Design of a Non-invasive Medical System for Measuring Bilirubin by Photometric Method

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Abstract

Newborn jaundice is when a baby has a high level of bilirubin in the blood. Bilirubin is a yellow substance that the body creates when it replaces old red blood cells. The liver helps break down the substance so it can be removed from the body in the stool. High levels of bilirubin make baby's skin and whites of the eyes look yellow. This is called jaundice.

Any infant who appears jaundiced should have bilirubin levels measured right away. Recently, the method used for measure bilirubin level is an invasive method, which is not a comfortable method for both infants and doctors and . Doctors face many difficulties in take the sample of blood from patients especially from infants, because of the small size of infant arteries.

This project describes the design of an electronic instrument for measuring bilirubin by the optical method of light transmission through the skin. There was the knowledge of light transmission and absorption on a specific tissue compartment applied. The relevant skin photo-diagnostics handle 455nm and 575nm. The registration of transmitted light of different frequency combinations presents the bilirubin quantity in human body by a non-invasive way.

ملخص المشروع

يحدث الصفار لدى الاطفال حديثي الولادة عندما ترتفع نسبة مادة البيلروبين في الدم، و البيلروبين هو مادة صفراء اللون تنتج من تحلل وتكسر خلايا الدم الحمراء، هذا التحلل والتكسر قد يكون طبيعيا او غير طبيعيا. عندما ترتفع نسبة البيلروبين في الدم الى نسب فوق الطبيعية يصبح لون جلد الطفل أصفر، لكن الأمر لا يقتصر على لون الجلد، فاستمرار ارتفاع نسبة البيلروبين لنسب أعلى ولوقت أطول قد يكون مؤشرا لوجود خلل ما في جسم المولود.

الطريقة المستخدمة حاليا لقياس نسبة البيلروبين هي طريقة جراحية عن طريق اخذ عينات من دم الطفل عن طريق الإبر، هذه الطريقة قد تتسبب في مشاكل كثيرة مثل العدوى والالتهابات، بالإضافة الى انها متعبة وغير مريحة لكلا الطرفين ، الطفل والممرض، وقد يضطر الممرض لإجراء عملية سحب العينة لعدة مرات حتى يحصل على ما يحتاجه لإتمام الفحص بسبب صغر حجم شرايين الطفل.

هذا المشروع يقوم على تصميم جهاز طبي يقوم بفحص وقياس نسبة البيلروبين في الدم من خلال طريقة غير جراحية تعتمد على مبدأ انعكاس الضوء عبر الجلد . وهذا يتطلب معرفة بامتصاص الضوء وانعكاسه على الأنسجة المرادة . حيث تم استخدام طولين موجيين اللأول عند 455nm والثاني عند 575nm . يتم استخدام الضوء المرسل لقياس كمية البيلروبين في جسم الانسان بطريقة غير جراحية .

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1.1 Project Overview

Newborn jaundice is when a baby has a high level of bilirubin in the blood. Bilirubin is a yellow substance that the body creates when it replaces old red blood cells. The liver helps break down the substance so it can be removed from the body in the stool. High levels of bilirubin make baby's skin and whites of the eyes look yellow. This is called jaundice.

Any infant who appears jaundiced should have bilirubin levels measured right away. Recently, the method used for measure bilirubin level is an invasive method, which is not a comfortable method for both infants and doctors. Doctors face many difficulties in take the sample of blood from patients especially from infants, because of the small size of infant arteries.

The idea of this project is to design a medical diagnostic instrument that has the ability to measure the bilirubin non-invasively. The measuring system will depend on the optical method of light reflectance through the skin.

1.2 Project Motivations

The method used in hospitals for measure of bilirubin level is an invasive method . Doctors face many difficulties in take the sample of blood from infants because of the small size of infant arteries.

1.3 Project Objectives

The main objective of this project is to design and Implement a Non-Invasive technique for bilirubin measurement with the following features:

- Less risk infections or osteomyelitis .
- Easy to use for doctors and nurses.
- Could be used at home.
- Simpler & Cheaper than current bilirubin measurement devices.

1.4 Literature Review

Current technologies allow us to determine the value of bilirubin using several methods, both invasive and non-invasive; each method has advantages and problems as follow:

- **Invasive Methods:**

Figure 1.1 : Invasive method

Most clinically used methods for the determination of bilirubin and its conjugates are based on its reaction to diazotized sulphanilic acid. It is based on the creation of azodyes, the so called azobilirubin that acts as an acid-basic indicator.

Later, there were various forms and conjugates of bilirubin found. It is based on oxidation with oxygento the green biliverdin catalysed by bilirubin oxidase. One of the other options is to determine bilirubin viabiliverdin after oxidation by vanadic acid. This reaction is based on the known oxidation of yellow bilirubin to green biliverdin. This allows for the determination of the total and the direct bilirubin [1].

- **Non-Invasive Methods**

Many developments on non-invasive bilirubin measurement devices occurred in the last few decades, trying to solve many problems in both technical and practical sides, none of them could combine the simplicity, quality, and frugality in the same time.[2]

The first attempts of non-invasive bilirubin measurements took place in 1960. Gosset described the use icterometer at that time. This device, based on reflectance measurements, was unsuitably sensitive and specific and provided reproducible results at the rate of 20 to 40%.

The first advanced and complicated device for non-invasive measurements of bilirubin was launched in 1980. This instrument provided a numerical index requiring the correlation of serum bilirubin. The device required basal measurements of serum bilirubin.

The Bili Chek unit measures within the wavelength range from 380 to 760nm and uses more than100 reading points. This allows corrections by interfering factors such as hemoglobin, melanin and the skin thickness. The disadvantage relates to the need to use a clean removable tip for each measurement and that increases the cost of measuring significantly. [1]

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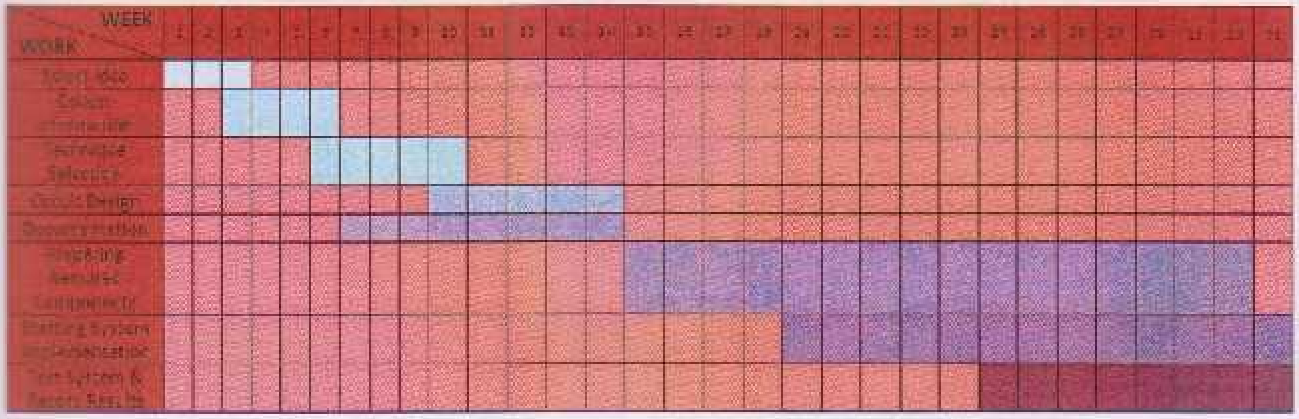
1.5 Expected Outcomes

According to our expectations, the intended device will be cheaper, simpler, easy to use, and have very small expected error, that provides reliable care after newborns within the postnatal care.

1.6 Time Table

The project time is distributed as follows:

Table 1.1:Time table



1.7 Project Cost

The cost of project components is provided in the table below.

Price	Quantity	Equipment
160 $	2	Optical sensors (transmiter)
200 $	2	Optical sensors (reciever)
20 $	6	Amplifiers
10 $	30	Resistors
10 $	15	Capacitors
20 $	3	Filters
100 $	1	Interface
520 $		**Total**

Table 1.2:Project Cost

Chapter Two

Physiological Background

2.1 Bilirubin

2.1.1Bilirubin Definition

Bilirubin is a yellow pigment that is in everyone's blood and stool. When old red blood cells are broken down bilirubin is made in the body. The breakdown of old cells is a normal, healthy process. After circulating in your blood, bilirubin then travels to your liver. In the liver, bilirubin is excreted into the bile duct and stored in your gall bladder. Eventually, the bilirubin is released the small intestine as bile to help digest fats and excreted with your stool at the end. [3]

Bilirubin attached to sugar is called "direct" or "conjugated" bilirubin, and bilirubin without sugar is called "indirect" or "unconjugated" bilirubin. All the bilirubin in your blood together is called "total" bilirubin.[1]

2.1.2 Bilirubin Chemistry

Bilirubin consists of an open chain of four pyrrole-like rings (tetrapyrrole). In heme, these four rings are connected into a larger ring, called a porphyrin ring . As shown in figure (2.1) .

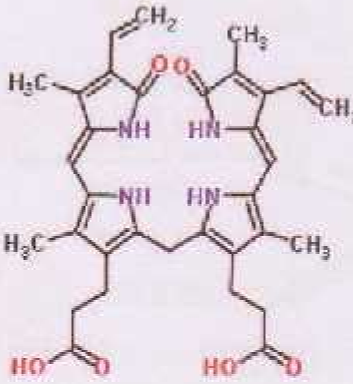


Figure 2.1: Bilirubin Chemistry

Bilirubin is very similar to the pigment phycobilin used by certain algae to capture light energy, and to the pigment phytochrome used by plants to sense light. All of these contain an open chain of four pyrrolic rings.

Like these other pigments, some of the double-bonds in bilirubin isomerize when exposed to light. This is used in the phototherapy of jaundiced newborns: the E,Z-isomers of bilirubin formed upon light exposure are more soluble than the unilluminated Z,Z-isomer, as the possibility of intramolecular hydrogen bonding is removed. This allows the excretion of unconjugated bilirubin in bile.[2]

2.1.3 Bilirubin Function

Bilirubin is created by the activity of biliverdin reductase on biliverdin, a green tetrapyrrolic bile pigment that is also a product of heme catabolism. Bilirubin, when oxidized, reverts to become biliverdin once again. This cycle, in addition to the demonstration of the potent antioxidant activity of bilirubin, has led to the hypothesis that bilirubin's main physiologic role is as a cellular antioxidant.[3]

2.2 Bilirubin Production and Metabolism .

2.2 .1 Bilirubin Production

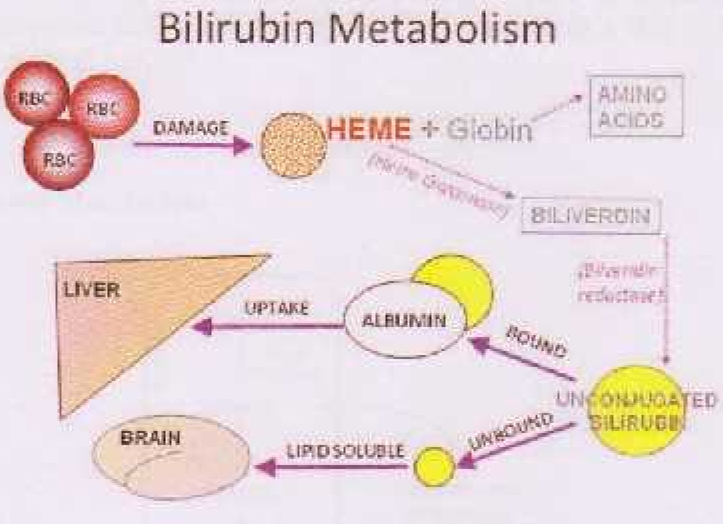


Figure 2.2: Bilirubin metabolism [4]

Bilirubin is the terminal product of heme metabolism. Heme is present in hemoglobin and in other oxidative compounds such as hepatic mitochondrial and microsomal cytochromes. As shown in figure (2.2) .Thus plasma bilirubin is part erythropoietic and part non-erythropoietic. Approximately, 85 % erythropoietic and 15% non-erythropoietic.

The erythropoietic fraction originates from two sources: the circulating normal aging red cells and the immature defective red cells of the bone marrow. The daily production of bilirubin is 250 to 350 mg.[4]

Shunt bilirubin is called that portion that does not originate from senescent circulating red cells but originates from immature and defective red cells (7%) and from non- hemoglobin heme compounds, particularly from hepatic cytochromes and from myoglobin.

Shunt bilirubin may be markedly elevated in certain pathologic states: sideroblastic anemia, megaloblastic anemia, erythroleukemia, lead poisoning and a congenital disorder called "idiopathic dyserythropoietic jaundice". The patients affected by this condition do not have hemolysis. They have hyperbilirubinemia and jaundice. The hyprbilirubinemia is due to shunt bilirubin.

Bilirubin from erythropoieticheme is produced by monocytic macrophages, reticulo-endothelium, in every organ but especially in the spleen, liver and bone marrow in order of importance.. The bilirubin from non-erythropoietic hepatic heme is produced in the hepatocytes.

The tetrapyrrolic ring of heme is broken by an oxygenase at the alpha bridge, the bond between the two carbons opposite to the gamma bridge which is between the two carbons carrying the two propionic acids. The tetrapyrrolic molecule from a ring is transformed into a tetrapyrrolic chain without iron.[5]

2.2.2 Bilirubin Metabolism

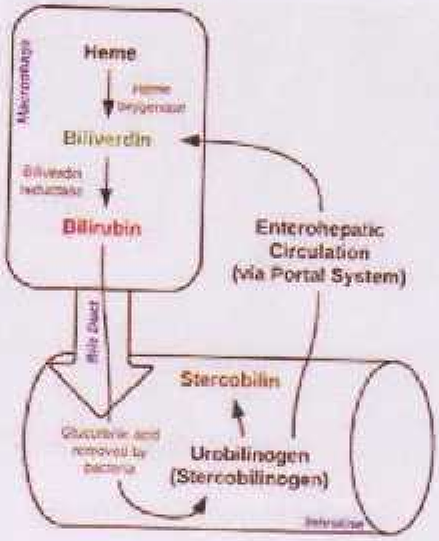


Figure 2.3: Heme metabolism

Bilirubin circulates in the bloodstream in two forms As shown in figure (2.3) .

- **Indirect (or unconjugated) bilirubin :** This form of bilirubin does not dissolve in water (it is insoluble). Indirect bilirubin travels through the bloodstream to the liver, where it is changed into a soluble form (direct or conjugated).
- **Direct (or conjugated) bilirubin :** Direct bilirubin dissolves in water (it is soluble) and is made by the liver from indirect bilirubin.

Total bilirubin and direct bilirubin levels are measured directly in the blood, whereas indirect bilirubin levels are derived from the total and direct bilirubin measurements.[6]

2.3 Urine tests , Blood tests and Blood levels.

2.3.1 Urine tests

Urine bilirubin may also be clinically significan as shown in figure (2.4) . Bilirubin is not normally detectable in the urine of healthy people. If the blood level of conjugated bilirubin becomes elevated, due to liver disease, excess conjugated bilirubin is excreted in the urine, indicating a pathological process. Unconjugated bilirubin is not water-soluble and so is not excreted in the urine. Testing urine for both bilirubin and urobilinogen can help differentiate obstructive liver disease from other causes of jaundice.[5]

Figure 2.4: Bilirubin urine test

2.3.2 Blood tests

Bilirubin is degraded by light. Blood collection tubes containing blood or (especially) serum to be used in bilirubin assays should be protected from illumination. For adults, blood is typically collected by needle from a vein in the arm. In newborns, blood is often collected from a heelstick, a technique that uses a small, sharp blade to cut the skin on the infant's heel and collect a few drops of blood into a small tube as shown in figure (2.5) . Non-invasive technology is available in some health care facilities that will measure bilirubin by using an instrument placed on the skin (transcutaneous bilirubin meter) .[7]

Figure 2.5: Bilirubin blood test

Bilirubin (in blood) is in one of two forms:

- Total bilirubin ("TBIL") measures both BU and BC. Total and direct bilirubin levels can be measured from the blood, but indirect bilirubin is calculated from the total and direct bilirubin.
- Indirect bilirubin is fat-soluble and direct bilirubin is water-soluble.[6]

2.3.3 Blood levels

The bilirubin level found in the body reflects the balance between production and excretion. Blood test results should always be interpreted using the reference range provided by the laboratory that performed the test, but typical (0.3 to 1.9 mg/dL) for adults and (340 µmol/L) for new borns .[7]

Table2.1 Bilirubin levels in adults

Bilirubin type	Bilirubin level
Total bilirubin	0.0–1.4 mg/dL or 1.7–20.5 µmol/L
Direct bilirubin	0.0–0.3 mg/dL or 1.7–5.1 µmol/L
Indirect bilirubin	0.2–1.2 mg/dL or 3.4–20.5 µmol/L

2.4 Mechanism of Action

Analysis of blood serum, transcutaneous measurement, and clinical are all possible methods for hyperbilirubinemia diagnosis. The standard method for bilirubin measurement is high performance liquid chromatography used on blood serum. [8]

2.5 Normal and Abnormal result for Bilirubin test

2.5.1Normal result for Bilirubin test

Laboratory test results may vary depending on your age, gender, health history, the method used for the test, and many other factors .

The normal result may be include :

- Adults: 0.1-0.3 mg/dL (1.7-5.1 micromol/ L) .
- Neonates: <1 mg/dL with normal total bilirubin .

2.5.2 Abnormal result for Bilirubin test

In an adult, high bilirubin may be due to problems with the liver, bile ducts, or gallbladder. Examples include:

- drug toxicity
- liver diseases like hepatitis
- Gilbert's disease (a genetic disease affecting some families)
- cirrhosis (scarring of the liver)
- biliary stricture (part of the bile duct is too narrow to allow fluid to pass)
- cancer of the gallbladder or pancreas
- gallstones . [10]

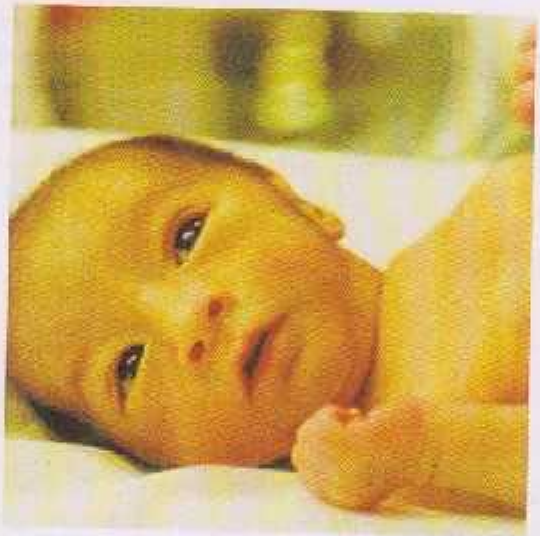


Figure 2.6 : Newborn suffer from Bilirubin

nother cause of high bilirubin may be due to problems in the blood instead of problems in the liver. The figure (2.6) newborn suffer from Bilirubin shows Blood cells breaking down too that can be caused by:

- Hemolytic anemia.

  - Too many blood cells being destroyed from an autoimmune disease.
  - Genetic defect.
  - Drug toxicity.
  - Infection.

- Transfusion reaction

The patient immune system can attack some blood given during a transfusion.

In an infant, high bilirubin and jaundice can be very dangerous, and may be caused by several factors. There are three common types:

- Physiological jaundice : at 2-4 days after birth, caused by a brief delay in the functioning of the liver, usually not serious.
- Breast feeding jaundice : during first week of life, caused by a baby not nursing well or low milk supply in the mother.
- Breast milk jaundice : after 2-3 weeks of life, caused by the processing of some substances in breast milk.[9][11]

All of these can be easily treated and are usually harmless if treated. Some more serious conditions that cause high bilirubin and jaundice in the infant:

- Abnormal blood cell shapes (like sickle cell anemia)
- Blood type mismatch between infant and mother (called erythroblastosisfetalis)
- Lack of certain important proteins due to genetic defects
- Bleeding in the scalp due to a difficult delivery
- High levels of red blood cells due to small size, prematurity
- Infections

In both adults and children, symptoms related to high bilirubin involve jaundice, a yellowing of the skin or eyes, fatigue, itchy skin, dark urine, and low appetite.[8]

2.6 Bilirubin Complications

Bilirubin is toxic to cells of the brain. If a baby has severe jaundice, there's a risk of bilirubin passing into the brain, a condition called acute bilirubin encephalopathy. [10][12]

That will cause a kernicterus ,which is a syndrome that occurs if acute bilirubin encephalopathy causes permanent damage to the brain. Kernicterus may result in:

- Involuntary and uncontrolled movements (athetoid cerebral palsy)
- Permanent upward gaze
- Hearing loss
- Improper development of tooth enamel .

Chapter Three

Conceptual Design

This chapter will illustrate the design and the principle of operation of the device, and the elements used. The basic concept for measuring bilirubin in this device is **"the optical method of light transmission"** through the skin.

3.1 Principle of Operation

Photometric measurements are based on direct measurements at the wavelength of 455nm, which is the absorption maximum of bilirubin. But there exists many other pigments of similar colors and reactions as bilirubin. Measurements may be also interfered by the presence of oxyhaemoglobin, which is often hemolytic and absorbs light at the wavelength of455nm.These interferences suppressed by the working process, by measurements taken at two wavelengths of 455 and 575nm. The bilirubin concentrations are found from the absorbency differences. The first wavelength (455nm) corresponds to the bilirubin content and the second (575nm) to the oxyhaemoglobin content.

3.2 System Block Diagram

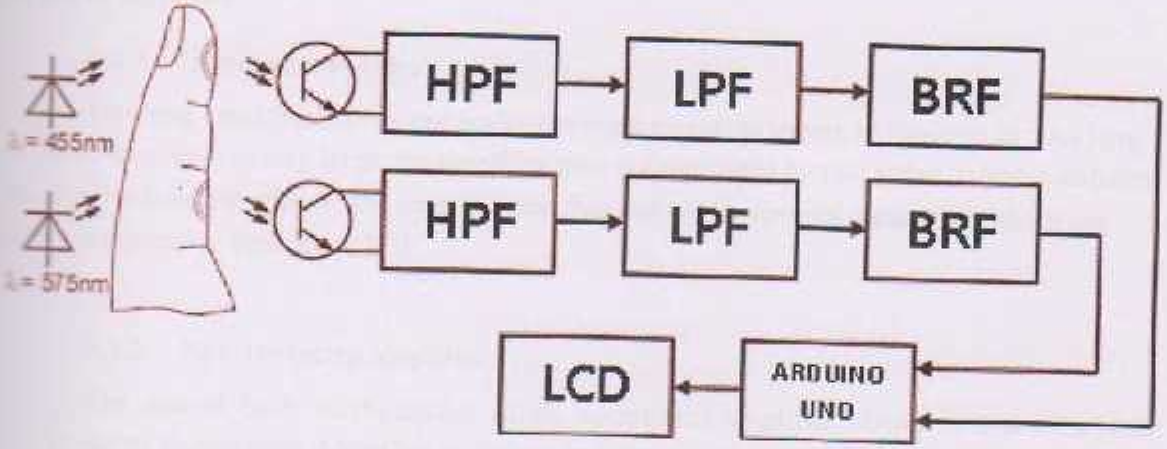


Figure 3.1: System Block Diagram

3.3 Amplifiers

An electronic amplifier is an electronic device that increase the power of a signal. It does this by taking energy from a power supply and controlling the output to match the input signal shape but with a larger amplitude. In this sense, an amplifier modulates the output of the power supply to make the output signal stronger than the input signal.[13]

Amplifier quality is characterized by a list of specifications that includes:

- Gain: the ratio between the magnitude of output and input signals
- Bandwidth: the width of the useful frequency range
- Efficiency: the ratio between the power of the output and total power consumption
- Linearity: the degree of proportionality between input and output
- Noise: a measure of undesired noise mixed into the output
- Output dynamic range: the ratio of the largest and the smallest useful output levels
- Slew rate: the maximum rate of change of the output
- Rise time, settling time, ringing and overshoot that characterize the step response
- Stability: the ability to avoid self-oscillation

Types of amplifier

3.3.1 Inverting amplifier

An inverting amplifier inverts and scales the input signal as shown in Figure (3.2) . As long as the op-amp gain is very large, the amplifier gain is determined by two stable external resistors (the feedback resistor R_F and the input resistor R_{in}) and not by op-amp parameters which are highly temperature dependent .[13]

3.3.2 Non-Inverting amplifier

The second basic configuration of an operational amplifier circuit is that of a Non-inverting Operational Amplifier as shown in Figure (3.3) . In this configuration, the input voltage signal, (Vin) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes "Positive" in value in contrast to the "Inverting Amplifier" circuit we saw in the last tutorial whose output gain is negative in value. The result of this is that the output signal is "in-phase" with the input signal .

3.3.3 Difference Amplifier

A differential amplifier is a type of electronic amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs as shown in figure (3.4).[1] It is an analog circuit with two inputs V_{in}^{-} and V_{in}^{+} and one output V_{out} in which the output is ideally proportional to the difference between the two voltages.

$$V_{\text{out}} = A(V_{\text{in}}^{+} - V_{\text{in}}^{-})$$

where A is the gain of the amplifier.[13]

3.3.4 Instrumentation amplifier

Instrumentation amplifier as shown figure (3.5) is a type of differential amplifier that has been outfitted with input buffer amplifiers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment. Additional characteristics include very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedances. Instrumentation amplifiers are used where great accuracy and stability of the circuit both short and long-term are required.

The electronic instrumentation amp is almost always internally composed of 3 op-amps. These are arranged so that there is one op-amp to buffer each input (+,−), and one to produce the desired output with adequate impedance matching for the function. [13]

3.4 Beer Lambert's Law and Related Equations

Beer Lambert's Law relates the absorption of light to the properties of the material through which the light is travelling. When light with specific wavelength (455nm and 575nm) passes through the solution there is usually a quantitative relationship between the solute concentration and the intensity of the transmitted light. The amount of light absorbed by the medium (solution) is proportional to the concentration of the absorbing material or solute. Also, Lambert describes how an intensity change with distance .the amount of light absorbed by the medium (solution) at a given wavelength is proportional to the path length of the light .[14]

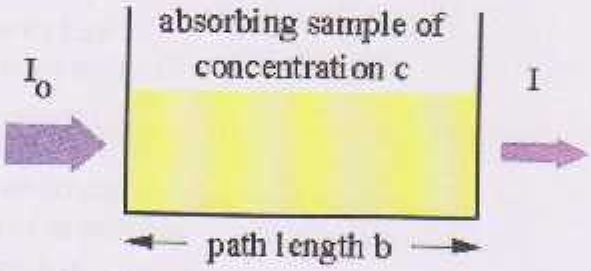


Figure 3.2: Beer Lambert Law

The absorbance of solution at given wavelength is related to:

a) Path length

b) Concentration of solute.

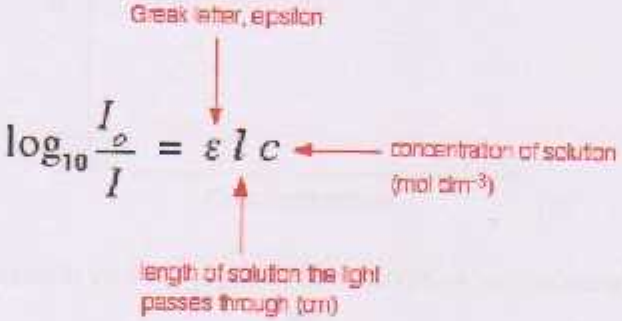
- Transmittance (T): is passing of light through the sample.

$$T = \frac{I_0}{I_{in}} \qquad (3.1)$$

Where: I_0 Is transmitted out light intensity, I_{in} is original light intensity.

- Absorbance (A) : is the amount of light absorbed by a sample (the amount of light that does not pass through the sample).

$$A = -log_{10}\frac{1}{T} \qquad (3.2)$$



(3.3)

Beer Lambert's Law

$$A(\lambda) = L * \varepsilon(\lambda) * C \tag{3.4}$$

Where:

A :Absorbance.

L : Optical path length

ε : Absorptivity of bilirubin

C: Concentration of bilirubin

The figure (3.10) shows the relationship between pathlength & transmission , figure (3.11) shows the relationship between pathlength & absorbance , and figure (3.12) shows the relationship between concentration & absorbance .[15] [16]

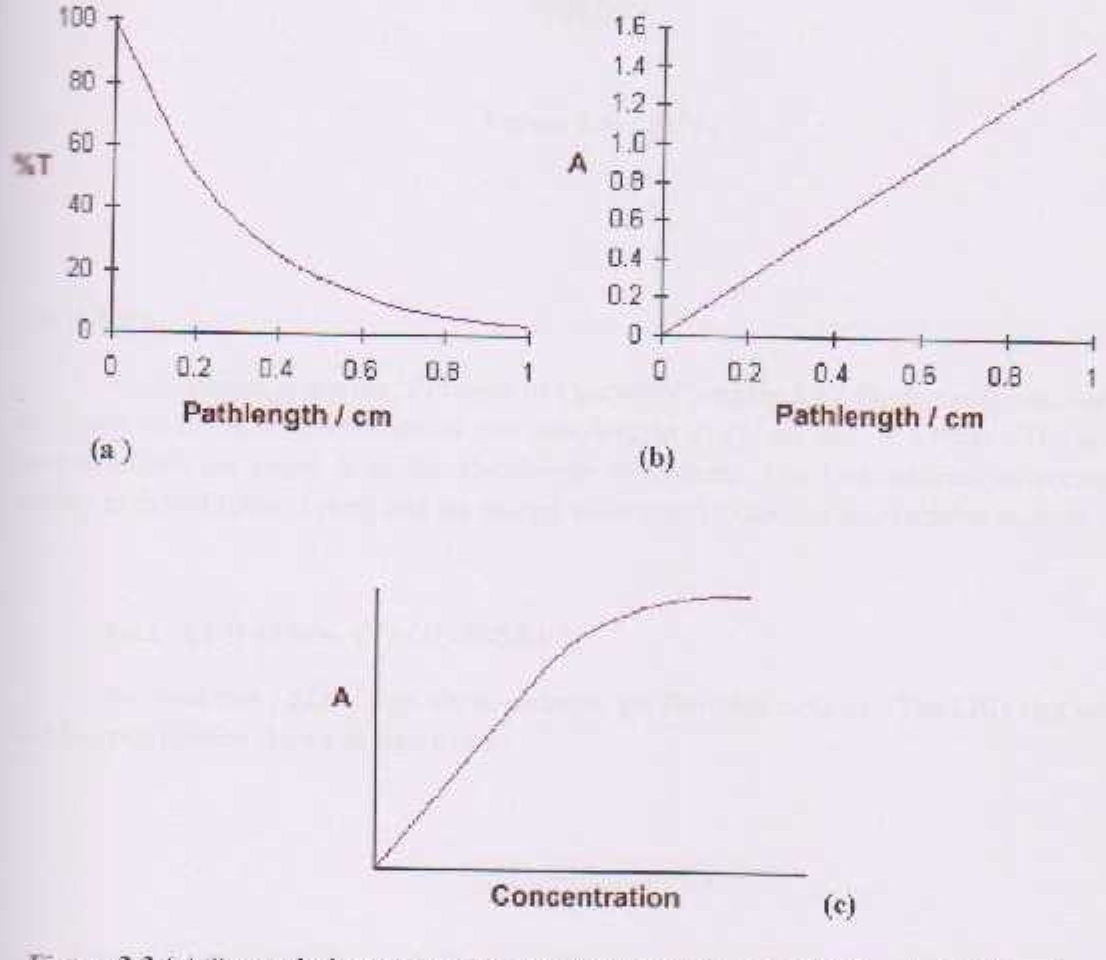


Figure 3.3 (a) Transmission vs. Pathlength . **(b):** Absorption vs. Pathlength .**(c)** Beer Lambert Law .

3.5 LM741 Operational Amplifiers

The LM741 (Figure 3.14) series are general purpose operational amplifiers. It is intended for a wide range of analog applications. The high gain and wide range of operating voltage provide superior performance in integrator, summing amplifier, and general feedback applications. It will be used in filtering stages.

Figure 3.4: LM741

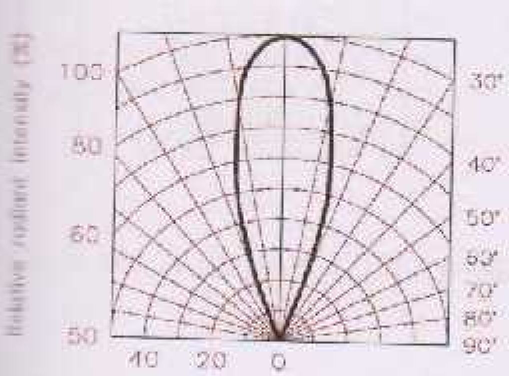
3.6 LED's .

As illustrated in section "Principle of Operation"(section 3.1), Photometric measurements are based on direct measurements of two wavelengths at 455nm and at 575nm . The bilirubin concentrations are found from the absorbency differences .The first wavelength corresponds mainly to the bilirubin content and the second wavelength to the oxyhaemoglobin content .

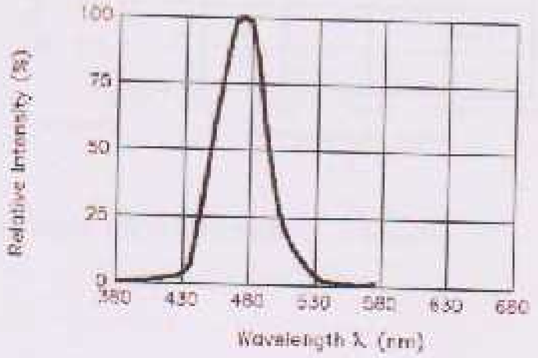
3.6.1 LED 455nm (VAOL-5GSBY4)

We used this LED at 455 nm in order to get Bilirubin content . The LED that we used and its specification shown in figure (3.5).

(a)



(b)



(c)

Figure 3.5: **(a)** LED 455nm (VAOL-5GSBY4). **(b)**Emit ion angle. **(c)**wavelength vs. intensity

3.6.2 LED 575nm (TLHG5400)

We used this LED at 575 nm in order to get oxyhaemoglobin content . The LED that we used and its specification shown in figure (3.6).

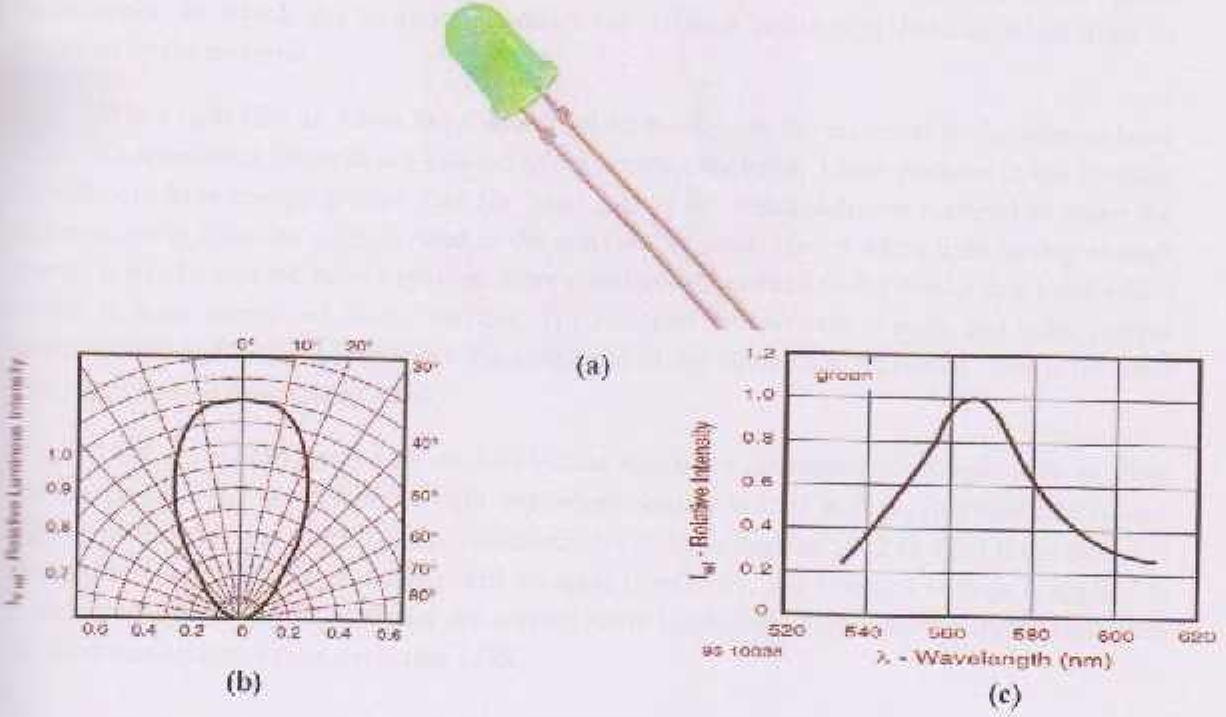


Figure 3.6: (a) . LED 575nm (**TLHG5400**). **(b)**Emit ion angle. **(c)** wavelength vs. intensity.

3.7 Light Dependent Resistor (LDR)

A Light Dependent Resistor (LDR) as shown in figure (3.7)or a photo resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells. They are made up of semiconductor materials having high resistance. There are many different symbols used to indicate a LDR, one of the most commonly used symbol is shown in the figure below. The arrow indicates light falling on it. [17]

Figure 3.7: LDR Shape

LDR works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the materials conductivity (Hence resistivity) reduces when light is absorbed by the material.

When light falls as when the photons fall on the device, the electrons in the valence band of the semiconductor material are excited to the conduction band. These photons in the incident light should have energy greater than the band gap of the semiconductor material to make the electrons jump from the valence band to the conduction band. Hence when light having enough energy is incident on the device more & more electrons are excited to the conduction band which results in large number of charge carriers. The result of this process is more and more current starts flowing and hence it is said that the resistance of the device has decreased .This is the most common working principle of LDR

LDR's are light dependent devices whose resistance decreases when light falls on them and increases in the dark. When a light dependent resistor is kept in dark, its resistance is very high. This resistance is called as dark resistance. It can be as high as 1012 Ω. And if the device is allowed to absorb light its resistance will decrease drastically. If a constant voltage is applied to it and intensity of light is increased the current starts increasing. Figure below shows resistance vs. illumination curve for a particular LDR.

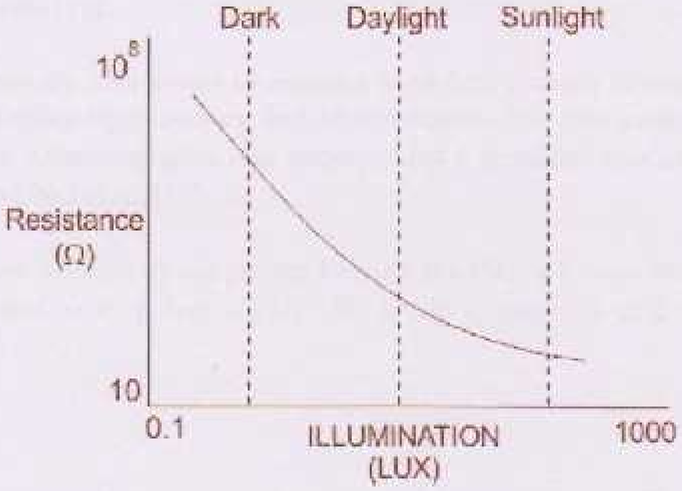


Figure 3.8: LDR characteristics

LDR's are non linear devices as shown in figure (3.8). There sensitivity varies with the wavelength of light incident on them. Some photocells might not at all response to a certain range of wavelengths. Based on the material used different cells have different spectral response curves.

When light is incident on a photocell it usually takes about 8 to 12ms for the change in resistance to take place, while it takes seconds for the resistance to rise back again to its initial value after removal of light. This phenomenon is called as resistance recovery rate. This property is used in audio compressors.

Also, LDR's are less sensitive than photo diodes and photo transistor. (A photo diode and a photocell (LDR) are not the same, a photo-diode is a p-n junction semiconductor device that converts light to electricity, whereas a photocell is a passive device, there is no p-n junction in this nor it "converts" light to electricity).

LDR's have low cost and simple structure. They are often used as light sensors. They are used when there is a need to detect absences or presences of light like in a camera light meter. Used in street lamps, alarm clock, burglar alarm circuits, light intensity meters, for counting the packages moving on a conveyor belt, etc.[17]

3.8 Arduino

Arduino is an open source board microcontroller, Arduino is designed to make electronic more accessible to artists, designer, hobbyists and anyone interested in creating interactive objects or environments.[18]

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language uses a simplified version of C++. The figure (3.9) shows Arduino UNO chip .[18]

We want to use Arduino in our project because the PIC is a chip, while the Arduino is a complete circuit board with power supply, IO headers, easer to deal with, and easer in programming

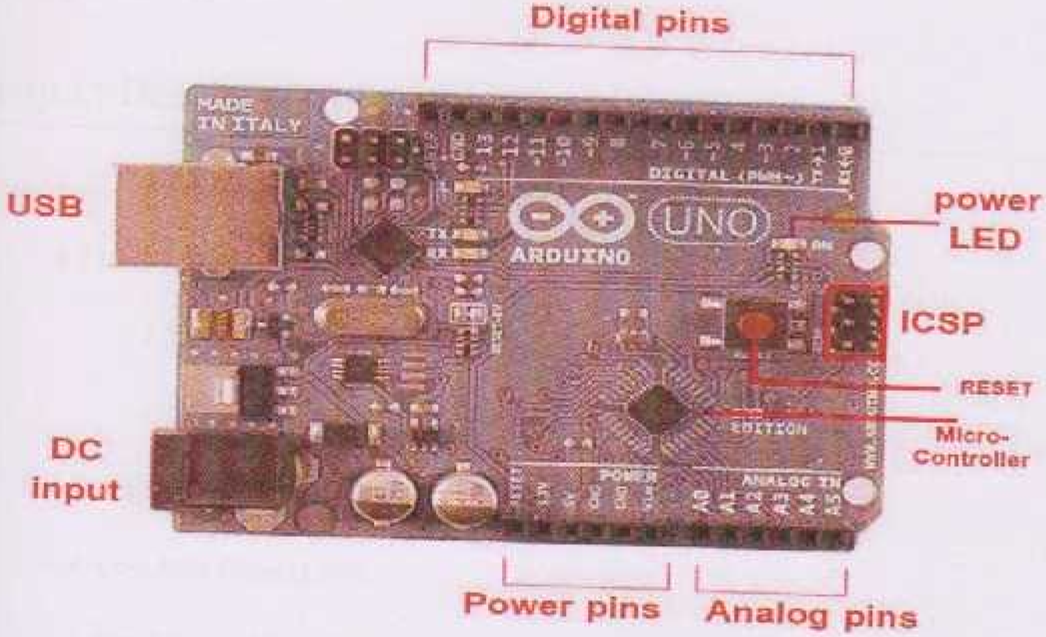


Figure 3.9: Arduino UNO chip

3.9 LCD

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications , as shown in figure (3.10) . LCD's are available in various shapes and sizes depending on the configurations. In our project we need to a **16x4 LCD** shown in the figure below . It is capable to display any character with ASCII values ranging from 0 to 255.[19]

Figure 3.10: 16×4 LCD Pin Diagram

Chapter Four

Project Design & Calculations

4.1 Overview

In this chapter will describe system connections and calculations.

4.2 LED Driving Circuit

In this section will show LED and phototransistor connections and calculations for both 455nm and 575nm.

4.2.1 Constant current source for driving LEDs at $\lambda = 455$ nm

A simple potential circuit for achieving this is shown in figure (4.1) in which an op-amp is combined with a bipolar transistor.

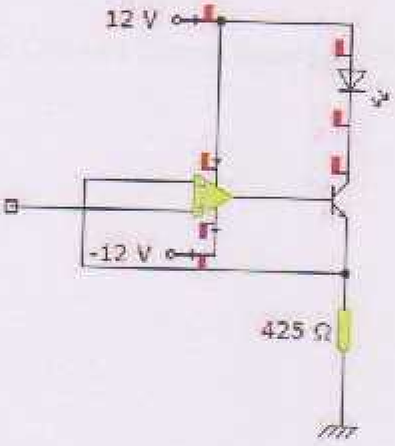


Figure 4.1: Constant Current Source at 445nm

$V_F = 3.5$ V ; $I_F = 20$ mA

$I_F = \frac{Vcc - VF}{R}$

$R = \frac{12 - VF}{IF} = \frac{12 - 3.5}{20\ mA} = 425\ \Omega$

4.2.2 Constant current source for driving LEDs at $\lambda = 575$ nm

The figure (4.3) shows constant current source for driving LEDs at $\lambda = 575$ nm .

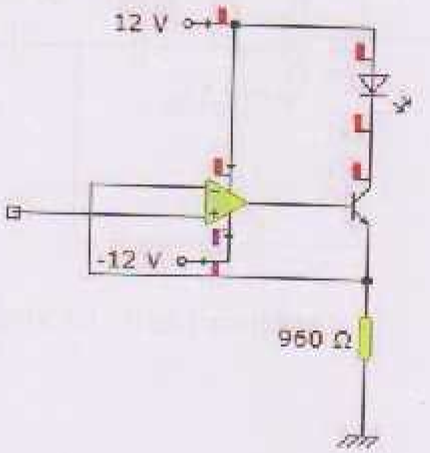


Figure 4.2: Constant Current Source at 575nm

VF = 2.4 V ; IF = 10 mA

$$IF = \frac{(Vcc - VF)}{R}$$

$$R = \frac{12 - VF}{IF} = \frac{12 - 2.4}{10\ mA} = 960\ \Omega$$

4.3 High Pass Filter (HPF)

It is an electronic filter that passes high frequency signals but attenuates signals with frequencies lower than the cutoff frequency. The actual amount of attenuation for each frequency varies from filter to filter . The filter that we used shown in figure (4.5) .

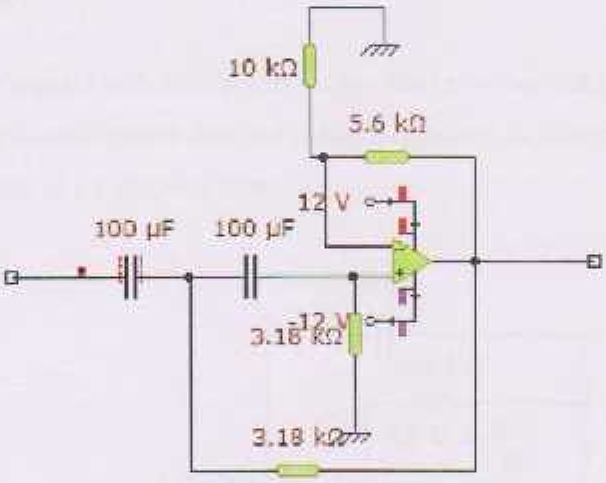


Figure 4.3 : High Pass Filter

$f_c = 0.5$ Hz

$C_1 = C_2 = 100\ \mu F$

$f_c = \frac{1}{2\pi R\sqrt{C1C2}}$

$R = 3.18\ k\Omega$

$R_2 = R_1 = R = 3.18\ k\Omega$

$G = 1 + \frac{Rf}{Rin}$

$\frac{Rf}{Rin} = 1.56 - 1$ (Sallen key)

$\frac{Rf}{Rin} = 0.56$

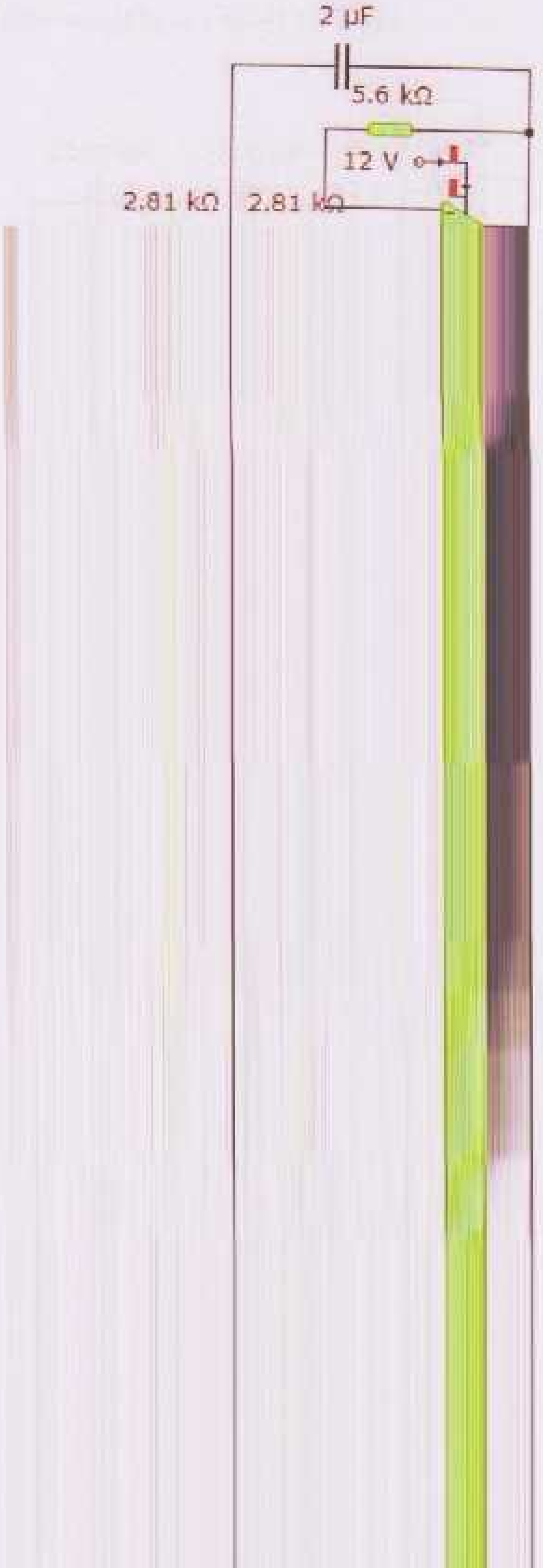
$R_f = 0.56\ R_{in}$

Let $R_{in} = 10\ k\Omega$

$R_f = 5.6$ k

4.4 Low Pass Filter (LPF)

Is a filter that passes signals with a frequency lower than a certain cut off frequency and attenuates signals with frequencies higher than the cutoff frequency, as shown in figure (4.6) . A low-pass filter is the opposite of a high-pass filter.



4.5 Band Reject Filter (BRF)

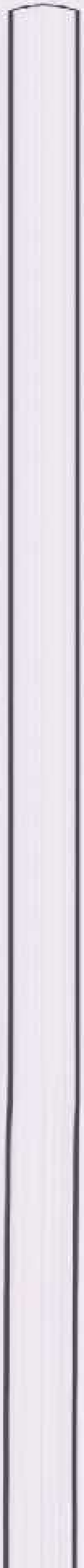
BRF filter passes all frequencies above and below a particular range set by the component values, as shown in figure (4.7) . Not surprisingly, it can be made out of a low-pass

$R_3 = \frac{1}{2} R_1 = 1.59\ k\Omega$

$C_3 = 2\ C_1 = 2\ \mu F$

4.6 Circuit Design

4.7 System Flow chart



4.8 System Software

```
#include <LiquidCrystal.h>
int LED455 = 8;
int LED571 = 0
```

```
float PT2_LEDL_R1=0, PT2_LEDL_R2=0, PT2_LEDL_R3=0, PT2_LEDL_R4=0,
PT2_LEDL_R5=0;

float SUB_PT2_R1=0, SUB_PT2_R2=0, SUB_PT2_R3=0, SUB_PT2_R4=0, SUB_PT2_R5=0;

float AVG_PT2=0;

float Absorb455=0, Absorb575=0,BAbsorb=0;

float Billirubin_Concentration=0,E=54870;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup(){

pinMode (LED455,OUTPUT);

pinMode (LED575,OUTPUT);

Serial.begin(9600);

lcd.begin(16,4);

}

void loop (){

 lcd.setCursor(1,0);

 lcd.print("Non-Invasive");

 lcd.setCursor(1,1);

 lcd.print("Medical System");

 lcd.setCursor(1,2);

 lcd.print("for Measuring");

 lcd.setCursor(1,3);

 lcd.print("Bilirubin");

  delay(5000);

 lcd.clear();

  delay(750);
```

```
lcd.setCursor(0,0);
lcd.print("Please Make Sure");
lcd.setCursor(0,1);
lcd.print("That Nothing in");
lcd.setCursor(0,2);
lcd.print("Finger Champer");
delay(3000);
lcd.clear();
delay(1000);
lcd.setCursor(0,0);
lcd.print("Taking Initial ");
lcd.setCursor(0,1);
lcd.print("Measurments");
lcd.setCursor(0,3);
lcd.print("Please Wait...");
digitalWrite(LED455,HIGH);
NF_PT1_LEDH_R1=analogRead(PhoTrans1);
delay(500);
digitalWrite(LED455,LOW);
NF_PT1_LEDL_R1=analogRead(PhoTrans1);
delay(500);
NF_SUB_PT1_R1= NF_PT1_LEDH_R1-NF_PT1_LEDL_R1;
digitalWrite(LED455,HIGH);
NF_PT1_LEDH_R2=analogRead(PhoTrans1);
delay(500);
```

```
digitalWrite(LED455,LOW);
 NF_PT1_LEDL_R2=analogRead(PhoTrans1);
 delay(500);
```

```
NF_AVG_PT1=(NF_SUB_PT1_R1+NF_SUB_PT1_R2+NF_SUB_PT1_R3+NF_SUB_PT1_R4
+NF_SUB_PT1_R5)/5;
 digitalWrite(LED575,HIGH);
 NF_PT2_LEDH_R1=analogRead(PhoTrans2);
 delay(500);
 digitalWrite(LED575,LOW);
 NF_PT2_LEDL_R1=analogRead(PhoTrans2);
 delay(500);
 NF_SUB_PT2_R1= NF_PT2_LEDH_R1-NF_PT2_LEDL_R1;

 digitalWrite(LED575,HIGH);
 NF_PT2_LEDH_R2=analogRead(PhoTrans2);
 delay(500);
 digitalWrite(LED575,LOW);
 NF_PT2_LEDL_R2=analogRead(PhoTrans2);
 delay(500);
 NF_SUB_PT2_R2= NF_PT2_LEDH_R2-NF_PT2_LEDL_R2;
 digitalWrite(LED575,HIGH);
 NF_PT2_LEDH_R3=analogRead(PhoTrans2);
 delay(500);
 digitalWrite(LED575,LOW);
 NF_PT2_LEDL_R3=analogRead(PhoTrans2);
 delay(500);
 NF_SUB_PT2_R3= NF_PT2_LEDH_R3-NF_PT2_LEDL_R3;
 digitalWrite(LED575,HIGH);
```

```
NF_PT2_LEDH_R4=analogRead(PhoTrans2);
delay(500);
digitalWrite(LED575,LOW);
NF_PT2_LEDL_R4=analogRead(PhoTrans2);
delay(500);
```

```
lcd.setCursor(0,0);
lcd.print("Taking");
lcd.setCursor(0,1);
lcd.print("Measurments");
lcd.setCursor(0,3);
lcd.print("Please Wait...");
digitalWrite(LED455,HIGH);
PT1_LEDH_R1=analogRead(PhoTrans1);
delay(500);
digitalWrite(LED455,LOW);
PT1_LEDL_R1=analogRead(PhoTrans1);
delay(500);
SUB_PT1_R1= PT1_LEDH_R1-PT1_LEDL_R1;
digitalWrite(LED455,HIGH);
PT1_LEDH_R2=analogRead(PhoTrans1);
delay(500);
digitalWrite(LED455,LOW);
PT1_LEDL_R2=analogRead(PhoTrans1);
delay(500);
SUB_PT1_R2= PT1_LEDH_R2-PT1_LEDL_R2;
digitalWrite(LED455,HIGH);
PT1_LEDH_R3=analogRead(PhoTrans1);
delay(500);
digitalWrite(LED455,LOW);
PT1_LEDL_R3=analogRead(PhoTrans1);
```

```
delay(500);
SUB_PT1_R3= PT1_LEDH_R3-PT1_LEDL_R3;
digitalWrite(LED455,HIGH);
PT1_LEDH_R4=analogRead(PhoTrans1);
delay(500);
digitalWrite(LED455,LOW);
PT1_LEDL_R4=analogRead(PhoTrans1);
delay(500);
SUB_PT1_R4= PT1_LEDH_R4-PT1_LEDL_R4;
digitalWrite(LED455,HIGH);
PT1_LEDH_R5=analogRead(PhoTrans1);
delay(500);
digitalWrite(LED455,LOW);
PT1_LEDL_R5=analogRead(PhoTrans1);
delay(500);
SUB_PT1_R5=PT1_LEDH_R5-PT1_LEDL_R5;
AVG_PT1=(SUB_PT1_R1+SUB_PT1_R2+SUB_PT1_R3+SUB_PT1_R4+SUB_PT1_R5)/5;
digitalWrite(LED575,HIGH);
PT2_LEDH_R1=analogRead(PhoTrans2);
delay(500);
digitalWrite(LED575,LOW);
PT2_LEDL_R1=analogRead(PhoTrans2);
delay(500);
SUB_PT2_R1= NF_PT2_LEDH_R1-NF_PT2_LEDL_R1;
digitalWrite(LED575,HIGH);
```

```
PT2_LEDH_R2=analogRead(PhoTrans2);
delay(500);
digitalWrite(LED575,LOW);
```

```
delay(500);

SUB_PT2_R5=PT1_LEDH_R5-PT2_LEDL_R5;

AVG_PT2=(SUB_PT2_R1+SUB_PT2_R2+SUB_PT2_R3+SUB_PT2_R4+SUB_PT2_R5)/5;

  Absorb455= log(NF_AVG_PT1/AVG_PT1);
```

Chapter Five

System Implementation & Testing

5.1 Low Pass Filter.

5.2 High Pass Filter.

5.3 Band Pass Filter.

5.4 Band Reject Filter.

5.5 Band Pass & Reject.

5.6 LED's & Reciever .

5.1 Low Pass Filter

The low pass filter (Figure 5.1) is constructed and connected with dc voltage source with 1V P-P with varying frequency to insure of frequency filtration range, and the results are obtained as recorded in table (5.1) and shown in figure (5.2).

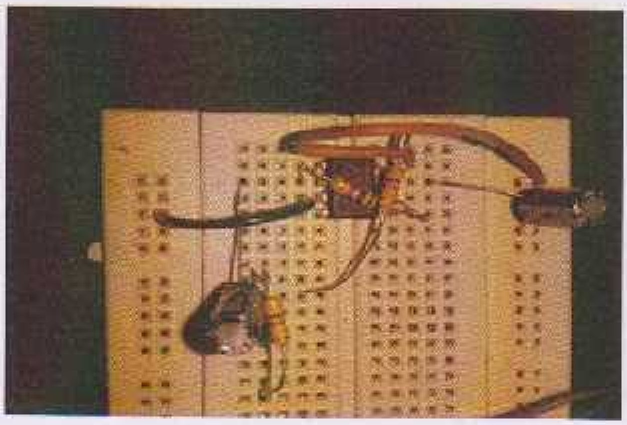


Figure 5.1: Low pass filter

Table 5.1: LPF Out Voltage vs. Frequency

Frequency (Hz)	2	5	10	20	30	40	50	80	100	150	200	300
Voltage (Vp-p)	1	1	1	1	1	0.780	0.550	0.280	0.240	0.130	0.128	0.96

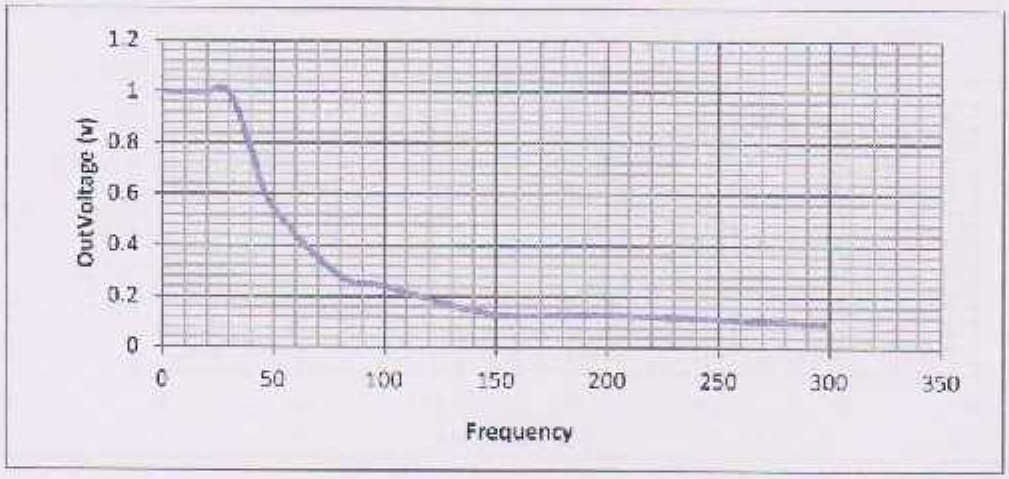


Figure 5.2: LPF OutVoltage vs. Frequency curve

5.2 High Pass Filter

The high pass filter (Figure 5.3) is constructed and connected with dc voltage source with 1V P-P with varying frequency to insure of frequency filtration range, and the results are obtained as recorded in table (5.2) and shown in figure (5.4).

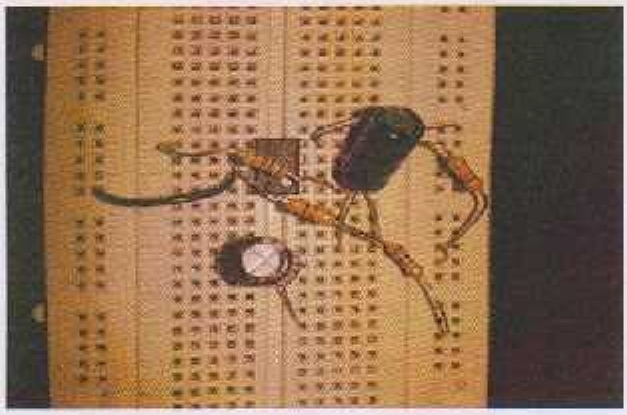


Figure 5.3: High pass filter

Table 5.2: HPF Out Voltage vs. Frequency

Frequency (Hz)	0.2	0.4	0.5	1	5	10	15
Voltage (Vp-p)	0.280	0.720	1.06	1.48	1.6	1.54	1.54
Frequency (Hz)	20	25	30	35	40	45	50
Voltage (Vp-p)	1.54	1.56	1.56	1.56	1.56	1.56	1.66

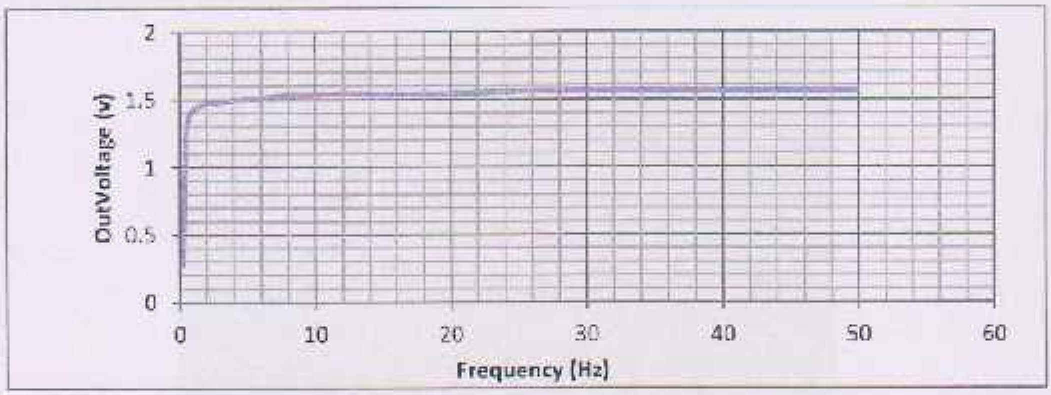


Figure 5.4: HPF OutVoltage vs. Frequency curve

5.3 Band Pass Filter

The BPF consist of LPF and HPF connected together. BPF is constructed and connected with dc voltage source with 1V P-P with varying frequency to insure of frequency filtration range, and the results are obtained as recorded in table (5.3) shown in figure (5.4).

Table 5.3: BPF Out Voltage vs. Frequency

Frequency (Hz)	0.2	0.4	0.5	1	5	10	15	20	25	30	35	40	45	50
Voltage (Vp-p)	0.32	0.84	1.14	1.53	1.62	1.56	1.53	1.46	1.4	1.3	1.16	1.02	0.88	0.79

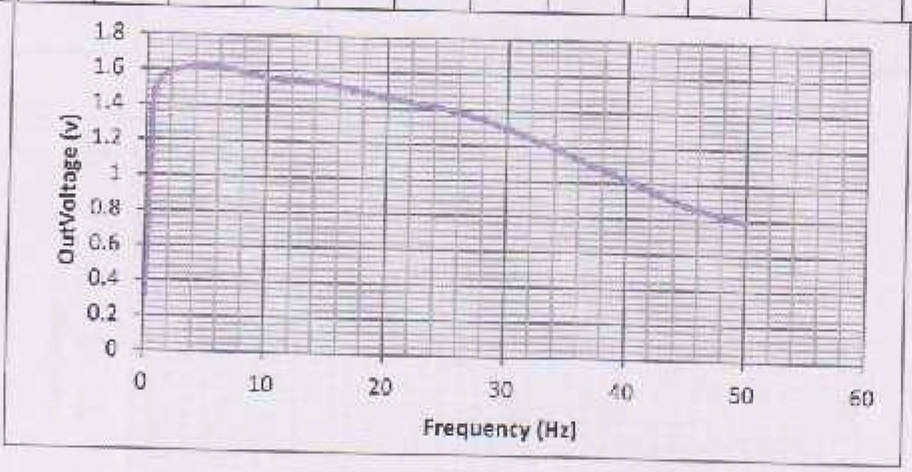


Figure 5.5: BPF OutVoltage vs. Frequency curve

5.4 Band Reject Filter.

BRF (Figure 5.6) is constructed and connected with dc voltage source with 1V P-P with varying frequency to insure of frequency filtration range, and the results are obtained as recorded in table (5.4) and shown in figure (5.7)

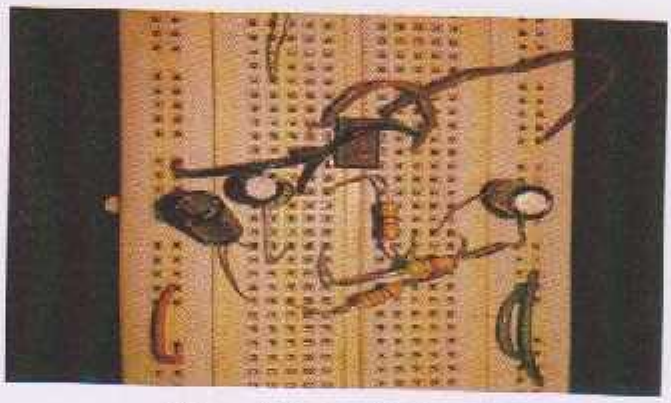


Figure 5.6: Band Reject Filter

Table 5.4: BRF Out Voltage vs. Frequency

Frequency (Hz)	0.8	1.8	2	5	10	15	20	25	30	35	40
Voltage (Vp-p)	1.12	1.02	1.02	0.98	0.8	0.6	0.5	0.38	0.3	0.2	0.18
Frequency (Hz)	45	50	55	60	70.	80	90	100	110	120	130
Voltage (Vp-p)	0.12	0.1	0.14	0.18	0.22	0.3	0.36	0.42	0.46	0.5	0.52
Frequency (Hz)	140	160	200	250	300	350	400	450	500	600	700
Voltage (Vp-p)	0.56	0.62	0.72	0.78	0.82	0.86	0.9	0.94	0.94	0.98	1

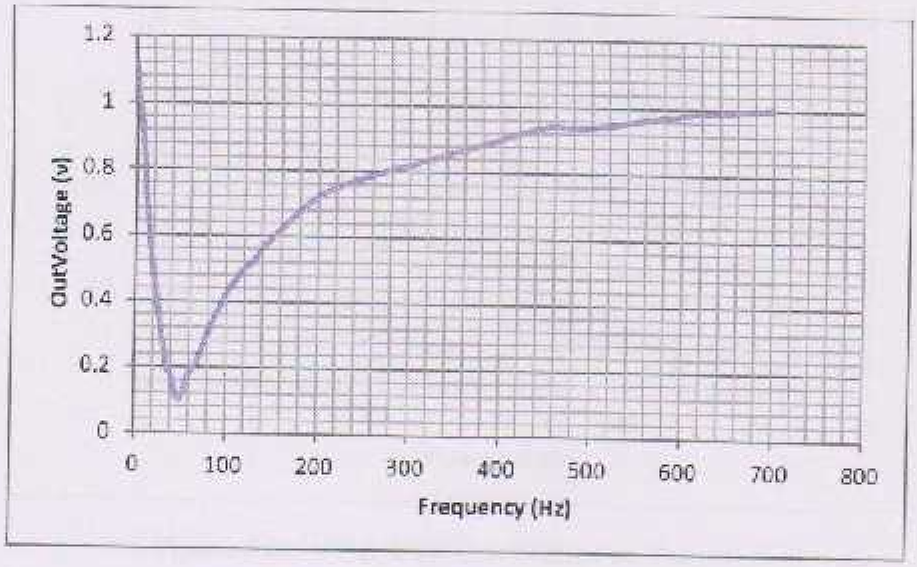


Figure 5.7: BRF OutVoltage vs. Frequency curve

5.5 Band Pass & Reject.

Consist of BPF and BRF connected together. BPF is constructed and connected with dc voltage source with 1V P-P with varying frequency to insure of frequency filtration range, and the results are obtained as recorded in table (5.5) and shown in figure (5.8)

Frequency (Hz)	0.5	1	2	5	10	15	20	25	30	35	40	45	50
Voltage (Vp-p)	1.14	1.44	1.52	1.44	1.12	0.9	0.76	0.54	0.42	0.36	0.26	0.22	0.12

Table 5.5: Band Pass & Reject Out Voltage vs. Frequency

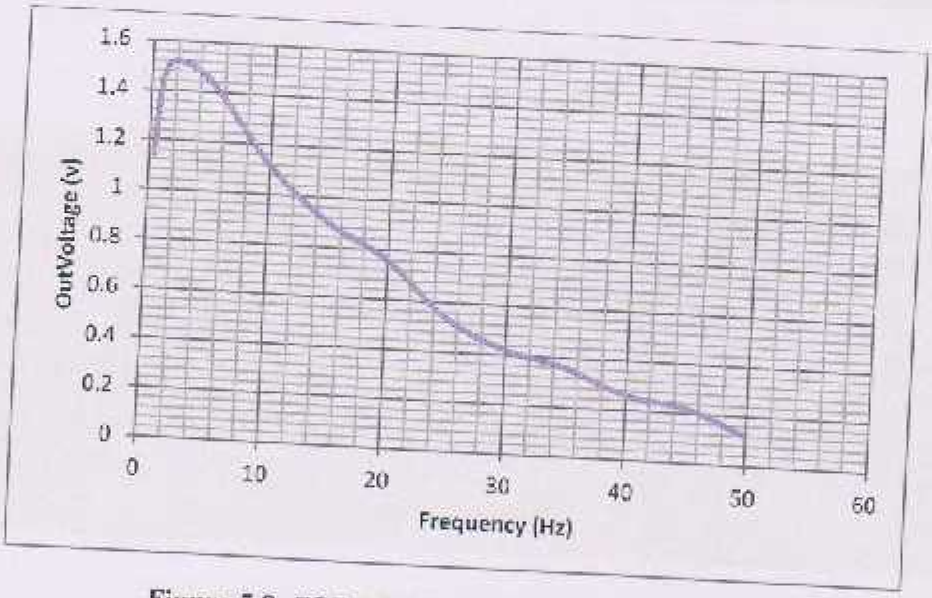


Figure 5.8: BPF & BRF Out Voltage vs. Frequency curve

5.6 LED's & Reciever

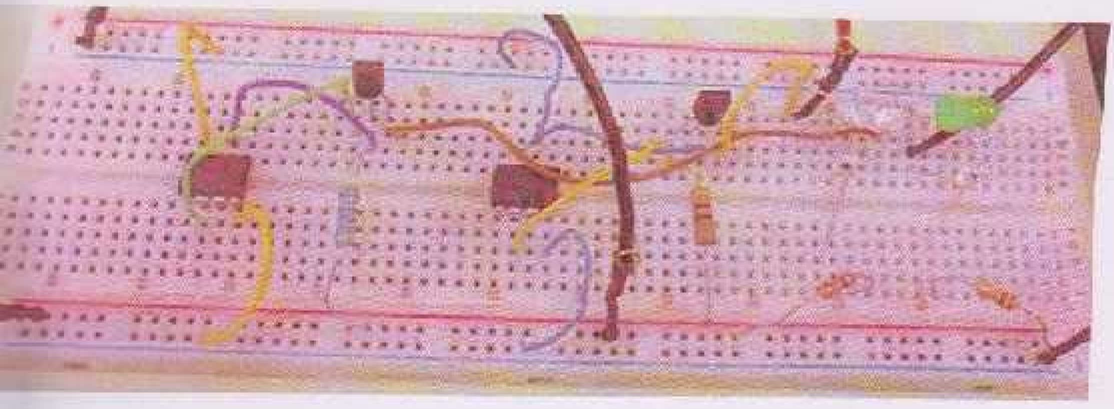


Figure 5.9: LED's without trigger

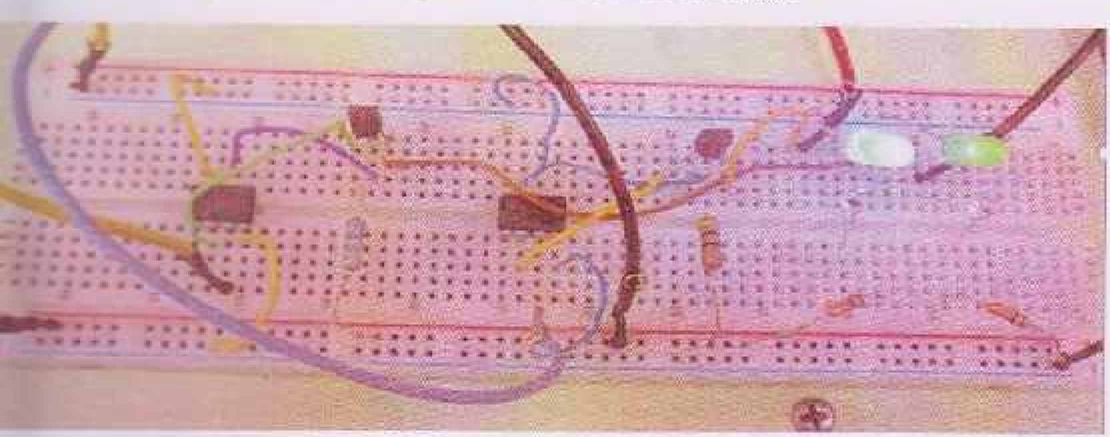


Figure 5.10 : LED's With trigger

Chapter Six

Conclusion & Results

6.1 Results

6.2 Conclusion

6.1 Results

Table 6.1. Bilirubin measurement results achieved with the use of the implemented bilirubin photometer in confrontation with the results gained by the blood sample (CBC).

Test Number	Bilirubin level measured by CBC (μmol/L)	Bilirubin level measured by Implemented device (μmol/L)	Relative error in %
1	6.087	7	14.9
2	9.43	9	- 4.5
3	7.8	9	15.3
4	6.32	7	10.7
5	10.01	8	- 20
6	18.2	14	- 23.1
7	8.4	9	7.1
8	11.2	12	7.14

The results of the tests have shown the principal measuring accuracy. The error level in measurements reached 23.1%. The relative error in all measurements was lower than 3.2%

Relative Error = $\frac{|measured\ value - actual\ value|}{actual\ value}$

1. For Test number 1 Relative Error = $\frac{7-6.087}{6.087}$ * 100 %

   = 14.9 %

2. For Test number 2 Relative Error = $\frac{9-9.43}{9.43}$ * 100 %

   = - 4.5 %

3. For Test number 2 Relative Error = $\frac{9-7.8}{7.8}$ * 100 %

   = 15.3 %

4. For Test number 2 Relative Error = $\frac{7-6.32}{6.32}$ * 100 %

   = 10.7 %

5. For Test number 2 Relative Error = $\frac{8-10.01}{10.01}$ * 100 %

   = - 20%

6. For Test number 2 Relative Error = $\frac{14-18.2}{18.2}$ * 100 %

= - 23.1%

7. For Test number 2 Relative Error = $\frac{9-8.4}{8.4} * 100\ \%$

= 7.1%

8. For Test number 2 Relative Error = $\frac{12-11.2}{11.2} * 100\ \%$

= 7.14%

6.2 Conclusion

The objective of our project was design and implement a medical diagnostic measurement system for the bilirubin assessment . The system was implemented as a photometric method with two specific wavelengths for the non invasive bilirubin value assessment.

The electronic device was implemented and connected to an LCD to show the result of the test . The relevant test was done in the Al-Hussein hospital in Beit Jala have good results related to both the implemented bilirubin photometer and the results gained by the blood sample (CBC).. The maximum error in eight subjects reached less than 23.1% and the relative error was 3.2%.

References:

[1] : Franchinib M , Targher G, Lippi G, Advances in Clinical Chemistry ,volume 50 , 2010 , Pages 47–63.

[2] : Jansen P, Bittar E, Principles of Medical Biology , 2004, volume 15 , Pages 257–289 .

[3] : Johnson L. , Encyclopedia of Gastroenterology , Bilirubin and Jaundice , 2004, Pages 219–222 .

[4] : Greene D , Holmes D , Jan Lin M , Liang J , Lorey T, Schmidt R, Clinica Chimica Acta , Development of an equation to correct for hemolysis in direct bilirubin measurements , volume 429 , 2014 , Pages 194–197.

[5]: http://www.ncbi.nlm.nih.gov/pubmed/16585313

[6]: Chowdhury J , Chowdhury N , Zakim and Boyer's Hepatology , Sixth Edition , 2012 , Pages 1079–1109.

[7]: http://www.webmd.com/digestive-disorders/bilirubin-15434

[8]: Romagnoli C , Zecca E, Catenazzi P , Barone G, Zuppa A, Clinical Biochemistry , Transcutaneous bilirubin m+- easurement: Comparison of Respironics BiliCheck and JM-103 in a normal newborn population ,Volume 45, Issue 9, 2012, Pages 659–662 .

[9]: Penhaker M, Kasik V, Hrvolova B, ELEKTRONIKA IR ELEKTROTECHNIKA , Advanced Bilirubin Measurement by a Photometric Method , VOL. 19, 2013 .

[10]: Dai J, Parry DM, Krahn J. Transcutaneous bilirubinometry: its role in the assessment of neonatal jaundice.Clin Biochem. 1997 .

[11]: Leite Md, Granato Vde A, Facchini FP, et al. Comparison of transcutaneous and plasma bilirubin measurement. J Pediatr (Rio J) 2007 .

[12] :Watchko JF. Neonatal hyperbilirubinemia-what are the risks? N Engl J Med. 2006 .

[13]: http://www.allaboutcircuits.com/vol_3/chpt_8/10.html

[14]: http://teaching.shu.ac.uk/hwb/chemistry/tutorials/molspec/beers1.htm

[15]: http://www.chemguide.co.uk/analysis/uvvisible/beerlambert.html

[16]: https://hplc.chem.shu.edu/NEW/Undergrad/Molec_Spectr/Lambert.html

[17] http://www.electrical4u.com/light-dependent-resistor-ldr-working-principle-of-ldr/

[18]: http://arduino.cc/en/Guide/Introduction

[19]: http://electronics.howstuffworks.com/lcd.htm

Appendix

Data Sheet

Light dependent resistors

NORP12 RS stock number 651-507
NSL19-M51 RS stock number 596-141

Two cadmium sulphide (cdS) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Guide to source illuminations

Light source	Illumination (Lux)
Moonlight	0.1
60W bulb at 1m	50
1W MES bulb at 0.1m	100
Fluorescent lighting	500
Bright sunlight	30,000

Circuit symbol

Light memory characteristics

Light dependent resistors have a particular property in that they remember the lighting conditions in which they have been stored. This memory effect can be minimised by storing the LDRs in light prior to use. Light storage reduces equilibrium time to reach steady resistance values.

NORP12 (**RS** stock no. 651-507)

Absolute maximum ratings

Voltage, ac or dc peak	320V
Current	75mA
Power dissipation at 30°C	250mW
Operating temperature range	-60°C to +75°C

Electrical characteristics

T_A = 25°C. 2854°K tungsten light source

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux 10 lux	- -	400 9	- -	Ω kΩ
Dark resistance	-	1.0	-	-	MΩ
Dark capacitance	-	-	3.5	-	pF
Rise time 1	1000 lux 10 lux	- -	2.8 18	- -	ms ms
Fall time 2	1000 lux 10 lux	- -	48 120	- -	ms ms

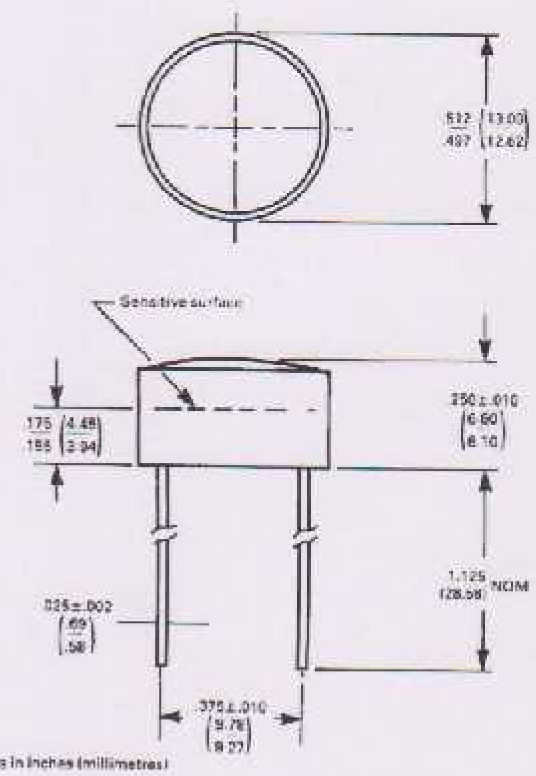
1. Dark to 110% R_L
2. To 10 × R_L

R_L = photocell resistance under given illumination.

Features

- Wide spectral response
- Low cost
- Wide ambient temperature range.

Dimensions



Units in inches (millimetres)

Figure 1 Power dissipation derating

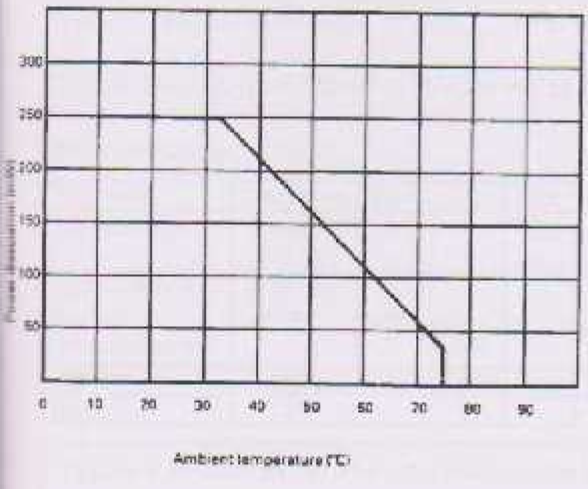
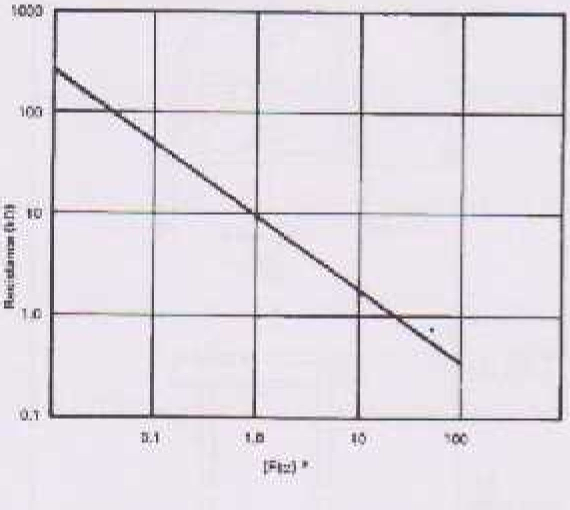
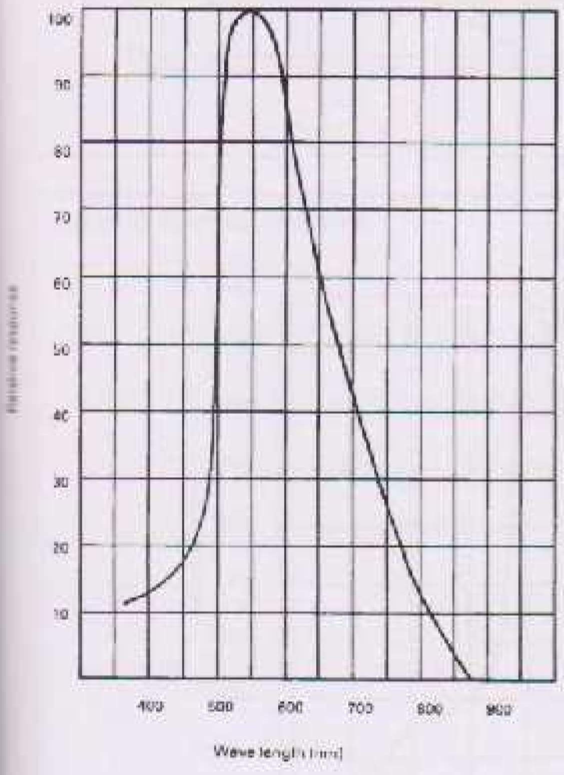


Figure 3 Resistance as a function of illumination



*1Ftc=10.764 lumens

Figure 2 Spectral response



Absolute maximum ratings

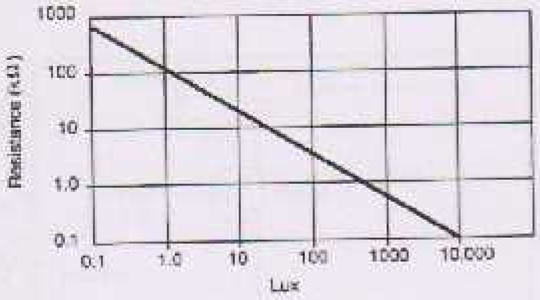
Voltage: ac or dc peak ______ 100V
Current ______ 5mA
Power dissipation at 25°C ______ 50mW*
Operating temperature range ______ -25°C +75°C

*Derate linearly from 50mW at 25°C to 0W at 75°C.

Electrical characteristics

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	10 lux 100 lux	20 -	- 5	100 -	kΩ kΩ
Dark resistance	10 lux after 10 sec	20	-	-	MΩ
Spectral response	-	-	550	-	nm
Rise time	10fc	-	45	-	ms
Fall time	10fc	-	55	-	ms

Figure 4 Resistance as a function illumination



Dimensions

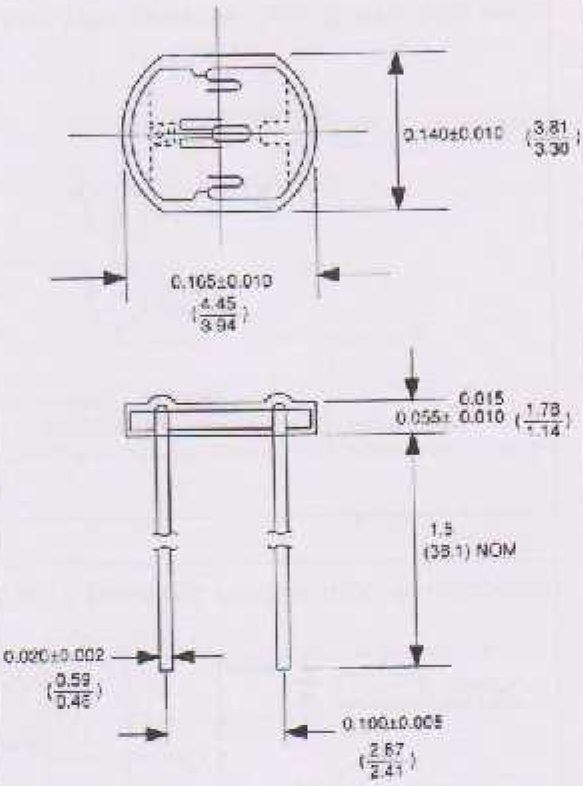
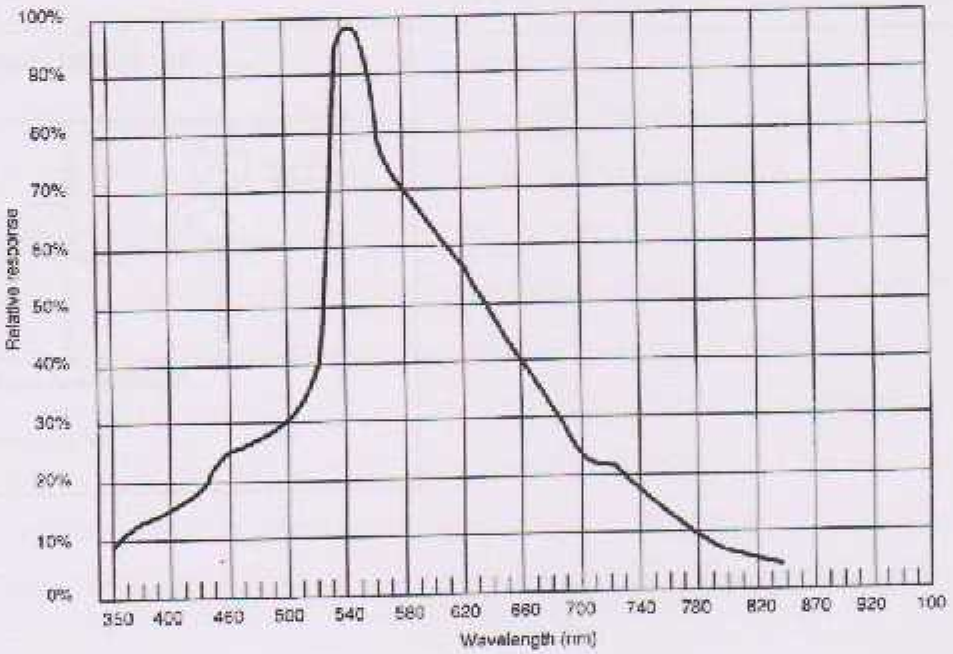
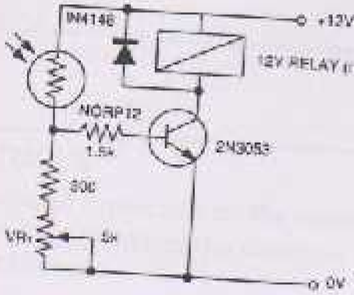


Figure 5 Spectral response



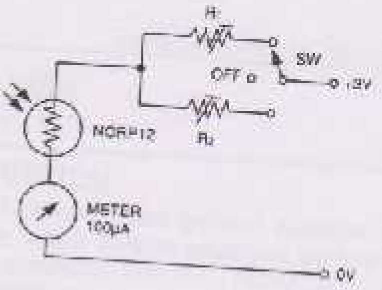
Typical application circuits

Figure 6 Sensitive light operated relay



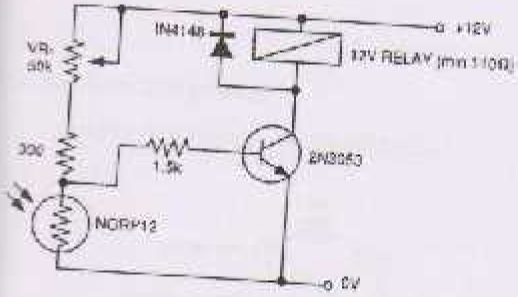
Relay energised when light level increases above the level set by VR.

Figure 9 Logarithmic law photographic light meter



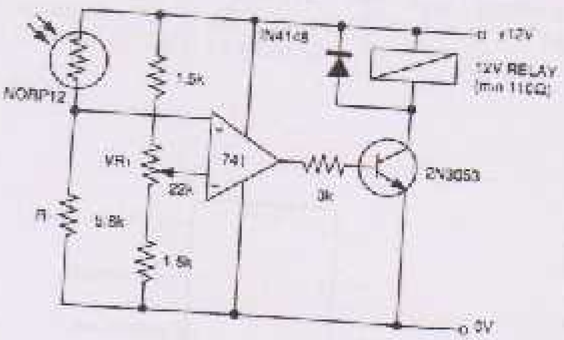
Typical value R^1 = 100kΩ
R^2 = 200kΩ preset to give two overlapping ranges.
(Calibration should be made against an accurate meter.)

Figure 7 Light interruption detector



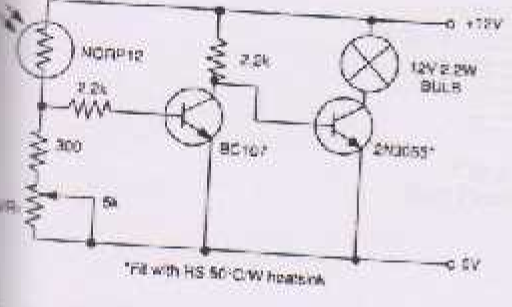
As Figure 6 relay energised when light level drops below the level set by VR_1

Figure 10 Extremely sensitive light operated relay



(Relay energised when light exceeds preset level.) Incorporates a balancing bridge and op-amp. R_1 and NORP12 may be interchanged for the reverse function.

Figure 8 Automatic light circuit



Adjust turn-on point with VR.

LM741 Operational Amplifier

Check for Samples: LM741

FEATURES

- Overload Protection on the Input and Output
- No Latch-Up When the Common Mode Range is Exceeded

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 ensured over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Connection Diagrams

LM741H is available per JM38510/10101

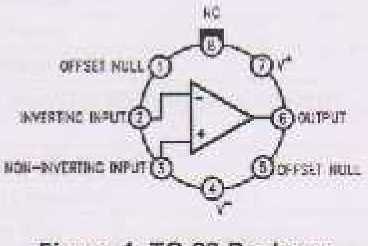


Figure 1. TO-99 Package
See Package Number LMC0008C

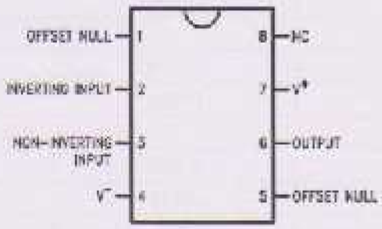


Figure 2. CDIP or PDIP Package
See Package Number NAB0008A, P0008E

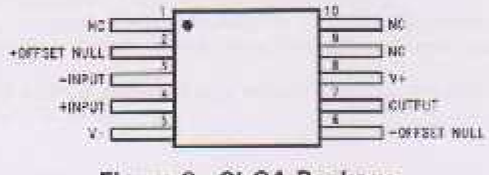


Figure 3. CLGA Package
See Package Number NAD0010A

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

Typical Application

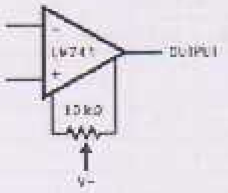


Figure 4. Offset Nulling Circuit

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings [1][2][3]

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation [4]	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage [5]	±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			
P0008E-Package (10 seconds)	260°C	260°C	260°C
NAB0008A- or LMC0008C-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
ESD Tolerance [6]	400V	400V	400V

(1) "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 ensure specific performance limits.
(2) For military specifications see RETS741X for LM741 and RETS741AX for LM741A.
(3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(4) For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.
(5) For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
(6) Human body model, 1.5 kΩ in series with 100 pF.

Electrical Characteristics [1]

Parameter	Test Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	
Average Input Offset Voltage Drift				15							μV/°C

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

Electrical Characteristics[1] (continued)

Parameter	Test Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = ±20V$	±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	$T_A = 25°C$, $V_S = ±20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = ±20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \le T_A \le T_{AMAX}$				±12	±13					V
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \ge 2\ kΩ$										V/mV
	$V_S = ±20V$, $V_O = ±15V$	50									V/mV
	$V_S = ±15V$, $V_O = ±10V$				50	200		20	200		V/mV
	$T_{AMIN} \le T_A \le T_{AMAX}$, $R_L \ge 2\ kΩ$,										V/mV
	$V_S = ±20V$, $V_O = ±15V$	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	$V_S = ±20V$										V
	$R_L \ge 10\ kΩ$	±16									V
	$R_L \ge 2\ kΩ$	±15									V
	$V_S = ±15V$										V
	$R_L \ge 10\ kΩ$				±12	±14		±12	±14		V
	$R_L \ge 2\ kΩ$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25°C$	10	25	35		25			25		mA
	$T_{AMIN} \le T_A \le T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \le T_A \le T_{AMAX}$										dB
	$R_S \le 10\ kΩ$, $V_{CM} = ±12V$				70	90		70	90		dB
	$R_S \le 50Ω$, $V_{CM} = ±12V$	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \le T_A \le T_{AMAX}$,										dB
	$V_S = ±20V$ to $V_S = ±5V$										dB
	$R_S \le 50Ω$	86	96								dB
	$R_S \le 10\ kΩ$				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 [4]	$T_A = 25°C$	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	$T_A = 25°C$										mW
	$V_S = ±20V$		80	150							mW
	$V_S = ±15V$					50	85		50	85	mW

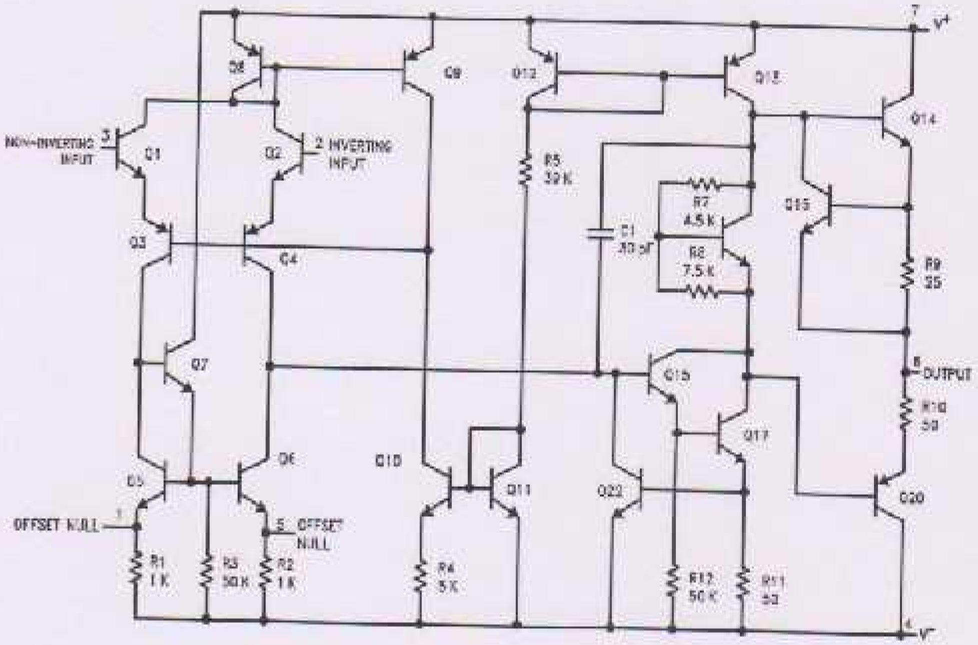
(4) Calculated value from: BW (MHz) = 0.35/Rise Time (μs).

Electrical Characteristics[(1)] (continued)

Parameter	Test Conditions	LM741A Min	LM741A Typ	LM741A Max	LM741 Min	LM741 Typ	LM741 Max	LM741C Min	LM741C Typ	LM741C Max	Units
LM741A	$V_S = \pm 20V$ $T_A = T_{AMIN}$ $T_A = T_{AMAX}$			165 135							mW
LM741	$V_S = \pm 15V$ $T_A = T_{AMIN}$ $T_A = T_{AMAX}$					60 45	100 75				mW

Thermal Resistance	CDIP (NAB0008A)	PDIP (P0008E)	TO-99 (LMC0008C)	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

SCHEMATIC DIAGRAM



REVISION HISTORY

Changes from Revision B (March 2013) to Revision C | **Page**

- Changed layout of National Data Sheet to TI format 4

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM741CH	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	0 to 70	(LM741CH ~ LM741CH)	Samples
LM741CH/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	0 to 70	(LM741CH ~ LM741CH)	Samples
LM741CN/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 70	LM 741CN	Samples
LM741H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	(LM741H ~ LM741H)	Samples
LM741H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 125	(LM741H ~ LM741H)	Samples
LM741J	ACTIVE	CDIP	NAB	8	40	TBD	Call TI	Call TI	-55 to 125	LM741J	Samples
U5B7741312	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	(LM741H ~ LM741H)	Samples
U5B7741393	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	0 to 70	(LM741CH ~ LM741CH)	Samples
U9T7741393	OBSOLETE	PDIP	P	8		TBD	Call TI	Call TI	0 to 70	LM 741CN	

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

[4] There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

[5] Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

[6] Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are seperated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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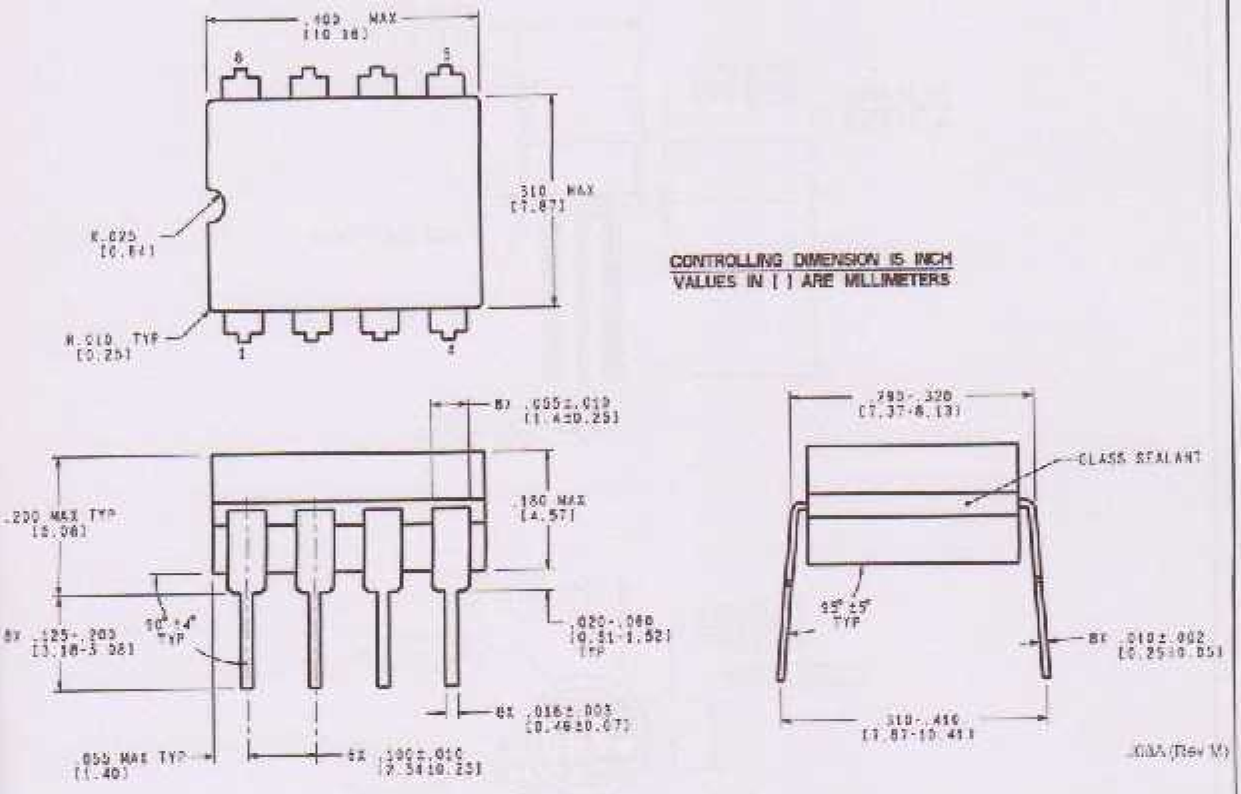
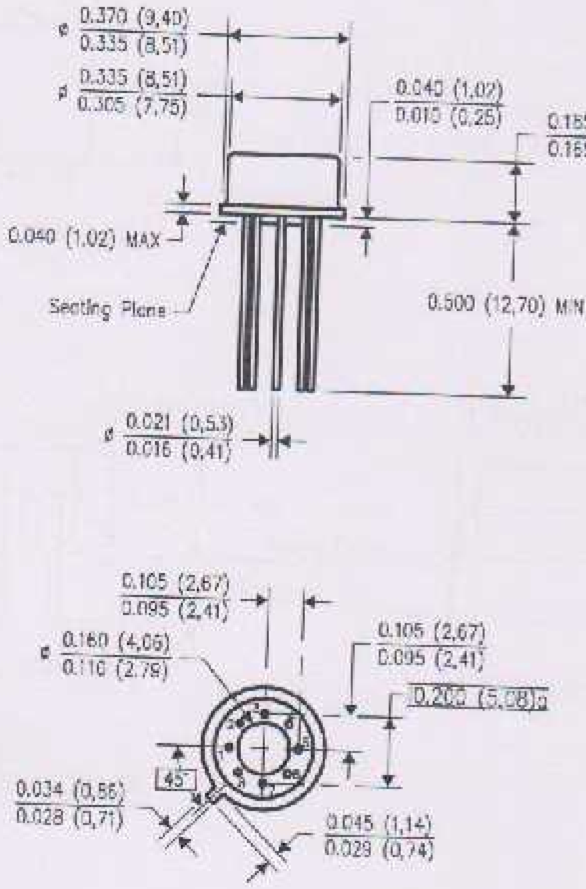
NAB0008A

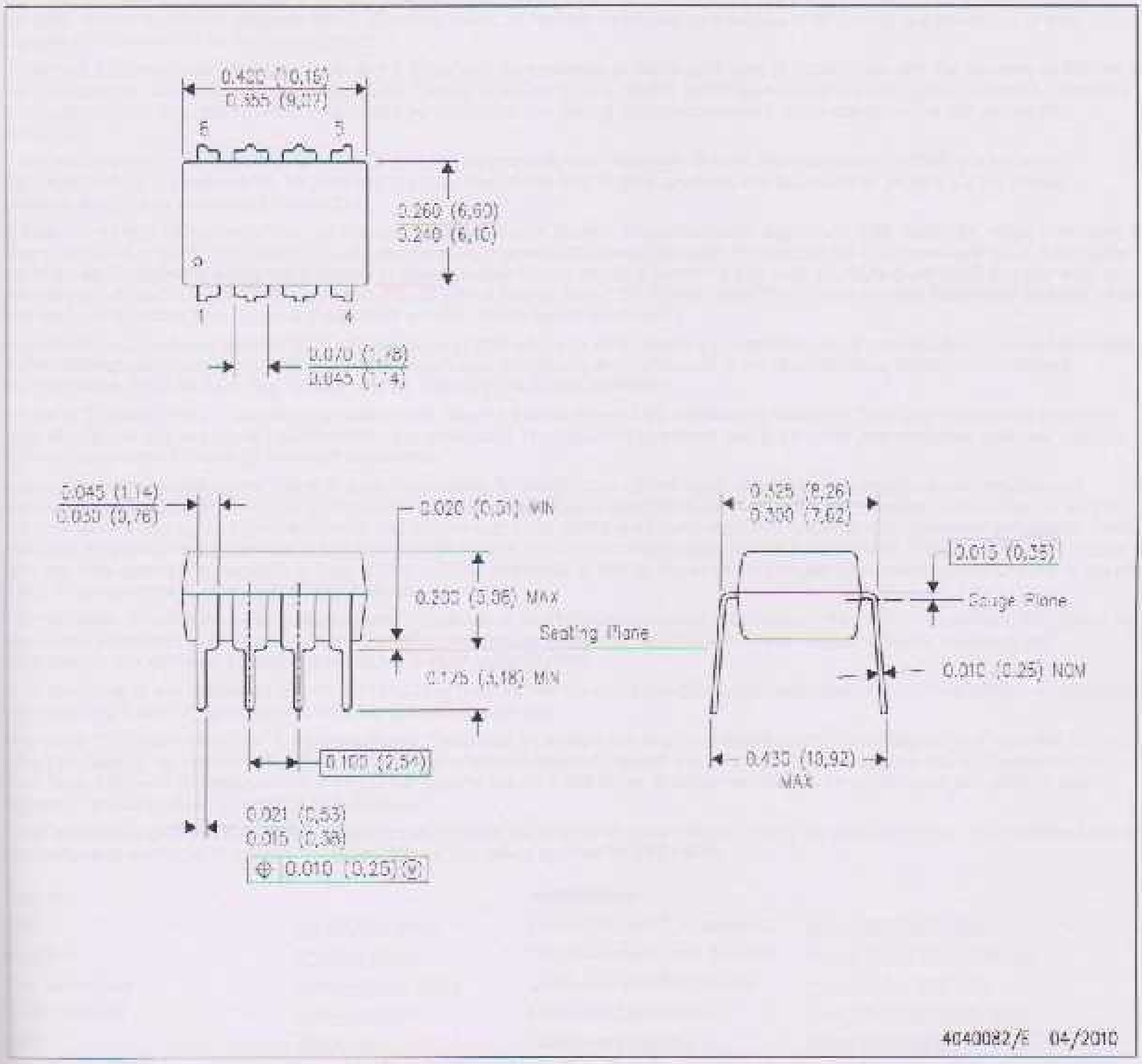

.405 MAX
[10.36]
8
5
.310 MAX
[7.87]
R.025
[0.64]
R.010 TYP
[0.25]
1
4
CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
8X .055±.010
[1.4±0.25]
.200 MAX TYP
[5.08]
.180 MAX
[4.57]
90°±4° TYP
8X .125-.203
[3.18-5.08]
.020-.060
[0.51-1.52]
TYP
8X .018±.003
[0.46±0.07]
.055 MAX TYP
[1.40]
6X .100±.010
[2.54±0.25]
.290-.320
[7.37-8.13]
GLASS SEALANT
95°±5° TYP
8X .010±.002
[0.25±0.05]
.310-.410
[7.87-10.41]
.08A (Rev M)

LMC (O-MBCY-W8) METAL CYLINDRICAL PACKAGE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
- D. Pin numbers shown for reference only. Numbers may not be marked on package.
- E. Falls within JEDEC MO-002/TO-99.

P (R-PDIP-T8) PLASTIC DUAL-IN-LINE PACKAGE



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001 variation BA.

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

SUPERBRIGHT LED LAMP

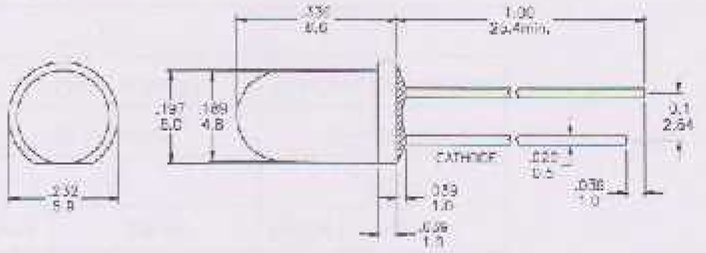
VAOL-5GSBY4

Feature
- Low Power Consumption
- High Intensity
- I.C. compatible

Applications
- Commercial Outdoor Sign Board
- Front Panel Indicator
- Dot-Matrix Module
- LED Bulb

Description
- These High Intensity LEDs are Based on InGaN/(ITO)Sapphire Material Technology
- Emitted color:Blue
- Water Transparent Lens

Package Dimension



※Tolerance : ± 0.01/0.25   Unit : ± inch/mm

Absolute Maximum Ratings at Ta=25℃

Symbol	Parameter	Max.	Unit
PD	Power Dissipation	120	mW
VR	Reverse Voltage	5	V
IAF	Average Forward Current	20	mA
IPF	Peak Forward Current (Duty=0.1, 1kHz)	85	mA
—	Derating Linear Form 25℃	0.4	mA/℃
Topr	Operating Temperature Range	−40 to + 80	℃
Tstg	Storage Temperature Range	−40 to + 100	℃
Lead Soldering Temperature [1.6mm (0.063inch) From Body] 260℃ For 5 Seconds.			

Electrical / Optical Characteristics and Curves at Ta=25℃

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
VF	Forward Voltage	IF= 20 mA		3.5	4.0	V
IR	Reverse Current	VR= 5 V			50	μA
△θ	Half Intensity Angle	IF= 20 mA		30		Deg.
IV	Luminous Intensity	IF= 20 mA		7000		mcd.
λd	Dominant Wavelength	IF= 20 mA		470		nm

OPTOELECTRONICS

...ting:theway

Electrical Characteristics at Ta=25℃

Symbol	Iv		Vf		λD	
Parameter	Luminous Intensity		Forward Voltage		Dominant Wavelength	
Condition	IF=20mA		IF=20mA		IF=20mA	
Unit	mcd		V		nm	
Binning	Grade	Range	Grade	Range	Grade	Range
	BIN 21	4900~6900	P1	3.0~3.2	B6	465~470
	BIN 22	6900~9700	P2	3.2~3.4	B7	470~475
			P3	3.4~3.6		
			P4	3.6~3.8		
			P5	3.8~4.0		

Intensity: Tolerance of minimum and maximum = ± 15%

Vf. Tolerance of minimum and maximum = ± 0.05v

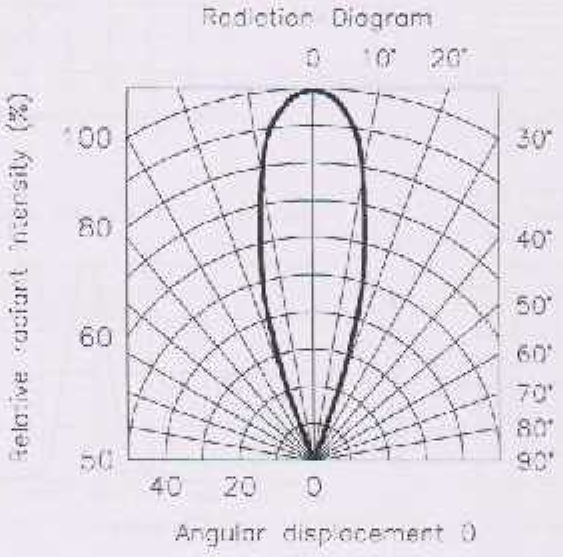
NOTE:

1. Static electricity and surge damages the LED. It is recommend to use a anti-static wrist band or anti-electrostatic glove when handing the LEDs. All devices, equipment and machinery must be properly grounded.

2. Specific binning requirements –please contact our home office

Radiation Diagram

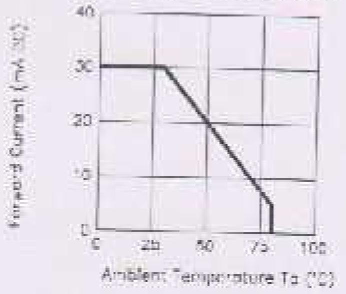
IF=20 mA 50% Power Angle Angle =30°



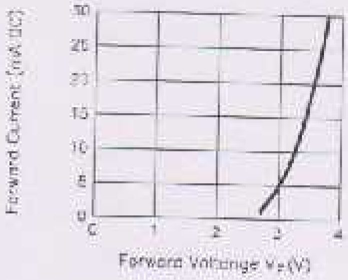
BLUE

Typical Electro-optical Characteristic Curves
(25°C Free Air Temperature Unless Otherwise Specified)

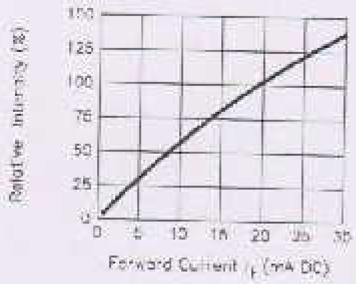
Forward Current
Vs. Ambient Temmperature



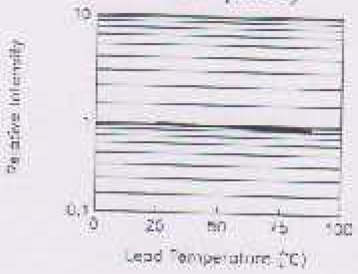
Forward Current
Vs. Forward Voltage



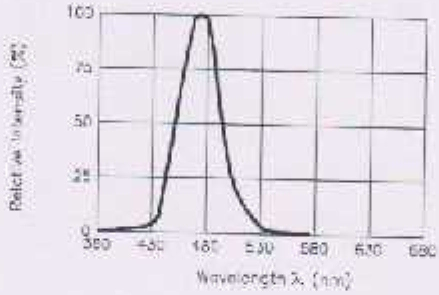
Relative Intensity
Vs. Forward Current



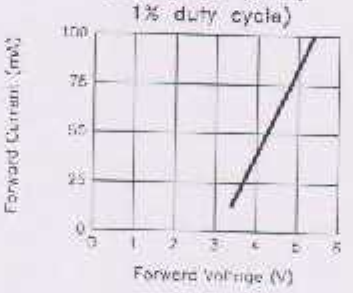
Relative Intensity
Vs. Lead Temperature
(Pulsed 20 mA; 300us pulse,
10ms period)



Relative Intensity Vs. Wavelength



Peak Forward Voltage
Vs. Forward Current
(100us test pulse,
1% duty cycle)



Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

VCC:

VAOL-5CSBY4

TLHR540., TLHY540., TLHG540.

High Efficiency LED, Ø 5 mm Tinted Diffused Package

19223

FEATRUES

- Choice of three bright colors
- Standard T-1¾ package
- Small mechanical tolerances
- Suitable for DC and high peak current
- Wide viewing angle
- Luminous intensity categorized
- Yellow and green color categorized
- TLH.54.. with stand-offs
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT
HALOGEN FREE
GREEN (5-2008)

DESCRIPTION

The TLH.54.. series was developed for standard applications like general indicating and lighting purposes.

It is housed in a 5 mm tinted diffused plastic package. The wide viewing angle of these devices provides a high on-off contrast.

Several selection types with different luminous intensities are offered. All LEDs are categorized in luminous intensity groups. The green and yellow LEDs are categorized additionally in wavelength groups.

That allows users to assemble LEDs with uniform appearance.

APPLICATIONS

- Status lights
- Off / on indicator
- Background illumination
- Readout lights
- Maintenance lights
- Legend light

PRODUCT GROUP AND PACKAGE DATA

- Product group: LED
- Package: 5 mm
- Product series: standard
- Angle of half intensity: ± 30°

PARTS TABLE

PART	COLOR	LUMINOUS INTENSITY (mcd)			at I_F (mA)	WAVELENGTH (nm)			at I_F (mA)	FORWARD VOLTAGE (V)			at I_F (mA)	TECHNOLOGY
		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		
TLHR5400	Red	1.6	10	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR5400-AS12Z	Red	1.6	10	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR5401	Red	4	12	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR5405	Red	6.3	14	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR5405-AS12Z	Red	6.3	14	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR5405-AS21	Red	6.3	14	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR5405-KSZ	Red	6.3	14	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHY5400	Yellow	1.6	10	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY5400-AS12Z	Yellow	1.6	10	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY5401	Yellow	4	12	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY5405	Yellow	6.3	14	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY5405-KSZ	Yellow	6.3	14	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHG5400	Green	1.6	10	-	10	562	-	575	10	-	2.4	3	20	GaAsP on GaP
TLHG5400-AS12Z	Green	1.6	10	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG5400-BT12	Green	1.6	10	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG5401	Green	4	12	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG5405	Green	6.3	15	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG5405-AS12Z	Green	6.3	15	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG5405-KSZ	Green	6.3	15	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified) TLHR54.., TLHY54.. , TLHG54..				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	6	V
DC forward current	T_{amb} ≤ 65 °C	I_F	30	mA
Surge forward current	t_p ≤ 10 µs	I_{FSM}	1	A
Power dissipation	T_{amb} ≤ 65 °C	P_V	100	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	-40 to +100	°C
Storage temperature range		T_{stg}	-55 to +100	°C
Soldering temperature	t ≤ 5 s, 2 mm from body	T_{sd}	260	°C
Thermal resistance junction/ambient		R_{thJA}	350	K/W

OPTICAL AND ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified) TLHR540., RED							
PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity [1]	I_F = 10 mA	TLHR5400	I_V	1.6	10	-	mcd
		TLHR5401	I_V	4	12	-	mcd
		TLHR5405	I_V	6.3	14	-	mcd
Dominant wavelength	I_F = 10 mA		λ_d	612	-	625	nm
Peak wavelength	I_F = 10 mA		λ_p	-	635	-	nm
Angle of half intensity	I_F = 10 mA		φ	-	± 30	-	deg
Forward voltage	I_F = 20 mA		V_F	-	2	3	V
Reverse voltage	I_R = 10 µA		V_R	6	15	-	V
Junction capacitance	V_R = 0 V, f = 1 MHz		C_j	-	50	-	pF

Note

[1] In one packing unit I_{Vmin}/I_{Vmax} ≤ 0.5

OPTICAL AND ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified) TLHY540., YELLOW							
PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity [1]	I_F = 10 mA	TLHY5400	I_V	1.6	10	-	mcd
		TLHY5401	I_V	4	12	-	mcd
		TLHY5405	I_V	6.3	14	-	mcd
Dominant wavelength	I_F = 10 mA		λ_d	581	-	594	nm
Peak wavelength	I_F = 10 mA		λ_p	-	585	-	nm
Angle of half intensity	I_F = 10 mA		φ	-	± 30	-	deg
Forward voltage	I_F = 20 mA		V_F	-	2.4	3	V
Reverse voltage	I_R = 10 µA		V_R	6	15	-	V
Junction capacitance	V_R = 0 V, f = 1 MHz		C_j	-	50	-	pF

Note

[1] In one packing unit I_{Vmin}/I_{Vmax} ≤ 0.5

OPTICAL AND ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified) TLHG540., GREEN							
PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity [1]	I_F = 10 mA	TLHG5400	I_V	1.6	10	-	mcd
		TLHG5401	I_V	4	12	-	mcd
		TLHG5405	I_V	6.3	15	-	mcd
Dominant wavelength	I_F = 10 mA		λ_d	562	-	575	nm
Peak wavelength	I_F = 10 mA		λ_p	-	565	-	nm
Angle of half intensity	I_F = 10 mA		φ	-	± 30	-	deg
Forward voltage	I_F = 20 mA		V_F	-	2.4	3	V
Reverse voltage	I_R = 10 µA		V_R	6	15	-	V
Junction capacitance	V_R = 0 V, f = 1 MHz		C_j	-	50	-	pF

Note

[1] In one packing unit $I_{Vmin}/I_{Vmax} \leq 0.5$

LUMINOUS INTENSITY CLASSIFICATION		
GROUP	LUMINOUS INTENSITY (mcd)	
STANDARD	MIN.	MAX.
M	1.6	3.2
N	2.5	5
P	4	8
Q	6.3	12.5
R	10	20
S	16	32
T	25	50
U	40	80
V	63	125
W	100	200
X	130	260
Y	180	360
Z	240	480

Note

- Luminous flux is tested at a current pulse duration of 25 ms and an accuracy of ± 11 %.
  The above type numbers represent the order groups which include only a few brightness groups. Only one group will be shipped on each bag (there will be no mixing of two groups in each bag).
  In order to ensure availability, single brightness groups will not be orderable.
  In a similar manner for colors where wavelength groups are measured and binned, single wavelength groups will be shipped on any one bag.
  In order to ensure availability, single wavelength groups will not be orderable.

COLOR CLASSIFICATION				
GROUP	DOM. WAVELENGTH (nm)			
	YELLOW		GREEN	
	MIN.	MAX.	MIN.	MAX.
0				
1	581	584		
2	583	586		
3	585	588	562	565
4	587	590	564	567
5	589	592	566	569
6	591	594	568	571
7			570	573
8			572	575

Note

- Wavelengths are tested at a current pulse duration of 25 ms.

TYPICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

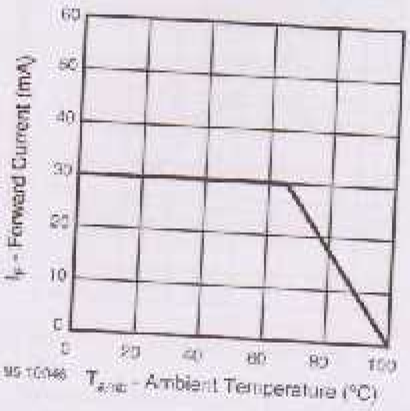


Fig. 1 - Forward Current vs. Ambient Temperature

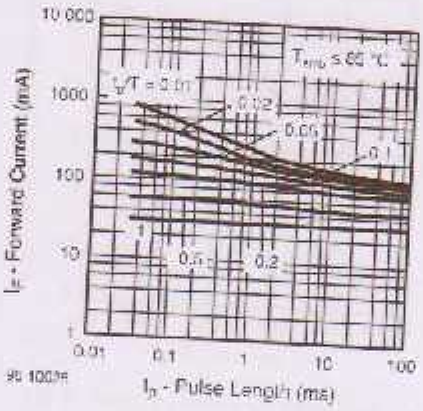


Fig. 2 - Forward Current vs. Pulse Length

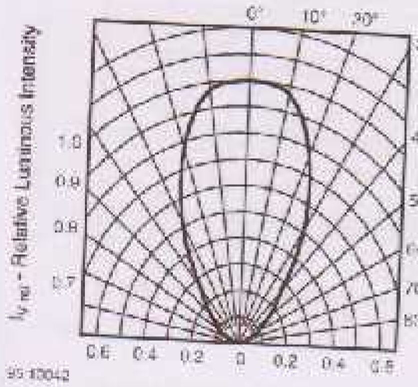


Fig. 3 - Rel. Luminous Intensity vs. Angular Displacement

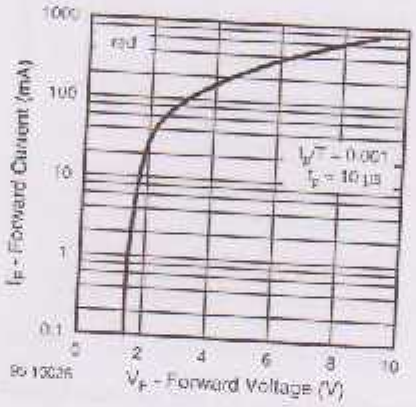


Fig. 4 - Forward Current vs. Forward Voltage

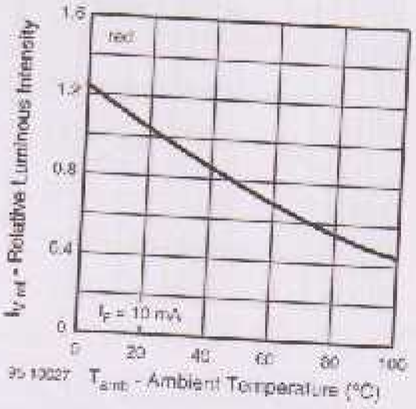


Fig. 5 - Relative Luminous Intensity vs. Ambient Temperature

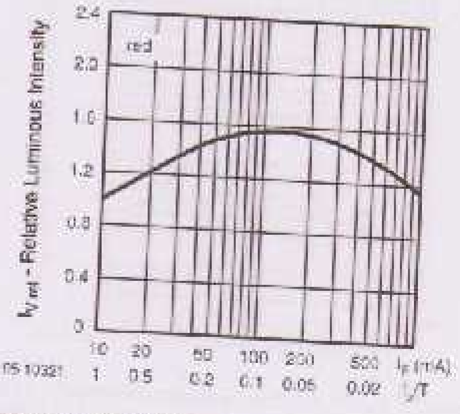


Fig. 6 - Relative Luminous Intensity vs. Forward Current/Duty Cycle

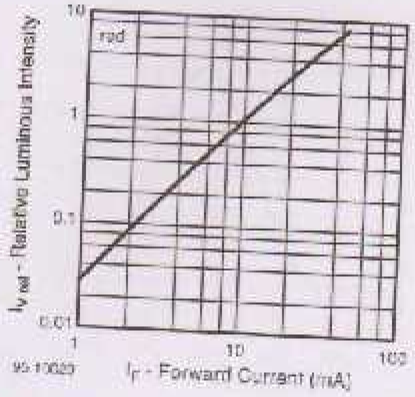


Fig. 7 - Relative Luminous Intensity vs. Forward Current

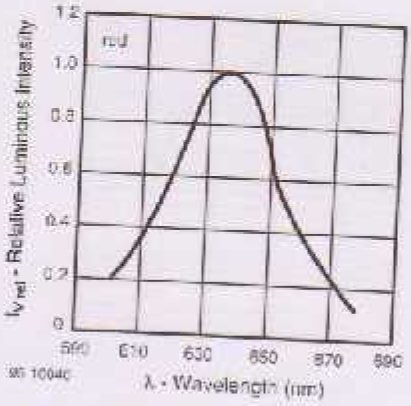


Fig. 8 - Relative Intensity vs. Wavelength

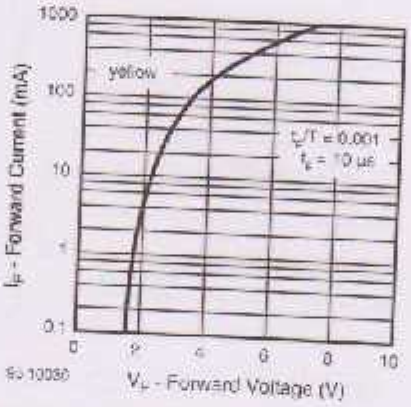


Fig. 9 - Forward Current vs. Forward Voltage

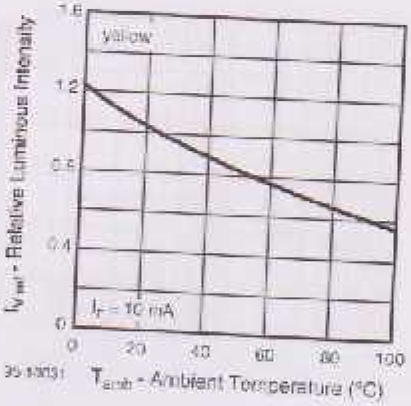


Fig. 10 - Relative Luminous Intensity vs. Ambient Temperature

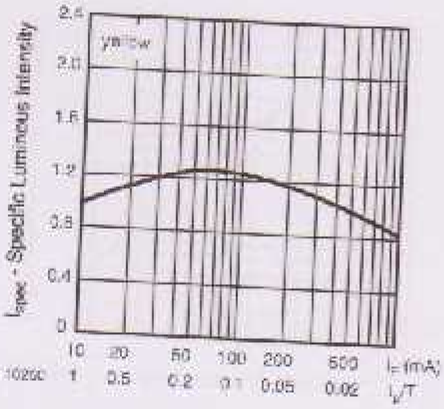


Fig. 11 - Relative Luminous Intensity vs. Forward Current/Duty Cycle

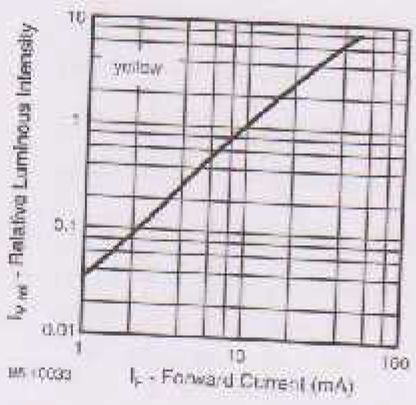


Fig. 12 - Relative Luminous Intensity vs. Forward Current

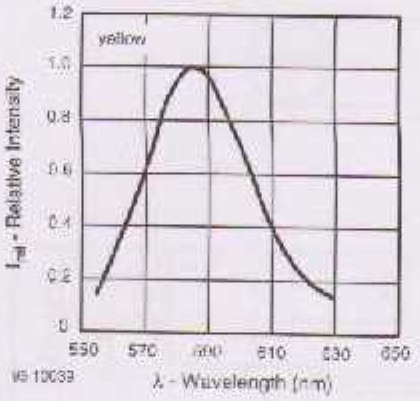


Fig. 13 - Relative Intensity vs. Wavelength

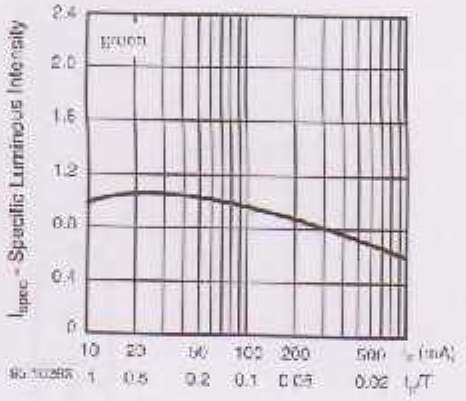


Fig. 16 - Specific Luminous Intensity vs. Forward Current

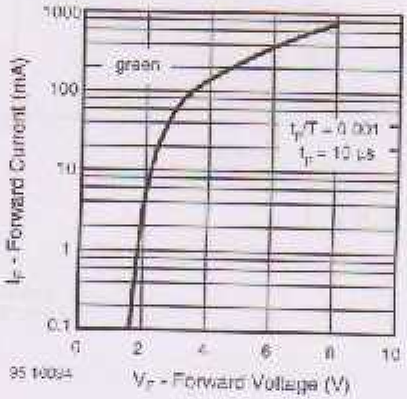


Fig. 14 - Forward Current vs. Forward Voltage

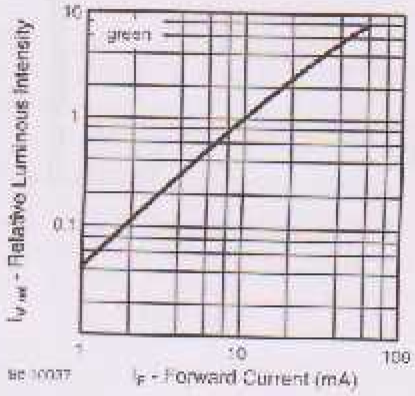


Fig. 17 - Relative Luminous Intensity vs. Forward Current

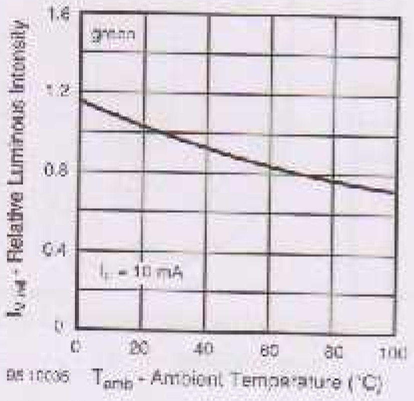


Fig. 15 - Relative Luminous Intensity vs. Ambient Temperature

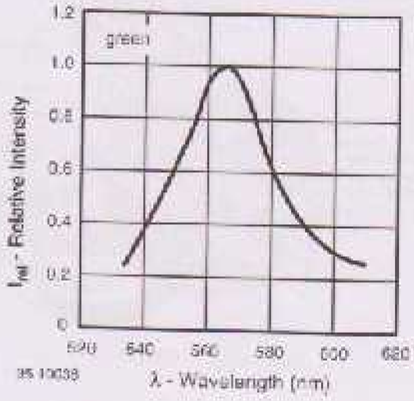
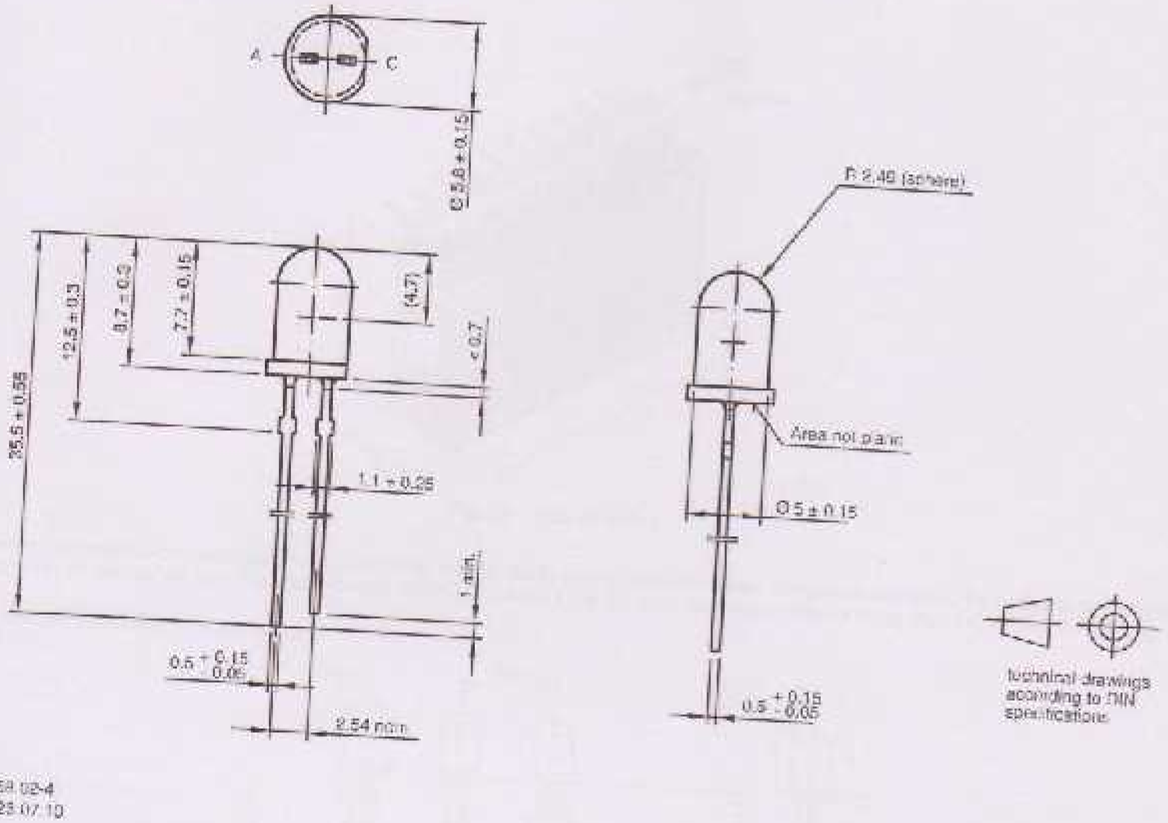


Fig. 18 - Relative Intensity vs. Wavelength

PACKAGE DIMENSIONS in millimeters



REEL

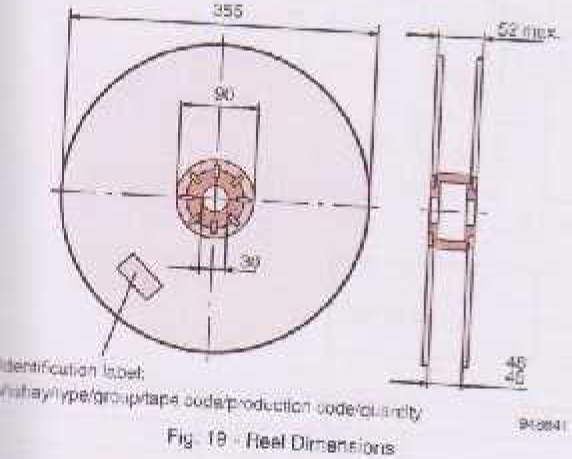


Fig. 19 - Reel Dimensions

TAPE

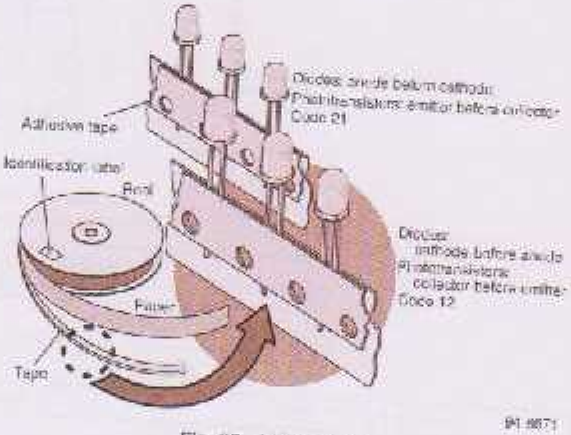


Fig. 20 - LED in Tape

S12 = cathode leaves tape first
S21 = anode leaves tape first

AMMOPACK

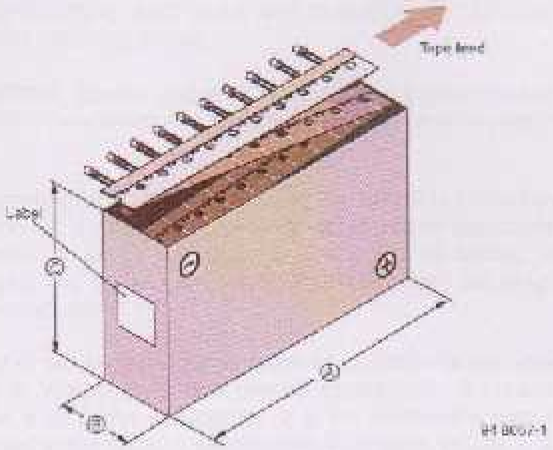
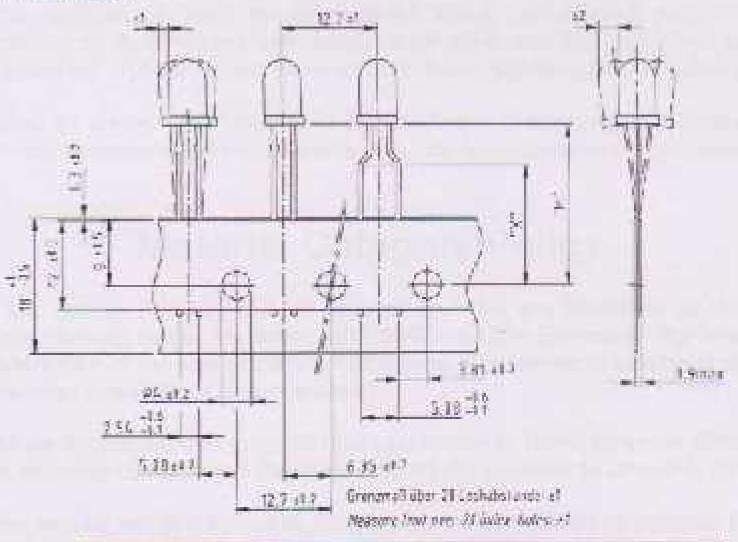


Fig. 21 - Tape Direction

Note

- The new nomenclature for ammopack is e.g. ASZ only, without suffix for the LED orientation. The carton box has to be turned to the desired position: "+" for anode first, or "-" for cathode first. AS12Z and AS21Z are still valid for already existing types, BUT NOT FOR NEW DESIGN.

TAPE DIMENSIONS in millimeters



Quantity per:	Ammopack/reel (Mat.-No. 1764)
	1000

946172_1

Option	Dim. "H" ± 0.5 mm	Dim. "X" ± 0.5 mm
AS	17.3	-
BT	20.0	16.0
KS	19.7	-

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