ELR 4202C Project: Finger Pulse Display Module

Overview:

The project will use an LED light source and a phototransistor light receiver to create an electrical signal that indicates the pulse motion of blood through the finger tip with each heart beat. This signal will be processed to produce a display of that pulse on a 10-LED bar graph. Additionally, the laboratory equipment will be used to record and produce a hard copy of the measured pulse output. Each team will design and fabricate a module, submit a written technical report and make a Powerpoint presentation with a demonstration of its operation.

There are three aspects of this project to be divided among your team members:

- Report on the clinical aspects of finger tip blood flow and absorption characteristics of blood.
- Create a sensing transducer and electronics to detect pulse from the finger tip
- Design, fabricate and test the electronic module

A. Clinical Research

Optical absorption measurement
Optical properties of hemoglobin – wavelength/absorption plot
How Optical plethysmography works? Mechanics of blood flow through capillaries.
Morphology of pulse flow waveform
Determine appropriate frequency specifications for filter response allowing flow pulse amplification

B. Fabricate a Patient Interface

clip to hold optical elements
shield from surrounding light – Why?
Phototransistor principle of operation
Use of IR or Red
Interference?

C. Design and Test the Electronic module

Input amplifier, filter amplifier, scaling amplifier, bar graph
The attached information will help in carrying out this task. The following sections give details of the electronics, arragned in the suggested order for building them.

D. The technical report

This must contain a summary of the clinical aspects of blood flow measurement and show aspects to decide on the design elements of the project. The design of the patient interface must be described with respect to facilitating the measurement and optimize the detected signal. The electronic module design must be described with design equations, written rationale, and test results included.

E. Presentation

Summarize briefly the clinical aspects, the interface design and the electronic module. Then demonstrate the module with a human subject on the date assigned to your team..

Project Details:

Block Diagram

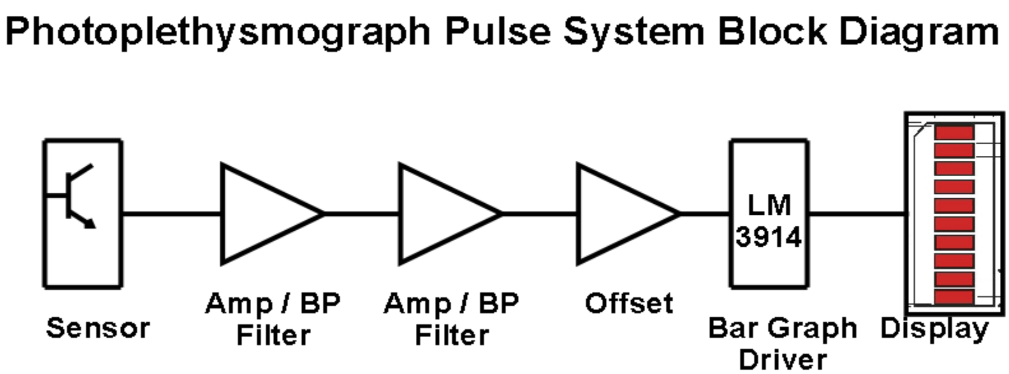


Illustration 1: Project Block Diagram

Hardware to be used

Fabricate the electronics on a "proto-board" and use ± 3 volts for the power source. You may use the lab power supplies for development but a battery pack will be substituted for the final demonstration. You will use the LM 3914 IC, a 10-segment LED bar graph and the TLC 2274 quad op amp. Build the circuitry with carbon film resistors rated for 1/4 watt with 5% tolerance and capacitors such as polyester film or metallized film with a tolerance of 5% and a voltage rating of 50 volts. All of these components are available from the BME lab and must be returned at the end of the semester.

The display assembly

This section of the project implements the 10-segment bar graph display with a switch to select its display mode. The display is created by combining an LM 3914 (or equivalent) integrated circuit, a 10-segment LED and resistors. A typical circuit diagram is shown below, as taken from the reference listed below.

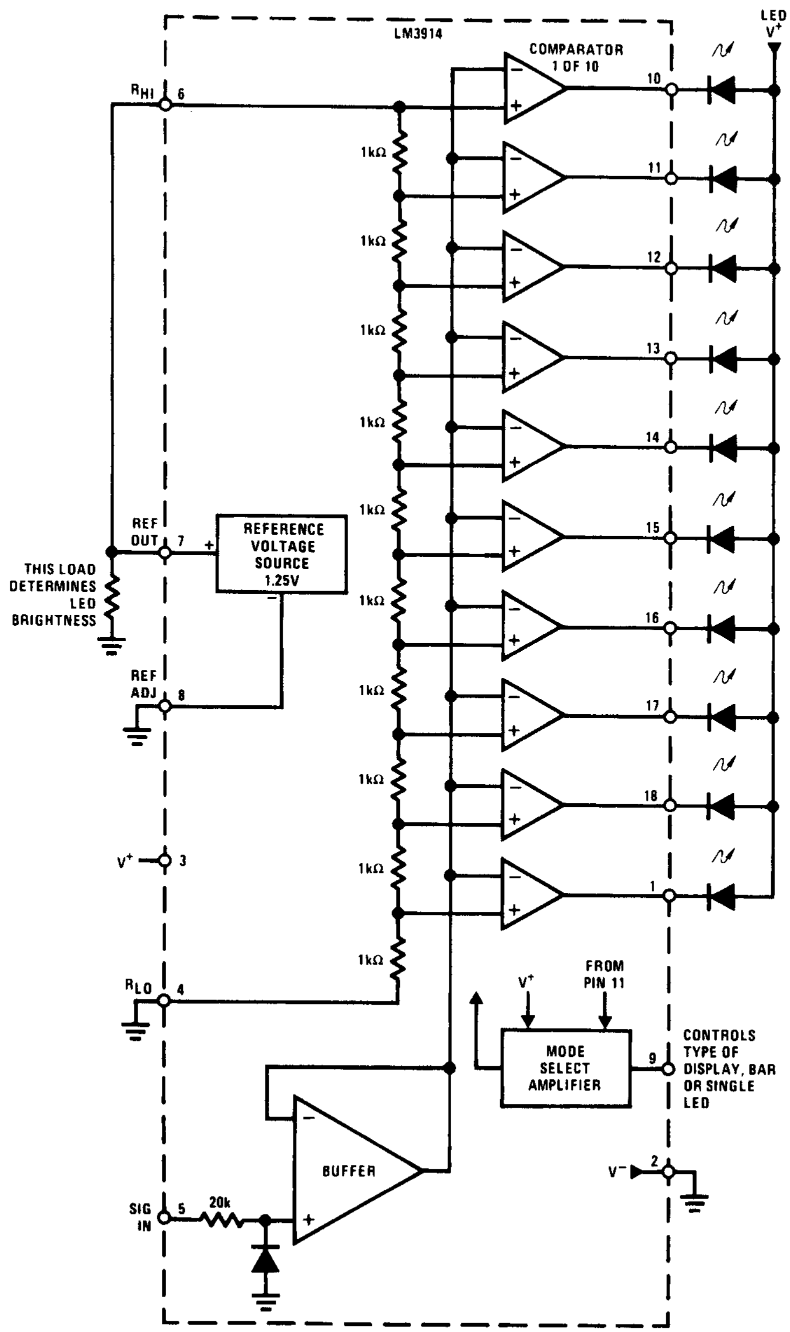


Illustration 2: LM 3914 Display Driver

ADDITIONAL NOTES:

The power connections are slightly different than shown above. Apply the +3 volts to pin 3 of the IC and to the common anode of the LED's. Apply the -3 volts to pin 2 of the IC. The "ground", the midpoint of the batteries, is applied to pins 4 and 8.

The resistor between pins 7 and 8 determines the brightness of the LED's and its value should be normally 1000 ohms or more with higher resistance causing less brightness. Of course, the life of the batteries is better with less brightness (see the reference).

Testing the display

The input signal is applied to pin 5 of the IC. The voltage levels on pins 6 and 4 establish the upper and lower voltage limits that will be displayed. With the circuit shown, those limits are +1.25 volts and ground.

Test the circuit by applying a sinusoidal voltage to pin 5, after first confirming the voltage on the oscilloscope. Use a sinusoid of 1 Hz with a peak voltage of ±1.25 volt. This should cause the display to sweep to full scale and back to dark and then remain dark for ½ second. Slowly reduce the amplitude and observe that the number of lit segments is reduced. When the amplitude drops to approximately 0.125 volt, only a single segment should light up. Document these events in your report.

Alternative Power Supply

The class web site has the description for an alternative power supply arrangement using the remaining op-amp. This will allow the circuit to be powered by a battery aiding demonstration in the classroom.

Exercise #1 Obtaining a signal and design a sensor holder

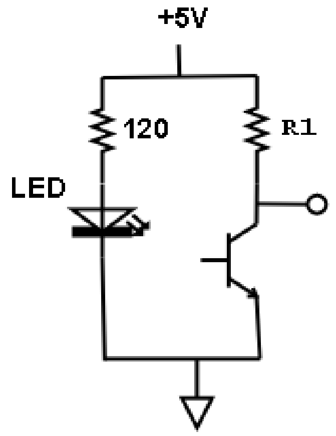


Illustration 3: Sensor Schematic

Connect phototransistor with 22KOhm collector resistor for R1 and observe collector voltage with room lights on and off. Capture trace from Oscilloscope with room lights on. Is ambient light a problem?

Configuration #1:

Change phototransistor collector resistor to 1MOhm. Insert visible red LED to face (shine its light at the sensor) phototransistor so finger can be inserted between them. This should allow light to shine through finger and be detected by the phototransistor.

Shield the sensor from ambient light and insert finger between light source and sensor. What is the collector voltage on the phototransistor? Is the transistor operating in a linear range? If not, adjust resistor value so collector voltage is about half the supply voltage with finger inserted in the light path.

A/C couple the Oscilloscope, connect to collector of phototransistor, and set Oscilloscope input channel gain to 50mV/div. Place the finger between the light source and sensor. Is a cardiac pulse there? Capture trace from Oscilloscope and document characteristics of signal.

Configuration #2

Change phototransistor collector resistor to 220 KOhm. Position the visible red LED beside the phototransistor so the finger can be placed against them. This should allow light to shine into the finger so backscatter illumination can be detected by the phototransistor. Both the light emitter and sensor should face the same direction. Some opaque material will need to be placed between the emitter and sensor so the sensor only detects backscatter and not lateral illumination from the light source.

Shield the sensor from ambient light and place finger against light source and sensor. What is the collector voltage on the phototransistor? Is the transistor operating in a linear range? If not, adjust resistor value so collector voltage is about half the supply voltage with finger against both devices. The sensor should be close to V+ when the finger is away from the sensor.

A/C couple the Oscilloscope, connect to collector of phototransistor, and set Oscilloscope input channel gain to 50mV/div. Place the finger against the light source and sensor. Is a cardiac pulse there? Capture trace from Oscilloscope and document characteristics of signal.

Why is there no signal if the emitter and sensor are very close to each other? What happens when the sensor and the emitter are about 1cm apart?

Determine required specifications:

From the experimental observations and the traces recorded, determine the required specifications for buffer amplifiers gain and offset plus filter frequency responses based on size of the signal and the input requirements of the display plus research about the frequency characteristics of the photo pulse signal.

Design a sensor holder:

Devise and document a way to mount the emitter and sensor to minimize the interference and maximize the signal sensitivity.

Photo of ideas for sensor holders:

Illustration 4: Backscatter – holes side-by-side

Illustration 5: Clip – Transmissive - hole on top and bottom

Exercise #2

Design a circuit to meet the specifications of the sensor output signal and the display input signal requirements. The full block diagram should be realized.

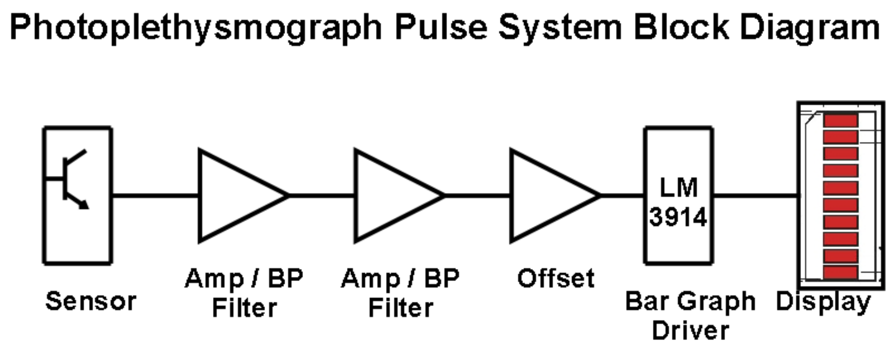


Illustration 6: System Block Diagram

Below is a generic filter block schematic that can be used. This filter is a first order filter formed with the high-pass input section going into a high impedance non-inverting amplifier. The low-pass section is determined by the characteristics of Cf and Rf.

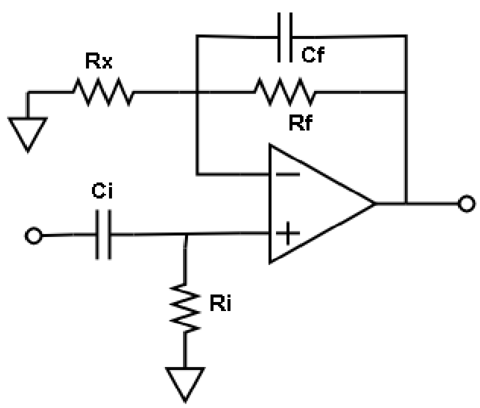


Illustration 7: Band Pass Filter Block Diagram

Sample schematic in the Appendix, Illustration 9, is a copy of the schematic in Reference #1. The values must be changed based on the filter characteristics and sensor performance results from Exercise #1.. Determine the specific values and draw the complete circuit schematic with all the correct values used for this project.

Place the finger against the light source and sensor. Determine that a cardiac pulse is there. Capture traces from Oscilloscope and label characteristics of signal at the output of each filter in the block diagram Illustration 6 plus the input to the Bar Graph Driver.

Appendix: Items for information and reference

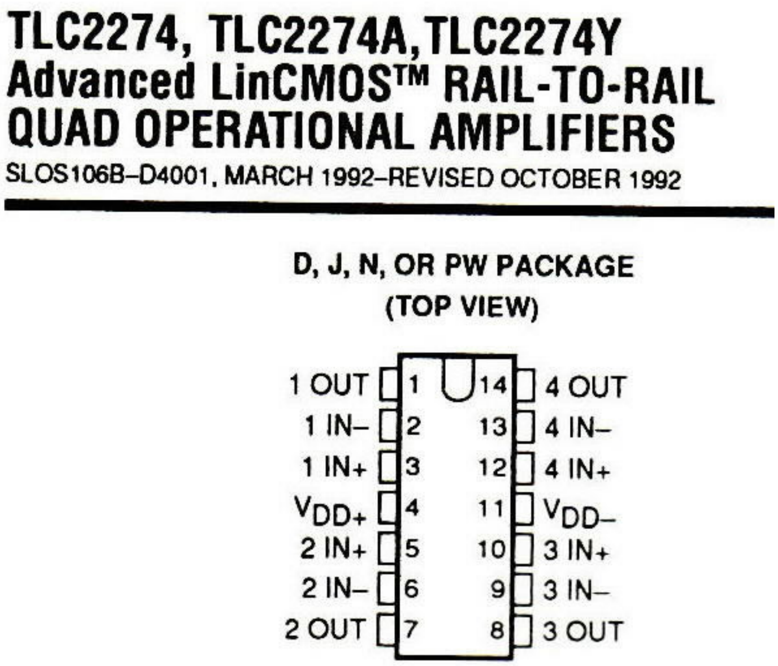


Illustration 8: Pinout for Quad Op-Amp

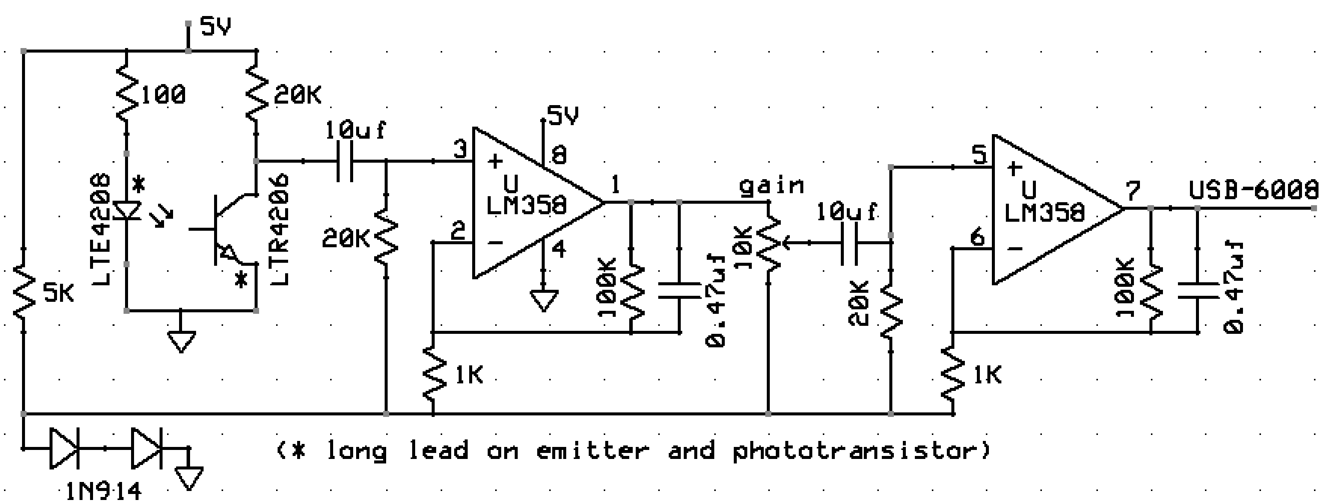


Illustration 9: Reference 1: Schematic

Values need to be filled in for the amplitudes and frequency response required based on measurements for your sensor and oscilloscope observations.

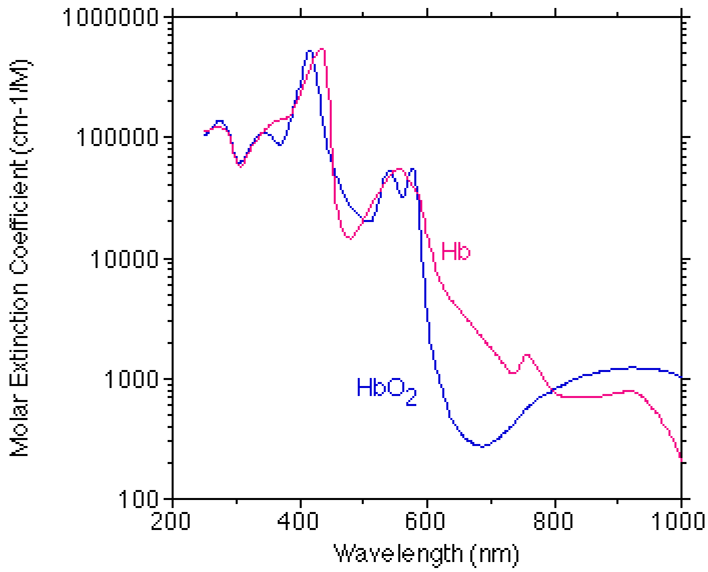


Illustration 10: Reference 4: Optical Absorption of Hemoglobin

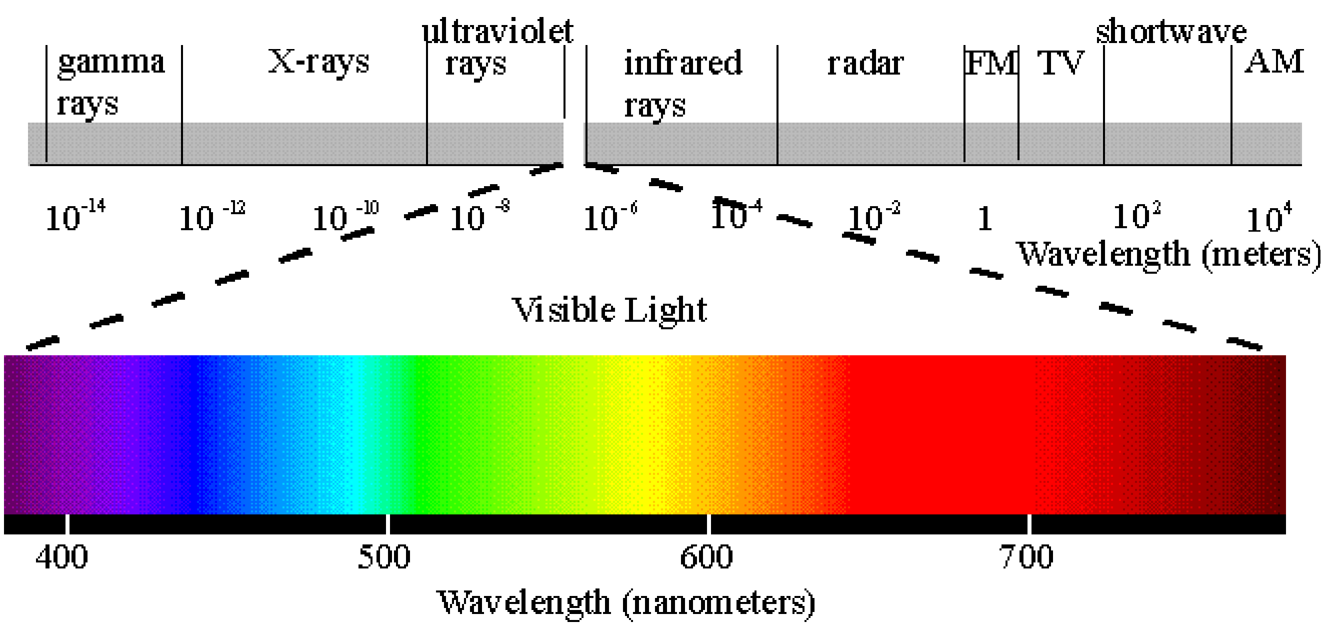


Illustration 11: Reference #5: Visible Light Spectrum

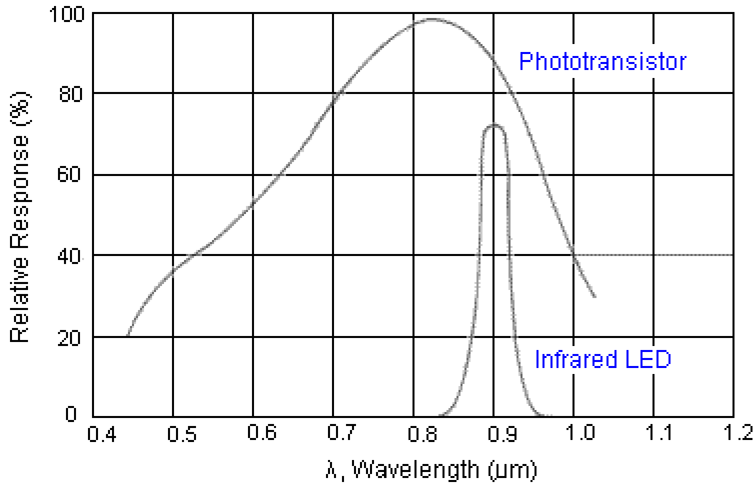
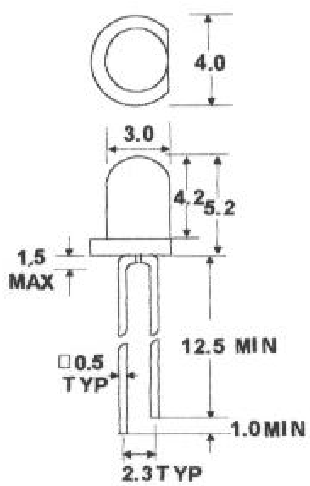


Illustration 12: Reference #6: How Phototransistors work

LIGITEK

NPN SILICOM PHOTOTRANSISTOR LED LAMPS **LPT2023** SERIES

Package Dimension



Note:All dimension are in millmeter tolerance is ± 0.25mm unless otherwise noted.

Features

- High illumination sensitivity
- Stable characteristics
- Spectrally and mechanically matched with IR emitter

Description

The LPT2023 series are silicon nitride passivated NPN planar phototransistors with exceptionally stable characteristics and high illumination sensitivity the cases of LPT2023 are encapsulated in clear plastic T1 package individually

. MAXIMUN RATINGS (TA=25℃)

PARAMETER	MAXIMUM RATINGS	UNIT
Power Dissipation	100	mw
Collect-Emitter Voltage	30	V
Emitter-Collect Voltage	5	V
Operating Temperature	-50℃ TO +100℃	
Storage Temperature Range	-50℃ TO +100℃	
Lead Soldering Temperature (1.6mm From Body)	260℃ for 5 seconds	

. ELECTRICAL CHARACTERISTICS (TA=25℃)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT	TEST CONDITION
Collect-Emitter Breakdown Voltage	V(BR)CEO	30			v	Ic=1mA Ee=0mw/cm^2
Emitter-Collector Breakdown Voltage	V(BR)ECO	5			v	Ie=100mA Ee=0mw/cm^2
Collect-Emitter Saturation Voltage	VCE(sat)			0.4	v	Ic=0.5mA Ee=20mw/cm^2
Rise Time	tr		5		µs	Vce=30v ic=800µA, RL=1KΩ
Fall Time	tf		5		µs	
Collector Dark Current	Iceo			100	nA	Vce=10v Ee=0mw/cm^2
On State Collector Current	Ip(on)	1		2	mA	Vce=5v Ee=1mW/cm^2 λ=940nm
		2		4	mA	
		4		8	mA	
		8			mA	

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LITEON

T-1(3mm) Solid State LED Lamps

LTL-4201/4202 Red
LTL-4211/4212 Bright Red
LTL-4221/4222 High Efficiency Red
LTL-4231/4232 Green
LTL-4251/4252 Yellow
LTL-4291/4292 Red Orange

Features

- High intensity.
- Popular T-1 Diameter package.
- Selected minimum intensities.
- Wide viewing angle.
- General purpose leads.
- Reliable and rugged.

Description

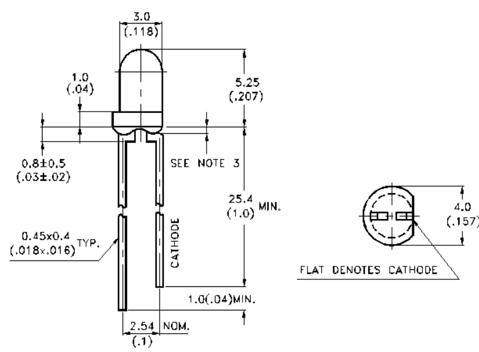
The Red source color devices are made with Gallium Arsenide Phosphide Red Light Emitting Diode.
The Bright Red source color devices are made with Gallium Phosphide on Gallium Phosphide Red Light Emitting Diode.
The High Efficiency Red and Red Orange source color devices are made with Gallium Arsenide Phosphide on Gallium Phosphide Orange Light Emitting Diode. The Green source color devices are made with Gallium Phosphide on Gallium Phosphide Green Light Emitting Diode.
The Yellow source color devices are made with Gallium Arsenide Phosphide on Gallium Phosphide Yellow Light Emitting Diode.

Devices

Part No. LTL-	Lens	Source Color
4201	Red Diffused	Red
4202	Red Transparent	
4211	Red Diffused	Bright Red
4212	Red Transparent	
4221	Red Diffused	Hi. Eff. Red
4222	Red Transparent	
4231	Green Diffused	Green
4232	Green Transparent	
4251	Yellow Diffused	Yellow
4252	Yellow Transparent	
4291	Orange Diffused	Red Orange
4292	Orange Transparent	

Package Dimensions

LTL-42x1/42x2 Series



Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ± 0.25mm (.010") unless otherwise noted.
3. Protruded resin under flange is 1.5mm (.059") max.
4. Lead spacing is measured where the leads emerge from the package.
5. Specifications are subject to change without notice.

Absolute Maximum Ratings at Ta=25℃

Parameter	Red	Bright Red	Green	Yellow	Hi. Eff. Red Red Orange	Unit
Power Dissipation	80	40	100	60	100	mW
Peak Forward Current (1/10 Duty Cycle, 0.1ms Pulse Width)	200	60	120	80	120	mA
Continuous Forward Current	40	15	30	20	30	mA
Derating Linear From 50℃	0.5	0.2	0.4	0.25	0.4	mA/℃
Reverse Voltage	5	5	5	5	5	V
Operating Temperature Range	-55℃ to +100℃					
Storage Temperature Range	-55℃ to +100℃					
Lead Soldering Temperature [1.6mm (.063 in.) from body]	260℃ for 5 Seconds					

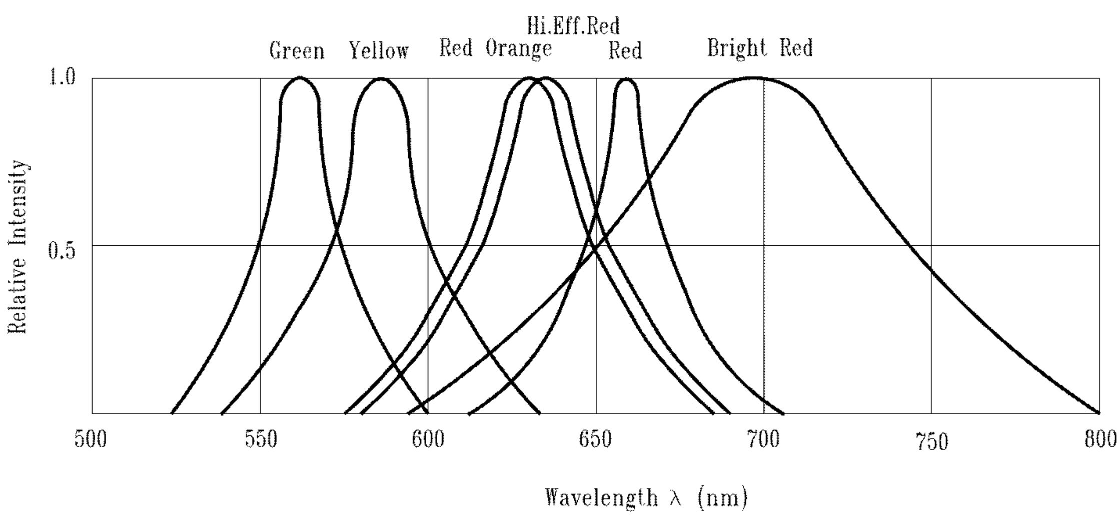


Fig.1 Relative Intensity vs. Wavelength

THROUGH HOLE LAMPS

References

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