprandial levels; and 8 to 13 mg/dl per decade after a glucose challenge.

the plasma values and must always be compared with concurrently measured plasma values for adequate clinical interpretation [9] .

3.4 The Use of the Spectrophotometer and Beer's Law

Scientists use many methods to determine the identity and quantity of a substance in samples.

Spectroscopy is a simple and powerful method for performing both qualitative and quantitative analyses. Each chemical species has a unique spectral fingerprint based on where electrons are located with respect to the nucleus.

For example, a solution of sodium ions sprayed into a flame will change the flame's color to a bright yellow, while a solution of lithium ions will cause the flame to burn a deep red color.

These flame tests reveal the solution's emission spectrum – the wavelength (or color) of light revealed by the flame is due to excited electrons within atoms and ions in the solution relaxing to a lower energy state, emitting photons. A photon is a packet of light energy, the first indication that light may have particle-like properties.

The flame provides the energy used to excite the electrons within the metal ions. The wavelength of radiation emitted can then be used to determine the energy lost by the electron as it relaxes.

Since electrons can occupy only discrete energy states, the way radiation interacts with matter can indicate its chemical identity. Chemists commonly use absorbance spectroscopy, or how a substance absorbs photons of light, to obtain both qualitative (identity) and quantitative (amount) information. The quantitative measurement is achieved because each photon of light absorbed corresponds to the excitation of a single electron.

Of course, in the laboratory, analyses are performed on large numbers of atoms or molecules, therefore a relationship must be established to obtain quantitative information.

Initial spectrophotometric studies measured transmittance, which is defined as the fraction of light that passes through the sample:

$$T = \frac{I}{Io} \quad \text{…….. (3.1)}$$

%T= T x 100

Where:

Io*:* is the intensity of the light passing through the solvent.

I*:* is the intensity of light that passes through the sample solution.

Percent transmittance (%T) is simply the transmittance fraction multiplied by 100. A more useful quantity in performing analyses is the absorbance or the negative log of transmittance (A = **– log T**).

A linear relationship exists between absorbance and concentration known as Beer's Law (**A = ε b c**), where:

b: is the length of the path traveled by light through the sample.

c:is the concentration.

ε : is a molar absorptive constant that depends on both wavelength and substance.

This linear relationship between concentration and absorbance allows scientists to use spectroscopy for quantitative measurements of unknown samples.

Chapter

4 Project conceptual design

4.1 Project objectives.

4.2 General block diagram.

4.3 Operating principles.

Chapter four

Project conceptual design

Our project is to design and build **Glucose measurement device** by measuring the quantity of light transmitted through a sample of blood Placed In the test tube using light source and Light detector, and processing the analog voltage signal to display it on LCD**.**

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

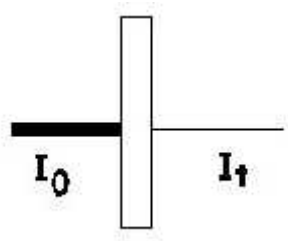
Beer's Law states that the absorbance, A(λ), of a species at a particular wavelength of electromagnetic radiation, λ, is proportional to the concentration, c, of the absorbing species and to the length of the path, l, of the electromagnetic radiation through the sample containing the absorbing species. This can be written in the form:

$$A(\lambda) = e(\lambda)\, l\, c$$

The proportionality constant e (λ) is called the absorptive of the species at the wavelength, λ.

[e (λ) is called the molar absorptive if the concentration is measured in *moles/liter*.]

It is common to use the *energy* carried by the radiation per *unit area* per *unit time*, which is called the intensity, I, to measure of the "amount" of electromagnetic radiation impinging on a surface. For a partially transparent sample, we can consider the fraction of the intensity that is permitted to pass through the sample as a measure of the transmittance of the sample. In fact, we define the percent transmittance, %T , of a sample in terms of the intensity of the light incident on the sample, I_0 , and the light transmitted through the sample, I_t as:



$$\%T = 100\ I_t / I_0$$

A completely transparent sample will have $I_t = I_0$, and its percent transmittance will be, appropriately, 100. Similarly, a sample which permits no radiation of a particular wavelength to pass through it will have $I_t = 0$, and a corresponding percent transmittance of 0.

Since the more interesting materials are those that absorb electromagnetic radiation at some frequencies, we define absorbance of light of wavelength λ by a sample in terms of the percent transmittance. Since the amount of radiation absorbed can vary over an extremely wide range, it is useful to define absorbance logarithmically. The absorbance of a sample is defined in terms of percent transmission as follows:

$$A(\lambda) = \log (100 / \%T)$$

4.1 project objectives:

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

1. To increase our conception and to get greater depth of understanding the laboratory instrumentation.
2. To be used as an instructional purpose in the biomedical laboratory at PPU.
3. To design a glucose measurement device by using light absorption property.

4.2 General block diagram

Fig 4.1 shows the general block diagram of our project, which contains the following main part:

- Dc power source.
- Light components.
- Test tube.
- Amplification circuit.
- Microcontroller
- Liquid Crystal Display (LCD).

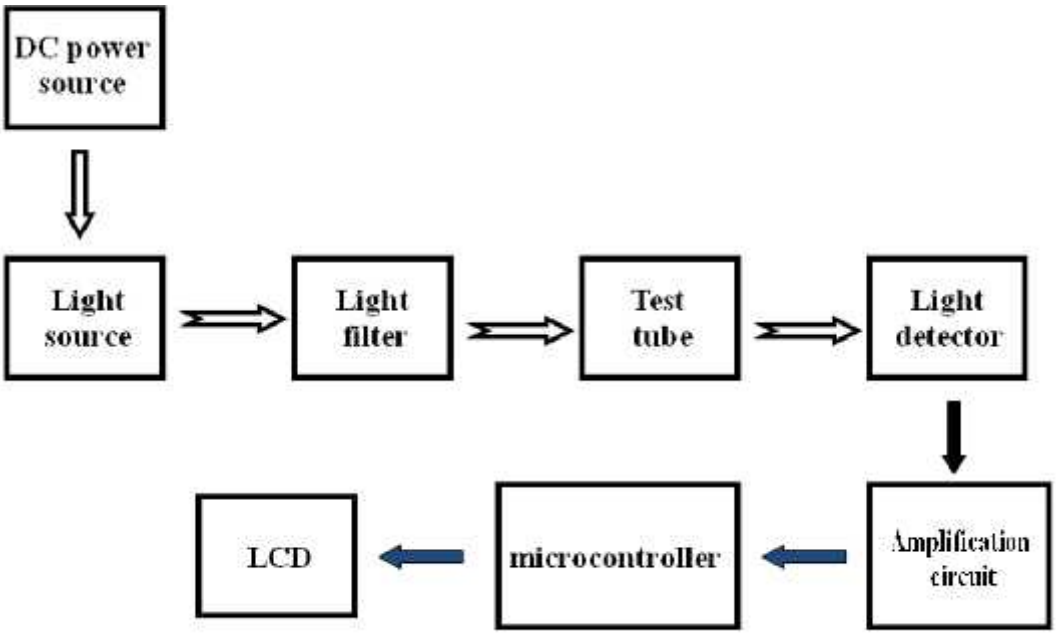


Fig. 4.1: General block diagram

4.2.1 The power source

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

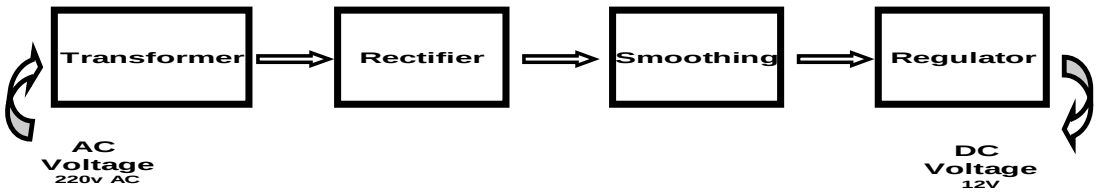


Fig.4.2: Block diagram of regulated power supply system

The circuit of power supply contains:

1. **Transformer:** is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism) and, second, that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil. 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 [15] .

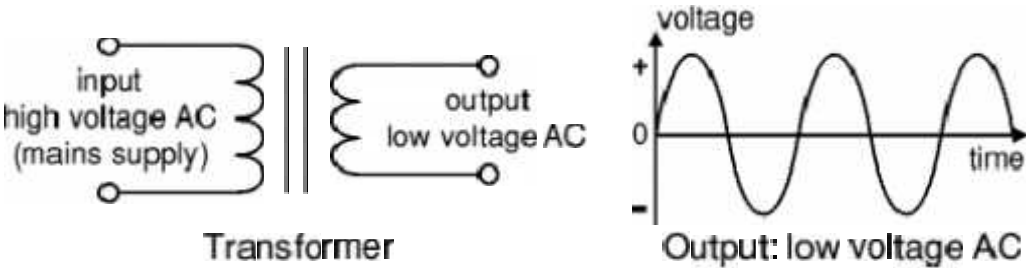


Fig 4.3: Transformer

2. **Rectifier** (full wave rectifier): is an electrical device that converts alternating current to direct current or at least to current with only positive value [18] .

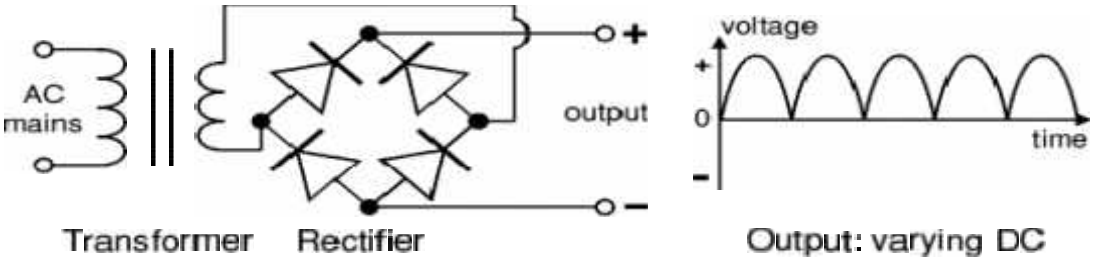


Fig 4.4: Transformer and Rectifier

In half wave rectification, either the positive or negative half of the AC wave is passed, while the other half is blocked, depending on the polarity of the rectifier. Half wave rectification can be achieved with a single diode.

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

3. **Smoothing**: smoothes the DC from varying greatly to a small ripple [18] .

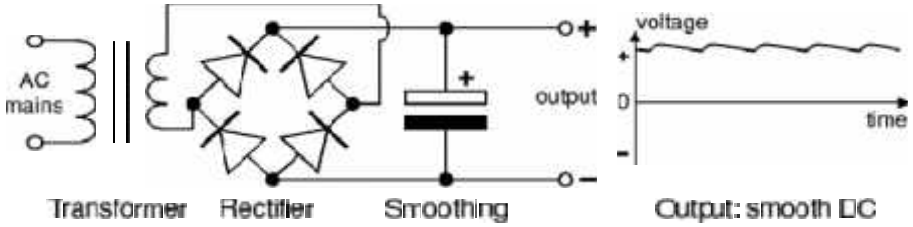


Fig4.5: Transformer, Rectifier and Smoothing

4. **Regulator**: designed to automatically maintain a constant voltage level.[18] .

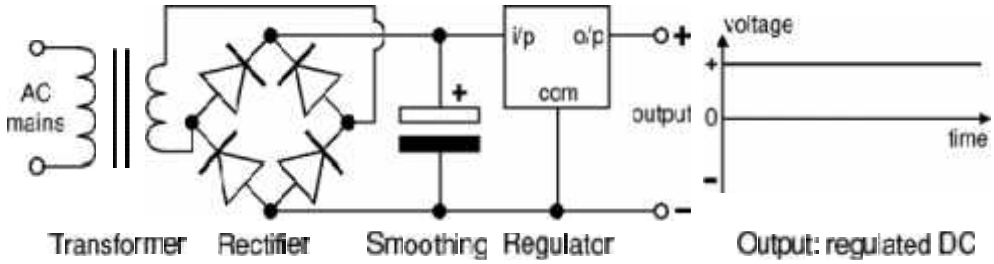


Fig4.6: Transformer, Rectifier, Smoothing and Regulator

4.2.2 Light path components

In our design the light path started with the halogen lamp until it reach the detector; the component of this path are shown in fig 4.7:

1. Light source.
2. Optical filter.
3. Light detector.

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

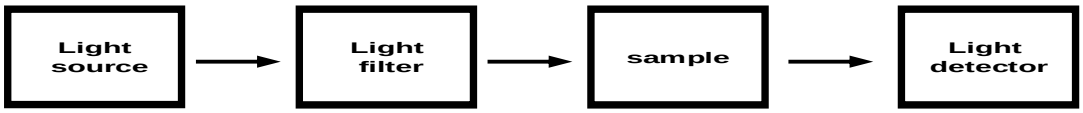


Fig4.7: Light path block diagram

4.2.2.1 Light source

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

This lamp has a special characteristic like:

- Halogen lamps (incandescent lamps) that contain halogen gases such as iodine and bromine that allows working at higher temperatures and higher efficiencies.

Halogen lamps consist of a tungsten filament inside a quartz envelope that is filled with halogen gas. In halogen lamps, the quartz envelope is closer to the filament than the glass used in conventional light bulbs. Heating the filament to a high temperature causes the tungsten atoms to evaporate and combine with the halogen gas. These heavier molecules are then deposited back on the filament surface. Moreover this recycling process increases the life of the tungsten filament and enables the halogen lamp to produce more light per units of energy.

The power source must be of voltage and energy to make the lamp ON state all of 2A, this can achieve by the schematic shown in fig 4.2.

4.2.2.2 Optical filter

Light filter is an optical element such as a sheet of glass, gelatin, or plastic dyed in a specific manner to absorb selectively light of certain colors. Filters are needed to restrict the emitted light to the green region of the spectrum light [19] .

A 530 nm filter (GREEN) are included in our design to select only 530nm light to passes through the sample and block the other entire wavelength.

Since the wavelength=530nm, the frequency of light calculated via the following equation:

$$F = \frac{C}{\lambda} \quad \text{..... (4.1)}$$

$$F = \frac{3*10^{8}}{530*10^{-9}} = 5.6*10^{14}\,Hz$$

Where: c: is the speed of light ($3*10^{8}$m/s).

F: is the light frequency (Hz).

λ: is the light wavelength(m).

Fig 4.8: Green filter of 350n [10]

4.2.2.3 Light detector

The light detector is an electronic device, which provides a variable signal (voltage and current) based on a change in electromagnetic light intensity. The real job of the light detector is to convert light power into electrical power.

There are many types of light detectors (photodiodes, phototransistors, photo resistors, and photomultipliers).

Silicon phototransistors and **Cadmium Sulfide (CdS) photocells** are the most common and least expensive forms of light sensing. Both of these sensors incur less current flow when darkened than when lighted. Phototransistors change their conductance; photocells change their resistance depending on the intensity of the light falling on them.

Photocells are extremely easy to work with; being just variable resistors controlled by light intensity, but their response time is slow compared to the phototransistor's semiconductor junction. As the resistance of the photocell reduces (as more light hits it) the voltage on the analog input will go up. If the resistance of the photocell increases (less light hits it) the voltage on the analog input will fall towards ground (0V).

The **phototransistor** is a light-sensitive current source: the more light which reaches the phototransistor, the more current passes through it. Unlike the **photodiode**, that usually requires an op amp circuit to raise their voltage levels.

A **photodarlington** is another type of sensor. Which are much more light-sensitive than phototransistors (they have two stages of gain instead of one), but have slower response times and higher saturation voltage than the phototransistor devices.

A **photodiode** is a type of photodetector capable of converting light into either current or voltage, depending upon the mode of operation, in our design we use a photodiode which convert light into voltage.

A phototransistor is better to use than any light sensing if very rapid response time is required. Also, these devices are more sensitive to green light, and they have a very high sensitivity compared to other types of sensors.

Since the phototransistor not available in local market we used photodiode, the suitable wavelength for measured glucose concentration is 530 nm, so we used a photodiode of wavelength 400-900 nm.

4.2.3 Test tube

A **test tube**, also known as a culture tube, sample tube, test flute or flaccid flute, is a piece of laboratory glassware composed of a finger-like length of glass tubing, open at the top, with a rounded U-shaped bottom.

We use a test tube in our design to put the blood sample on it.

Features:

- Test tubes are available in a variable lengths and widths to serve a varying number of needs.
- Test tubes are designed to allow easy heating of these samples.
- Test tube allows the light to pass through it.

Fig 4.9: Test tube.[9]

4.2.4 Signal processing stage

The following block diagram (Fig 4.11) shows the last component needed to complete our design:

1. Amplification circuit.
2. Voltage divider.
3. Microcontroller
4. LCD.

Fig 4.10: Signal processing block diagram

4.2.4.1 Amplification circuit.

Since the output voltage of the photodiode is small, we have to amplify it by using the amplification circuit; the following figure shows this circuit.

$V_{out} = I_{in} * R_1$ …… (4.2)

$V_{out} = 0.1 * 10^{-3} * 100 * 10^{3} = 10$ V.

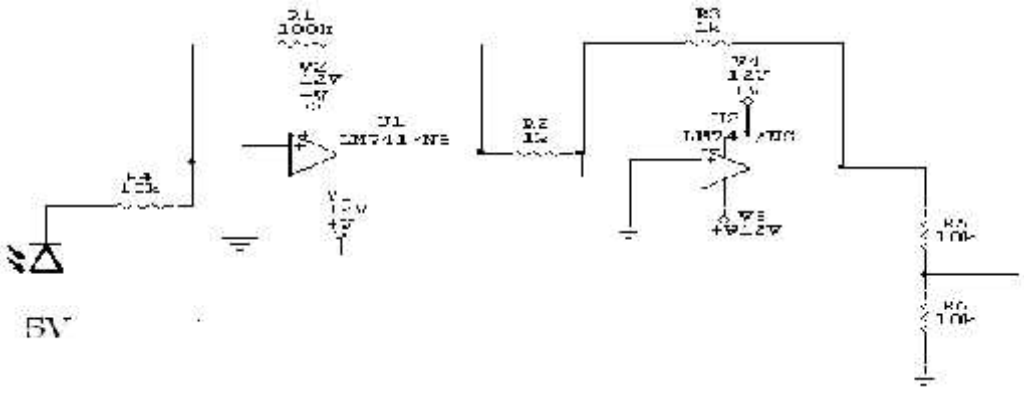


Fig. 4.11: amplification circuit.

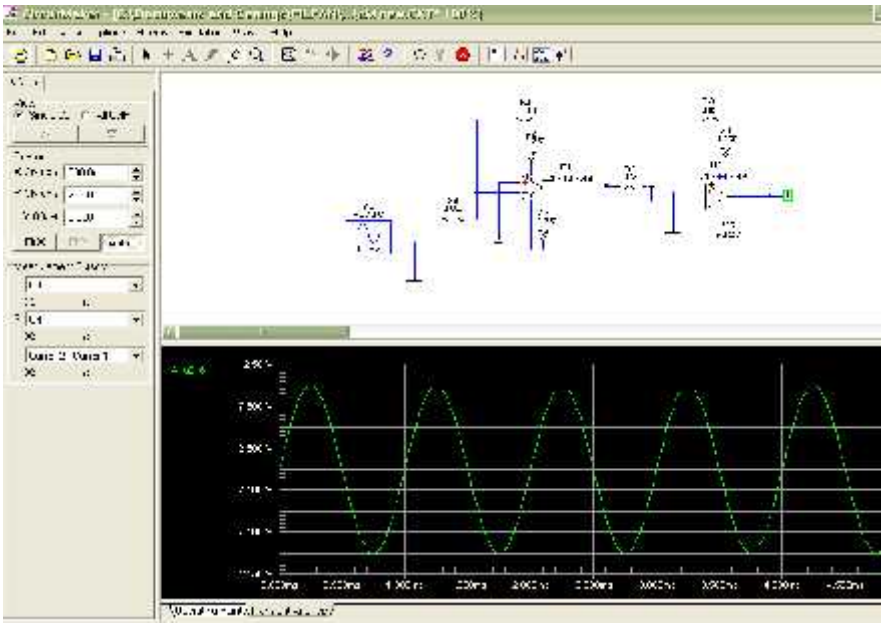


Fig. 4.12: simulation of previous circuit.

4.2.4.2 Voltage divider

Since the microcontroller we used work at the rang of 0-5 volte, and our signal range is from 0-10 volt we need to use a voltage divider circuit ,as shows in the following figure.

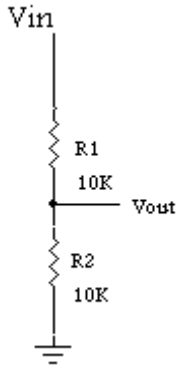


Fig.4.13: Voltage divider circuit.

$$Vout = \left(\frac{R_2}{R_1 + R_2} \right) * Vin \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.3)$$

$$Vout = \left(\frac{10}{10+10} \right) * Vin = \frac{1}{2} * Vin \ldots\ldots\ldots\ldots\ldots (4.4)$$

4.2.4.4 PIC Microcontroller

We use the PIC18F4550 in our project to:

1. Control the operation when start and when stopped.
2. Convert analog signal into digital signal.
3. Display the output on LCD screen.

Features:

- Cheap.
- Simple instruction set.
- Depends on the task.

4.2.4.3 Liquid Crystal Display (LCD)

This LCD that will display the level of glucose measure, indicate alarm when the measured value is abnormal. LCD has many characteristics such as safety viewing, clear for near distance and Low power consumption.

In our design we will use PC 1602-f, which shows in fig 4:15 [14]

Fig 4:14 :(PC1602-f).

Features:

- Application: Telephone applications, measuring instruments, electronic typewriters, handheld data banks. Security systems.
- Compact design.
- Low power consumption.
- 96 ASCII characters + 92 special letters.
- Built-in RAM including character generator.
- Built-in display data RAM.

4.3 Operation principles

These steps show how the system work and what is the tasks of operator to have at end a value of glucose concentration.

- The operator prepares the blood sample.
- After putting the blood sample in its holder the system work as follow:

    - ✓ The halogen lamp gives light with all wavelengths.
    - ✓ The filter allows the light with 530nm to pass through the sample.
    - ✓ The output light from the sample is function of the glucose concentration, as the concentration increased the transmittance light decreased and the absorbance increase (Beer's law).
    - ✓ The photodiode changes the light intensity on it to current passes through the resistor (voltage drop on R).
    - ✓ This signal inters to signal processing stage to get the glucose concentration value on LCD.

Chapter

5 Detailed Technical Project Design

5.1 Detailed Description of the Project Phases.

5.2 Subsystem Detailed Design.

Chapter five

Detailed Technical Project design

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

5.1 Detailed Description of the Project Phases

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

The detailed description of the project phases as follows:

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

- Sensory phase: we used a photodiode to detect the intensity passes out of blood sample to process by microcontroller.

- Processing phase: we used microcontroller which consist ADC to convert the analog signal into digital form to make it suitable to display on the LCD.

5.2 Subsystem Detailed Design.

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

5.2.1 Supply subsystem

In our design we need three different power supply +12V,-12V, - 5V, +5V, for supplying the halogen lamp, Op_Amp (LM741) and photodiode respectively. [15]

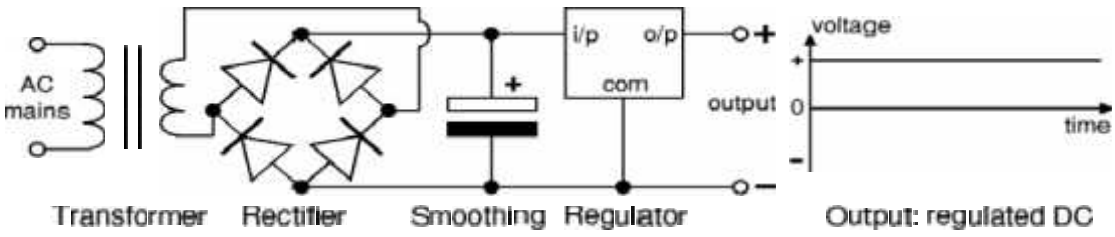


Fig5.1: Transformer, Rectifier, Smoothing and Regulator

From the previous figure, power supply contains four stages to covert 220V AC 50Hz to lower DC voltage, these stages as follows:

1. A transformer is the starting point, step down main AC voltage to a lower required AC voltage.

2. Full wave rectifier changes an alternating current to non-regulated direct current.
3. The filter will smooth the voltage signal more and more.

4. Regulator gives well-regulated DC voltage positive or negative according to the regulator number, such as 7812, 7912,7805,and 7905 for12V,-12V ,5V,and -5 respectively.

Main circuit:

The figure below shows the output of the photo diode which must connect to the current to voltage converter and voltage divider circuit.

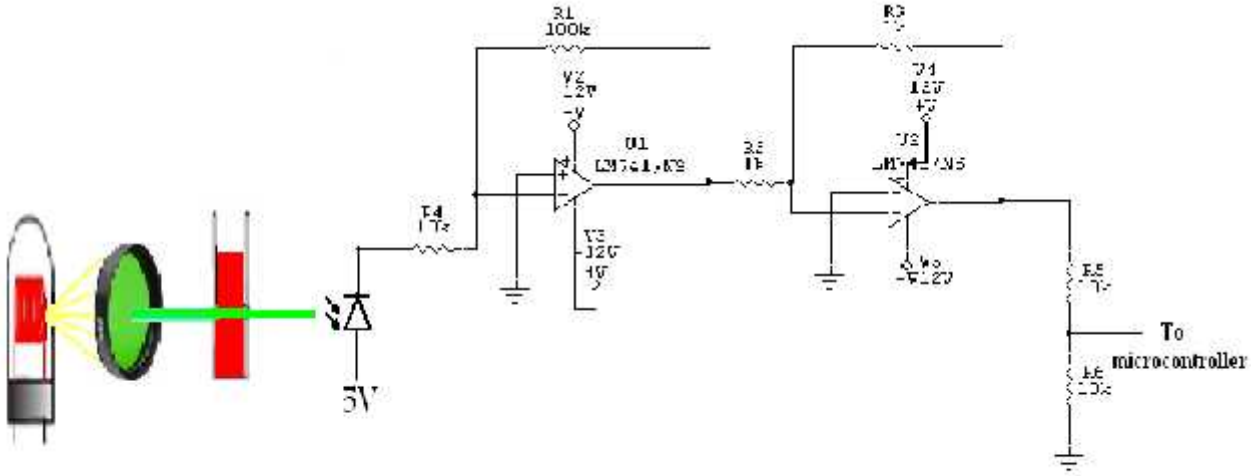


Fig.5.2: main circuit.

Chapter

6 Software

6.1 Software needed for the project.

6.2 Main program.

Chapter six

Software

6.1 Software needed for the project:

In this project we used a PIC microcontroller: to process the output value and to measure the glucose concentration. We use the C language for programming the chip to do the following steps:

- Use the PIC to control the system when start, and when stops and this case depends on the programming of the chip.
- Use the language to program the PIC to display the results on LCD screen.

6.2 Main program

```
#include<adc.h>
#include<delays.h>
#include<p18f4550.h>
#include"PPU_LCD.h"

#pragma config FOSC = INTOSC_HS
#pragma config WDT = OFF
#pragma config LVP = OFF
```

```
  int value[64][2];

void main(void)
{
  int port_a;
  int lcd1;
  int lcd2;
  int lcd3;
  int result,hlp,val;
  int i,j;
  int pre_val1,pre_val2;
  int post_val1,post_val2;
// int result;

  // as we have from 0 to 5 voltage
  // and have 8 bits range from 00000000 to 11111111
  // so  0 volt = 00000000
  // and 5 volt = 11111111
  // and so we have voltage 0 , 1 , 2 , 3 , 4 , 5
  // each step need  51 decimal
  // so any volatge we read we multiply it by value 51;
  // so we get the 8bit range from 0 to 255.
  value[0][0]=215;    value[0][1]=55;
  value[1][0]=209;    value[1][1]=59;
  value[2][0]=181;    value[2][1]=61;
  value[3][0]=178;    value[3][1]=63;
  value[4][0]=176;    value[4][1]=64;
  value[5][0]=175;    value[5][1]=66;
  value[6][0]=171;    value[6][1]=70;
  value[7][0]=168;    value[7][1]=73;
```

```
value[8][0]=164;    value[8][1]=76;
value[9][0]=161;    value[9][1]=81;
value[10][0]=158;   value[10][1]=85;
value[11][0]=156;   value[11][1]=94;
value[12][0]=149;   value[12][1]=96;
value[13][0]=146;   value[13][1]=99;
value[14][0]=145;   value[14][1]=102;
value[15][0]=143;   value[15][1]=105;
value[16][0]=143;   value[16][1]=111;
value[17][0]=141;   value[17][1]=114;
value[18][0]=138;   value[18][1]=119;
value[19][0]=136;   value[19][1]=126;
value[20][0]=135;   value[20][1]=128;
value[21][0]=135;   value[21][1]=135;
value[22][0]=134;   value[22][1]=139;
value[23][0]=133;   value[23][1]=141;
value[24][0]=133;   value[24][1]=145;
value[25][0]=132;   value[25][1]=154;
value[26][0]=130;   value[26][1]=156;
value[27][0]=128;   value[27][1]=159;
value[28][0]=128;   value[28][1]=164;
value[29][0]=125;   value[29][1]=179;
value[30][0]=124;   value[30][1]=181;
value[31][0]=123;   value[31][1]=183;
value[32][0]=122;   value[32][1]=189;
value[33][0]=121;   value[33][1]=191;
value[34][0]=120;   value[34][1]=195;
value[35][0]=120;   value[35][1]=198;
value[36][0]=119;   value[36][1]=199;
value[37][0]=118;   value[37][1]=201;
value[38][0]=118;   value[38][1]=208;
```

```
  value[39][0]=117;   value[39][1]=210;
  value[40][0]=116;   value[40][1]=211;
  value[41][0]=116;   value[41][1]=219;
  value[42][0]=114;   value[42][1]=221;
  value[43][0]=113;   value[43][1]=226;
  value[44][0]=112;   value[44][1]=232;
  value[45][0]=112;   value[45][1]=233;
  value[46][0]=112;   value[46][1]=245;
  value[47][0]=111;   value[47][1]=252;
  value[48][0]=111;   value[48][1]=260;
  value[49][0]=110;   value[49][1]=274;
  value[50][0]=109;   value[50][1]=277;
  value[51][0]=108;   value[51][1]=279;
  value[52][0]=107;   value[52][1]=281;
  value[53][0]=106;   value[53][1]=288;
  value[54][0]=106;   value[54][1]=289;
  value[55][0]=105;   value[55][1]=291;
  value[56][0]=104;   value[56][1]=293;
  value[57][0]=104;   value[57][1]=294;
  value[58][0]=103;   value[58][1]=297;
  value[59][0]=97;    value[59][1]=299;
  value[60][0]=87;    value[60][1]=301;
  value[61][0]=78;    value[61][1]=310;
  value[62][0]=51;    value[62][1]=330;
  value[63][0]=51;    value[63][1]=331;

OpenADC (ADC_FOSC_64  & ADC_LEFT_JUST & ADC_2_TAD,ADC_CH0
& ADC_INT_OFF & ADC_REF_VDD_VSS , ADC_1ANA);
ConvertADC();
while(BusyADC());
port_a=ADRESH;
```

```
lcd_init();
lcd_gotoyx(1,1);

  lcd1=0;
  lcd2=0;
  lcd3=0;
 //lcd_puti(result);

j=0;
    for(i=0;i<=63;i++)
      if (value[i][0]>=port_a)
      {
        j++;
        val=value[i][0];
        result=value[i][1];
      }

    if( (val!=port_a) && ((j!=0)&&(j!=63))   )
      {
       pre_val1 =value[j-1][0];
       pre_val2 =value[j-1][1];
       post_val1=value[j][0];
       post_val2=value[j][1];
      //printf("pre_val1=%d\n",pre_val1);
      //printf("pre_val2=%d\n",pre_val2);
      //printf("post_val1=%d\n",post_val1);
      //printf("post_val2=%d\n",post_val2);
       result = (int)((((post_val2-pre_val2)*(port_a-
pre_val1))/(post_val1-pre_val1))+pre_val2);
```

```
      }

    hlp=result;
    //printf("-----%d\n",hlp);
    if (hlp>0){ lcd1=hlp%10; hlp=(hlp-lcd1)/10;}
    if (hlp>0){ lcd2=hlp%10; hlp=(hlp-lcd2)/10;}
    if (hlp>0){ lcd3=hlp%10; };

lcd_puti(lcd1);
lcd_puti(lcd2);
lcd_puti(lcd3);
```

Chapter

7 System results.

7.1 Test and result.

7.2 Project safety.

7.3 Project maintenance.

Chapter seven

System results

7.1 Test and result

After finishing from built our design project, we test 64 blood samples on it in order to obtain the relationship between the glucose concentration and the output voltage of processing circuits before voltage divider circuit, and the results were as shown below:

Table 7.1

Test and results

# of sample	G %(mg/dl)	Output voltage
1	55	8.45
2	59	8.19
3	61	7.1
4	63	6.98
5	64	6.91
6	66	6.85
7	70	6.71
8	73	6.59
9	76	6.43
10	81	6.31
11	85	6.21
12	94	6.12
13	96	5.85
14	99	5.71
15	102	5.69
16	105	5.61
17	111	5.59
18	114	5.51
19	119	5.40
20	126	5.32
21	128	5.31
22	135	5.29
23	139	5.25
24	141	5.23

25	145	5.21
26	154	5.19
27	156	5.11
28	159	5.02
29	164	5.01
30	179	4.9
31	181	4.85
32	183	4.81
33	189	4.77
34	191	4.75
35	195	4.7
36	198	4.69
37	199	4.67
38	201	4.64
39	108	4.62
40	210	4.57
41	211	4.55
42	219	4.53
43	221	4.48
44	226	4.45
45	232	4.41
46	233	4.4
47	245	4.39
48	252	4.36
49	260	4.34
50	274	4.31
51	277	4.28
52	279	4.22
53	281	4.20
54	288	4.15
55	289	4.14
56	291	4.11
57	293	4.09
58	294	4.06
59	297	4.02
60	299	3.8
61	301	3.4
62	310	3.05
63	330	2.00
64	331	2.01

The relation between them is shown in curve below.

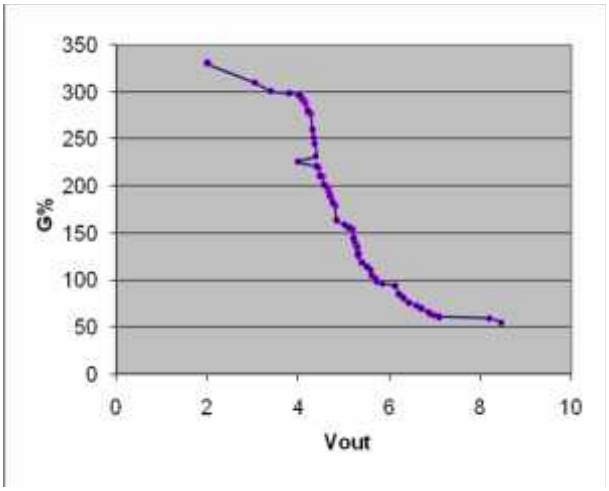


Fig.7.1: the relation between output voltage and G%.

After voltage divider circuit the relation became as shows in the following curve.

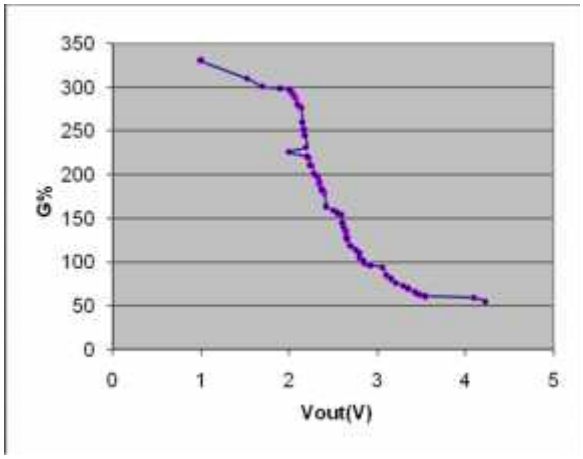


Fig.7.2: the relation between output voltage of voltage divider and G%.

► **Error calculations:**

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

$$error\ 1 = \left(\frac{truevalue\ - readvalue}{truevalue} \right) \times 100\ = \frac{115\ - 110}{115} \times 100\ \% = 4.3\ \%$$

$$error\ 2 = \left(\frac{truevalue\ - readvalue}{truevalue} \right) \times 100\ = \frac{220\ - 205}{220} \times 100\ \% = 6\ \%$$

$$error\ 3 = \left| \left(\frac{truevalue\ - readvalue}{truevalue} \right) \right| \times 100\ = \left| \frac{80\ - 85}{80} \right| \times 100\ \% = 8.7\ \%$$

$$error\ 4 = \left| \left(\frac{truevalue\ - readvalue}{truevalue} \right) \right| \times 100\ = \left| \frac{55\ - 53}{55} \right| \times 100\ \% = 3.6\ \%$$

► **Average error** : $\left(\overline{E} \right)$

$$\overline{E}\ \% = \sum_{1}^{4} \frac{E}{4} = \left(4.3 + 6 + 8.7 + 3.9 \right) / 4 = 5.6\ \%.$$

7.2 Project safety:

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

1. To prevent electrical hazared; don't touch the lamp wires.
2. Don't did the blood test unless you wearing the medical gloves.
3. Prevent the optical filter from touch by hand ;it may not work correctly.

7.3 Project maintenance:

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

1. Always check the LCD voltage; prevent it to be more than 5v.
2. Always check the wire connection.
3. Always check the PIC connection.
4. Always check the halogen lamp.

Chapter

8 Conclusions and recommendations

8.1 Conclusions.

8.2 Recommendations.

Chapter eight

Conclusions and recommendations

8.1 conclusions

Our project conclusions consist on our study and design:

1-The most effective way to measure the blood sugar is the optical method.

2-Our project designed to measure the value of glucose concentration, using suitable filter for the desired wavelength (530nm) which we need.

3- In our project we found that there is an inverse relationship between the glucose concentration and voltage output.

8.2 Recommendations

Future modifications can be carried out so system performance and efficiency is improved, these modifications include:

1- Implementation the system by using other types of sensors.
2- Improve the system by adding alarming on LCD in case of hypo or hyper glucose concentration.
3- Adding printer to print the result.

References

Books:

[1] Carl A.Burtis & Edward R.Ashwood, "Fundamentals Of Clinical Chemistry", 4th Edition.

[2] Lihong V.Wang & Hisin-Wu , "Biomedical Optics",Wiley 2007.

[3] Xueji Zhang & Huangxian Ju & Joseph Wang ,"Electrochemical Sensorss,Biosensors and Their Biomedical Applications",1st edition 2008,Elsevier 2008.

[4] John M.Brown & Joseph J.carr,"Introduction to Biomedical Equipment Technology", 4th Edition.

[5] Malvino," Electronic principles ", 6th Edition.

Papers:

[6] Austin Peay ,State University Department of Chemistry.

Websites:

[7] http://www.associatedcontent.com

[8] http://www.endocrineweb.com/insulin.html

[9] http://www.diabeteshome.ca/how-can-blood-sugar

[10] http://www.idf.org/home/index.cfm

[11] http://www.diabetes.niddk.nih.gov/dm/pubs

[12] ttp://www.cdc.gov/diabetes/faq/basics.htm

[13] http://www.apsu.edu/chem_page/General

[14] www.DatasheetCatalog.com

[15] http://www.public.iastate.edu/~gqtan/ADC.htm

Appendix A

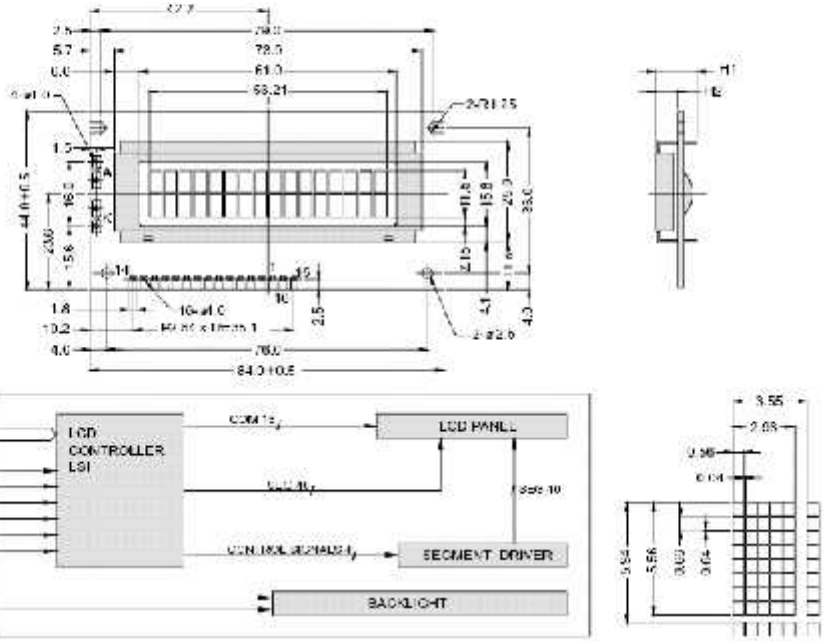
Datasheets of project Components

Data sheet for PC 1602-f [14]

POWERTIP

PC 1602-F

OUTLINE DIMENSION & BLOCK DIAGRAM



The tolerance unless classified ±0.3mm

MECHANICAL SPECIFICATION			
Overall Size	84.0 x 44.0	Module	H2 / H1
View Area	61.0 x 15.8	W/O B/L	5.1 / 9.2
Dot Size	0.56 x 0.66	EL B/L	5.1 / 9.2
Dot Pitch	0.60 x 0.70	Array LED B/L Edge LED B/L	9.4 / 14.0 - 8.6 / 11.6

PIN ASSIGNMENT		
Pin no	Symbol	Function
1	Vss	Power supply(GND)
2	Vdd	Power supply(+)
3	Vo	Contrast Adjust
4	RS	Register select signal
5	R/W	Data read / write
6	E	Enable signal
7	DB0	Data bus line
8	DB1	Data bus line
9	DB2	Data bus line
10	DB3	Data bus line
11	DB4	Data bus line
12	DB5	Data bus line
13	DB6	Data bus line
14	DB7	Data bus line
15	A	Power supply for LED B/L (+)
16	K	Power supply for LED B/L (-)

ABSOLUTE MAXIMUM RATING					
Item	Symbol	Condition	Min.	Max.	Units
Supply for logic voltage	Vdd-Vss	25°C	-0.3	7	V
LCD driving supply voltage	Vdd-Vee	25°C	-0.3	13	V
Input voltage	Vin	25°C	-0.3	Vdd+0.3	V

ELECTRICAL CHARACTERISTICS								
Item	Symbol	Condition	Min.		Typical		Max.		Units
Power supply voltage	Vdd-Vss	25°C	2.7		–		5.5		V
LCD operation voltage	Vop	Top	N	W	N	W	N	W	V
		-20°C	–	7.1	–	7.6	–	7.9	V
		0°C	4.5	–	5.1	–	5.3	–	V
		25°C	4.1	6.1	4.7	6.6	4.9	6.7	V
		50°C	3.9	–	4.4	–	4.6	–	V
		70°C	–	5.7	–	6	–	6.3	V
LCM current consumption (No B/L)	Idd	Vdd=5V	–		2		3		mA
Backlight current consumption	LED edge	VBL=4.2V	–		40		–		mA
	LED array	VBL=4.2V	–		120		–		mA

REMARK

LCD option: STN, TN, FSTN

Backlight Option: LED, EL Backlight feature, other Specs not available on catalog is under request.

Data sheet for PIC18F4550 :[14]

MICROCHIP **PIC18F2455/2550/4455/4550**

28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 Endpoints (16 bidirectional)
- 1-Kbyte Dual Access RAM for USB
- On-Chip USB Transceiver with On-Chip Voltage Regulator
- Interface for Off-Chip USB Transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power-Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 µA typical
- Sleep mode currents down to 0.1 µA typical
- Timer1 Oscillator: 1.1 µA typical, 32 kHz, 2V
- Watchdog Timer: 2.1 µA typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Four Crystal modes, including High-Precision PLL for USB
- Two External Clock modes, up to 48 MHz
- Internal Oscillator Block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - User-tunable to compensate for frequency drift
- Secondary Oscillator using Timer1 @ 32 kHz
- Dual Oscillator options allow microcontroller and USB module to run at different clock speeds
- Fail-Safe Clock Monitor:
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- High-Current Sink/Source: 25 mA/25 mA
- Three External Interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 5.2 ns (TCY/16)
  - Compare is 16-bit, max. resolution 83.3 ns (TCY)
  - PWM output: PWM resolution is 1 to 10 bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead time
  - Auto-shutdown and auto-restart
- Enhanced USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI (all 4 modes) and I²C™ Master and Slave modes
- 10-bit, up to 13-channel Analog-to-Digital Converter module (A/D) with Programmable Acquisition Time
- Dual Analog Comparators with Input Multiplexing

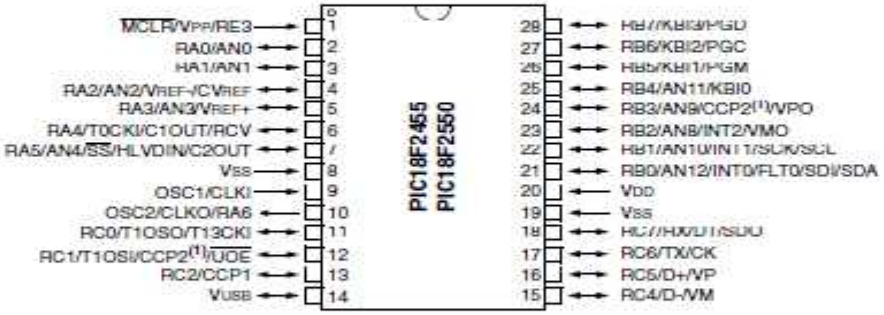
Special Microcontroller Features:

- C Compiler Optimized Architecture with optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory typical
- 1,000,000 Erase/Write Cycle Data EEPROM Memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-Programmable under Software Control
- Priority Levels for Interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Optional dedicated ICD/ICSP port (44-pin devices only)
- Wide Operating Voltage Range (2.0V to 5.5V)

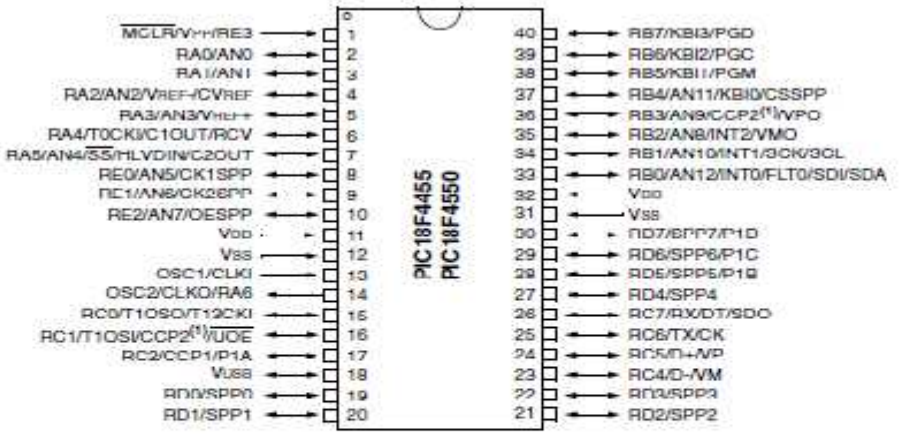
Device	Program Memory		Data Memory		I/O	10-Bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EUSART	Comparators	Timers 8/16-Bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I²C™			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

Pin Diagrams

28-Pin PDIP, SOIC



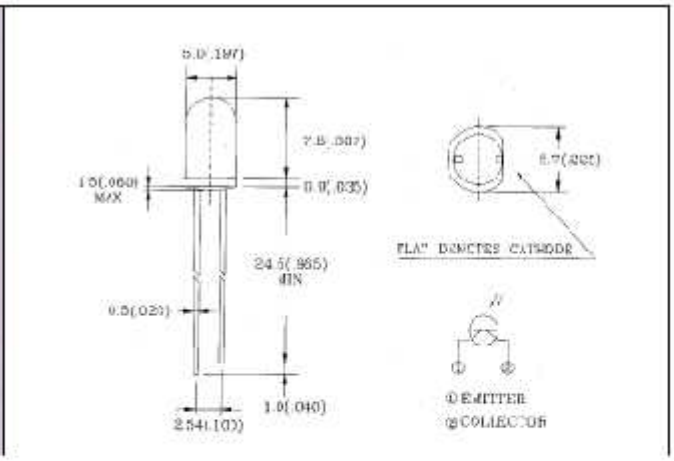
40-Pin PDIP



Note 1. RB3 is the alternate pin for CCP2 multiplexing.

Data sheet of photodiode [14]

PARA LIGHT **L-51ROPT1XX** 5.0mm PHOTODIODE



◆ABSOLUTE MAXIMUN RATING:(Ta=25°C)

Part No.	P_D (mw)	$V_{(BR)R}$ (V)	T_{OPR}	T_{STG}
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) MIN	TYP	MAX	BV_{ECO} (V) MIN	TYP	MAX	I_{CEO} (nA) MIN	TYP	MAX	$V_{CE(sat)}$ (V) MIN	TYP	MAX	t_r/t_f (uS) MIN	TYP	MAX	I_C (mA) MIN	TYP	MAX	C_{CB} (pF) MIN	TYP	MAX	λ (nm) MIN	PEAK	MAX
L-51ROPT1C	30			5					100			0.4		15/15		1.8	2.4			6.4		400		1050
L-51ROPT1D1	30			5					100			0.4		15/15		1.7	2.2			6.4		900	940	
L-51ROPT1D2	30			5					100			0.4		15/15		1.7	2.2			6.4		800	870	
TEST CONDITION	I_C=100uA E_e=0mW/cm²			I_E=100uA E_e=0mW/cm²			V_R=20V E_e=0mW/cm²			I_C=2mA E_e=0.5mW/cm²			VCE=5V I_C=1mA R_L=1000Ω			VCE=5V E_e=0.1mW/cm²			f=1MHZ VCE=3V E_e=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.

Data sheet of L7900[14]

ABSOLUTE MAXIMUM RATINGS

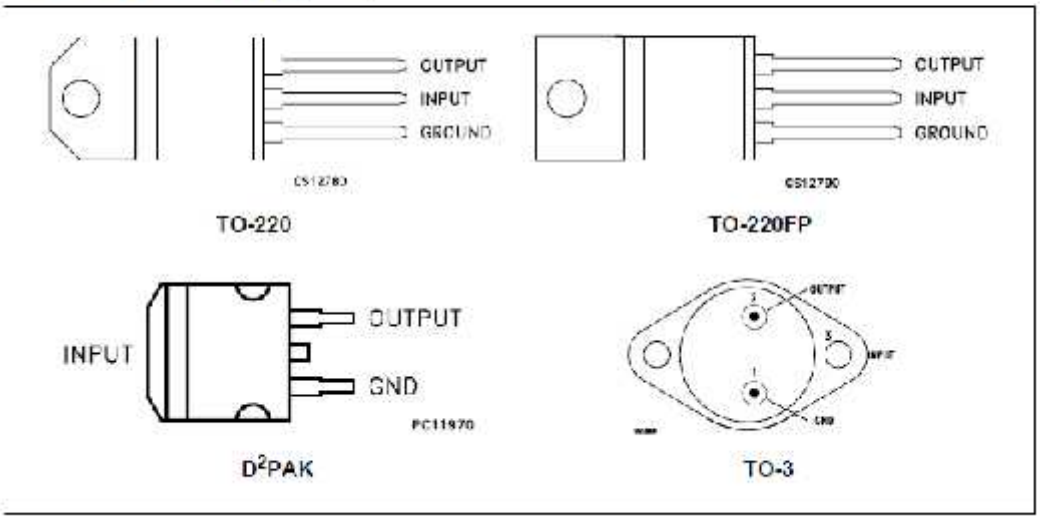
Symbol	Parameter[1]		Value	Unit
V_I	DC Input Voltage	for V_O = 5 to 18V for V_O = 20, 24V	-35 -40	V
I_O	Output Current		Internally Limited	
P_{tot}	Power Dissipation		Internally Limited	
T_{stg}	Storage Temperature Range		-65 to 150	°C
T_{op}	Operating Junction Temperature Range		0 to 150	°C

Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional operation under these condition is not implied

THERMAL DATA

Symbol	Parameter		D²PAK	TO-220	TO-220FP	TO-3	Unit
$R_{th\,j\text{-}case}$	Thermal Resistance Junction-case	Max	3	3	5	4	°C/W
$R_{th\,j\text{-}amb}$	Thermal Resistance Junction ambient	Max	62.5	50	60	35	°C/W

CONNECTION DIAGRAM (top view)



ABSOLUTE MAXIMUM RATINGS

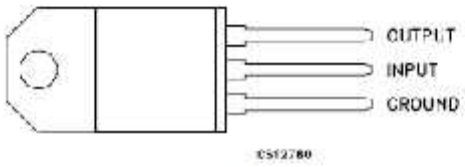
Symbol	Parameter[3]		Value	Unit
V_I	DC Input Voltage	for V_O = 5 to 18V	-35	V
		for V_O = 20, 24V	40	
I_O	Output Current		Internally Limited	
P_{tot}	Power Dissipation		Internally Limited	
T_{stg}	Storage Temperature Range		-65 to 150	°C
T_{op}	Operating Junction Temperature Range		0 to 150	°C

Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional operation under these condition is not implied.

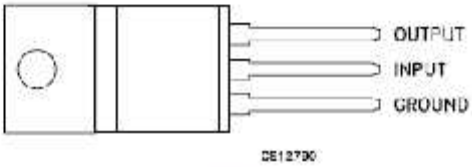
THERMAL DATA

Symbol	Parameter		D^2PAK	TO 220	TO 220FP	TO 3	Unit
$R_{thj\text{-}case}$	Thermal Resistance Junction-case	Max	3	3	5	4	°C/W
$R_{thj\text{-}amb}$	Thermal Resistance Junction-ambient	Max	62.5	50	60	35	°C/W

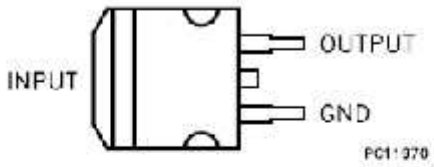
CONNECTION DIAGRAM (top view)



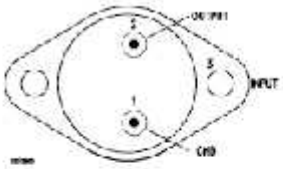
TO-220



TO-220FP



D^2PAK



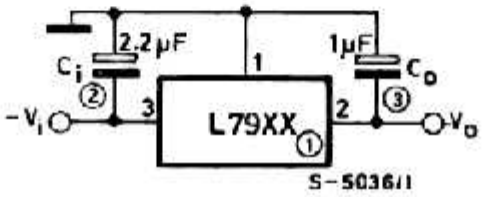
TO-3

ORDERING CODES

TYPE	TO-220	D²PAK (*)	TO-220FP	TO-3	OUTPUT VOLTAGE
L7905C	L7905CV	L7905ACD2T	L7905CP	L7905CT	5 V
L7952C	L7952CV	L7952ACD2T		L7952CT	-5.2 V
L7906C	L7906CV	L7906ACD2T	L7906CP	L7906CT	6 V
L7908C	L7908CV	L7908ACD2T	L7908CP	L7908CT	8 V
L7912C	L7912CV	L7912ACD2T	L7912CP	L7912CT	12 V
L7915C	L7915CV	L7915ACD2T	L7915CP	L7915CT	15 V
L7918C	L7918CV	L7918ACD2T	L7918CP	L7918CT	-18 V
L7920C	L7920CV	L7920ACD2T	L7920CP	L7920CT	20 V
L7922C	L7922CV	L7922ACD2T		L7922CT	22 V
L7924C	L7924CV	L7924ACD2T	L7924CP	L7924CT	-24 V

(*) Available in Tape & Reel with the suffix " TR".

TEST CIRCUIT



ELECTRICAL CHARACTERISTICS OF L7905C (refer to the test circuits, T_j 0 to 125°C, V_i 10V, I_O = 500 mA, C_i = 2.2 µF, C_O = 1 µF unless otherwise specified)

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = 25°C		-4.8	-5	-5.2	V
V_O	Output Voltage	I_O = -5 mA to -1 A $P_O \leq$ 15 W V_i = 8 to 20 V		-4.75	-5	-5.25	V
ΔV_O(*)	Line Regulation	V_i = -7 to -25 V	T_J = 25°C			100	mV
		V_i = -8 to -12 V	T_J = 25°C			50	
ΔV_O(*)	Load Regulation	I_O = 5 mA to 1.5 A	T_J = 25°C			100	mV
		I_O = 250 to 750 mA	T_J = 25°C			50	
I_d	Quiescent Current	T_J = 25°C				3	mA
ΔI_d	Quiescent Current Change	I_O = 5 mA to 1 A				0.5	mA
		V_i = -8 to -25 V				1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift	I_O = 5 mA			0.4		mV/°C
eN	Output Noise Voltage	B = 10 Hz to 100 KHz	T_J = 25°C		100		µV
SVR	Supply Voltage Rejection	ΔV_i = 10 V f = 120 Hz		54	60		dB
V_d	Dropout Voltage	I_O 1 A T_J 25°C ΔV_O 100 mV			1.4		V
I_{sc}	Short Circuit Current				2.1		A

(*) 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 cycle is used.

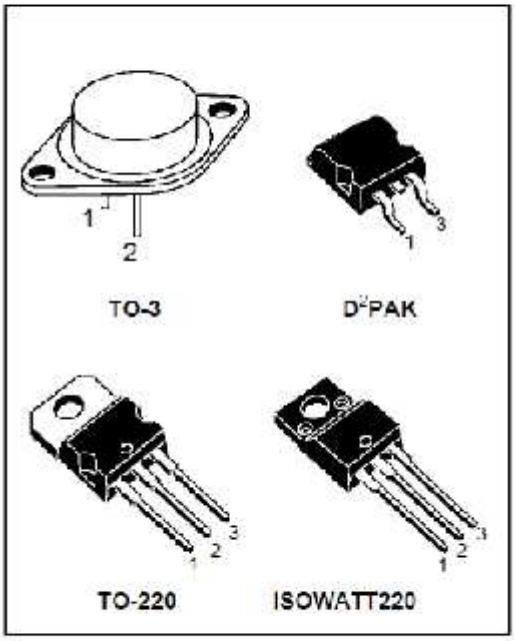
Data sheet of L7800[14]

SGS-THOMSON MICROELECTRONICS

L7800 SERIES

POSITIVE VOLTAGE REGULATORS

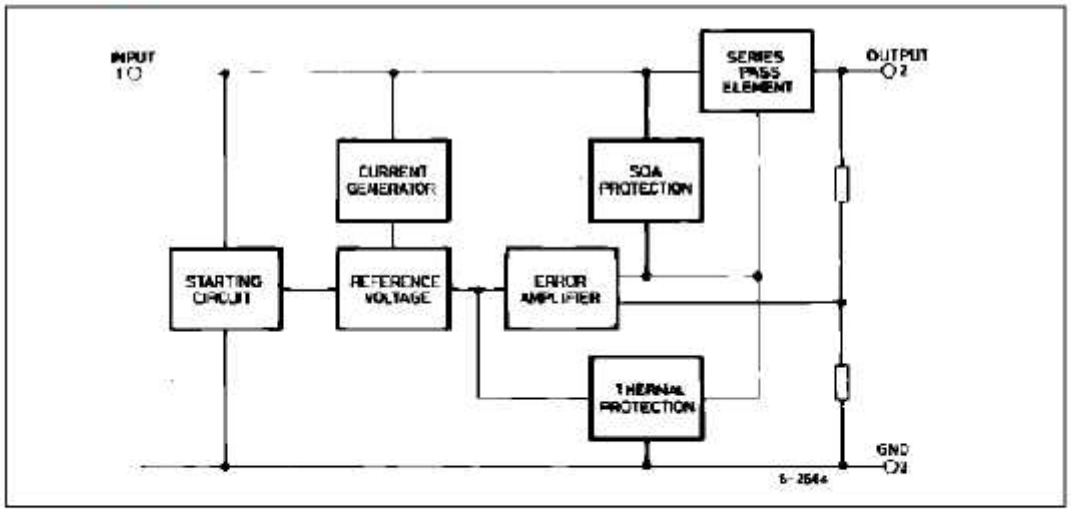
- OUTPUT CURRENT UP TO 1.5 A
- OUTPUT VOLTAGES OF 5; 5.2; 6; 8; 8.5; 9; 12; 15; 18; 24V
- THERMAL OVERLOAD PROTECTION
- SHORT CIRCUIT PROTECTION
- OUTPUT TRANSITION SOA PROTECTION



DESCRIPTION

The L7800 series of three terminal positive regulators is available in TO-220 ISOWATT220 TO-3 and D²PAK packages and several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

BLOCK DIAGRAM



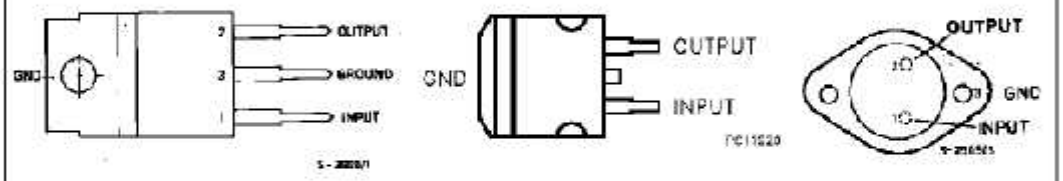
ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_i	DC Input Voltage (for V_O = 5 to 18V) (for V_O = 20, 24V)	35 40	V V
I_o	Output Current	Internally limited	
P_{tot}	Power Dissipation	Internally limited	
T_{op}	Operating Junction Temperature Range (for L7800) (for L7800C)	- 55 to 125 0 to 150	°C °C
T_{stg}	Storage Temperature Range	- 40 to 150	°C

THERMAL DATA

Symbol	Parameter		D^2PAK	TO-220	ISOWATT220	TO-3	Unit
$R_{thj\text{-}case}$	Thermal Resistance Junction-case	Max	3	3	4	4	°C/W
$R_{thj\text{-}amb}$	Thermal Resistance Junction-ambient	Max	62.5	50	60	35	°C/W

CONNECTION DIAGRAM AND ORDERING NUMBERS (top view)

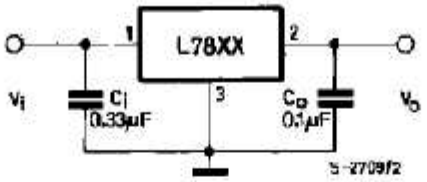


TO 220 & ISOWATT220 D^2PAK TO 3

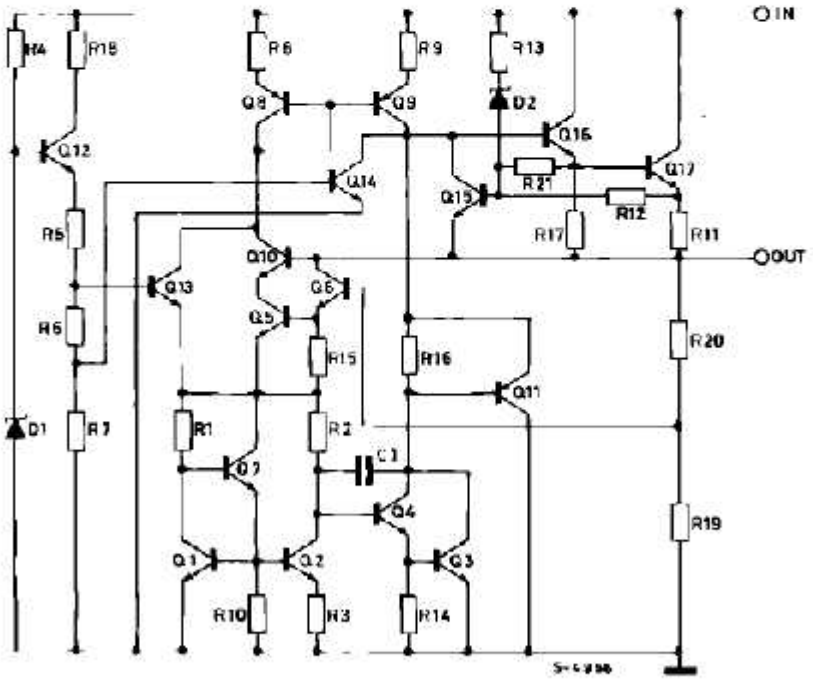
Type	TO-220	D^2PAK (*)	ISOWATT220	TO-3	Output Voltage
L7805				L7805T	5V
L7805C	L7805CV	L7805CD2T	L7805CP	L7805CT	5V
L7852C	L7852CV	L7852CD2T	L7852CP	L7852CT	5.2V
L7806				L7806T	6V
L7806C	L7806CV	L7806CD2T	L7806CP	L7806CT	6V
L7808				L7808T	8V
L7808C	L7808CV	L7808CD2T	L7808CP	L7808CT	8V
L7885C	L7885CV	L7885CD2T	L7885CP	L7885CT	8.5V
L7809C	L7809CV	L7809CD2T	L7809CP	L7809CT	9V
L7812				L7812T	12V
L7812C	L7812CV	L7812CD2T	L7812CP	L7812CT	12V
L7815				L7815T	15V
L7815C	L7815CV	L7815CD2T	L7815CP	L7815CT	15V
L7818				L7818T	18V
L7818C	L7818CV	L7818CD2T	L7818CP	L7818CT	18V
L7820				L7820T	20V
L7820C	L7820CV	L7820CD2T	L7820CP	L7820CT	20V
L7824				L7824T	24V
L7824C	L7824CV	L7824CD2T	L7824CP	L7824CT	24V

(*) AVAILABLE IN TAPE AND REEL WITH "-TR" SUFFIX

APPLICATION CIRCUIT



SCHEMATIC DIAGRAM



Data sheet of LM741 [14]

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

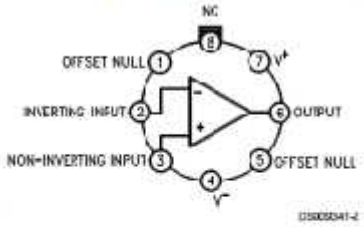
The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

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.

Connection Diagrams

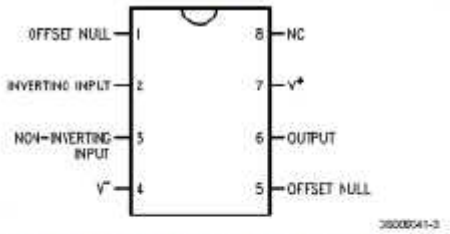
Metal Can Package



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



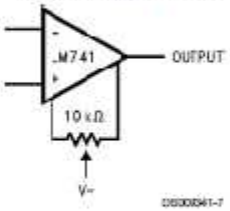
Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

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	−65°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			
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
	$R_S \le 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \le T_A \le T_{AMAX}$										
	$R_S \le 50\Omega$			4.0							mV
	$R_S \le 10\ k\Omega$						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
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_O = \pm 20V$	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 = ±20V, V_O = ±15V	50									V/mV
	V_S = ±15V, V_O = ±10V				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_L \geq 2\ k\Omega$,										
	V_S = ±20V, V_O = ±15V	32									V/mV
	V_S = ±15V, V_O = ±10V				25			15			V/mV
	V_S = ±5V, V_O = ±2V	10									V/mV
Output Voltage Swing	V_S = ±20V										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	V_S = ±15V										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L > 2\ k\Omega$				±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} = ±12V				70	90		70	90		dB
	$R_S \leq 50\Omega$, V_{CM} = ±12V	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	V_S = ±20V to V_S = ±5V										
	$R_S \leq 50\Omega$	80	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 5)	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 = ±20V		80	150							mW
	V_S = ±15V					50	85		50	85	mW
LM741A	V_S = ±20V										
	T_A = T_{AMIN}			165							mW
	T_A = T_{AMAX}			135							mW
LM741	V_S = ±15V										
	T_A = T_{AMIN}					80	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.

Appendix B

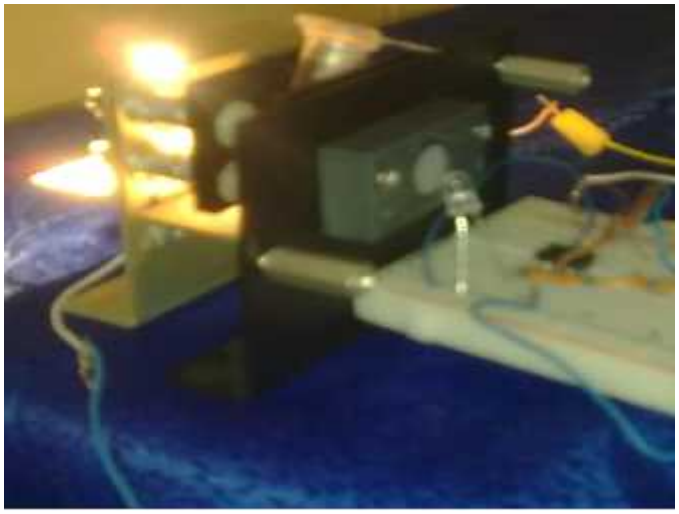
Over all system design in figures

Over all system design in figures

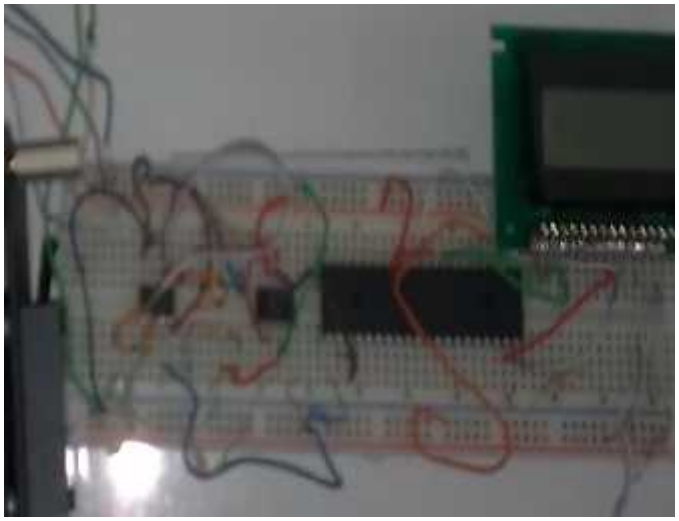
In this section we demonstrated the procedure of our project in figures as shown bellow.

The power supply.

The blood samples.



Optical path parts.



Signal processing parts.

All project components.

تم بحمد ا