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The LED History

LED's (light emitting diodes) are semiconductor devices that are designed to convert electrical energy to light when powered in a specific way. The construction and electrical behavior of the LED is similar to that of a rectifier diode that is used to convert alternating current to direct current.

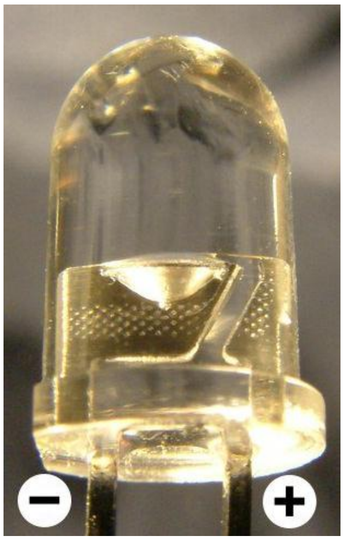
Just like the rectifier diode, the LED is made of a junction of semi conductive P-type and N-type materials that are connected to two terminals called anode and cathode respectively. This device will, like the rectifier diode, conduct electric current when its anode is positive with respect to its cathode and block current when the applied polarity is reversed.

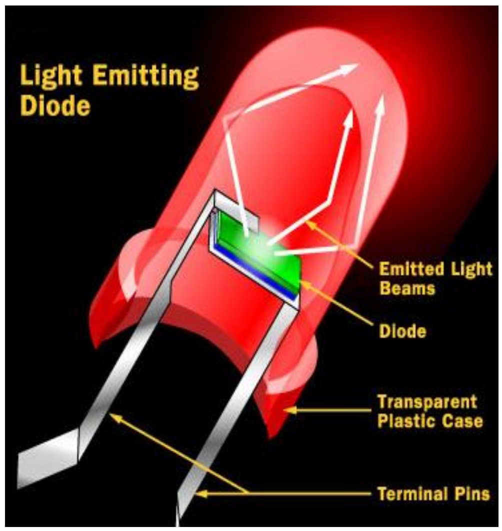
The development of the LED begun in the early 20th century at the Marconi Labs where researcher Henry Round reported that certain semiconductor PN junction will produce light when forward biased.

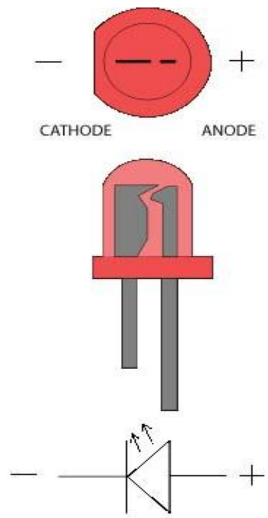
During the middle 1920s, Oleg Vladimirovich Losev reported that he had developed an LED device. Further work by RCA, Texas instrument and General Electric led to the development of practical devices for the purpose of light indicators during the sixties and seventies.

LED's remained as light indicators until the early nineties when work by Shuji Nakamura of Nichia Corporation developed the high brightness blue LED. This development along with other developments in phosphor materials led to the development of a blue LED which when coated with a special phosphor produced a considerable amount of white light suitable for illumination.

The first commercial red LEDs were commonly used as replacements for incandescent indicators, and in seven-segment displays, first in expensive equipment such as laboratory and electronics test equipments, then later in appliances such as TVs, radios, telephones, calculators, and even watches. These red LEDs were bright enough only for use as indicators, as the light output was not enough to illuminate an area. Later, other colors became widely available and also appeared in appliances and equipment. As the LED materials technology became more advanced, the light output was increased, while maintaining the efficiency and the reliability to an acceptable level, causing LEDs to become bright enough to be used for illumination, in various applications such as lamps and other lighting fixtures.







Unlike incandescent light bulbs, which light up regardless of the electrical polarity, LEDs will only light with correct electrical polarity. When the voltage across the *p-n junction* is in the correct direction, a significant current flows and the device is said to be *forward-biased*. If the voltage is of the wrong polarity, the device is said to be *reverse biased*, very little current flows, and no light is emitted. LEDs can be operated on an alternating current voltage, but they will only light with positive voltage, causing the LED to turn on and off at the frequency of the AC supply.

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The Benefits of LED Illumination

The development of the high brightness blue LED showed that it was possible to think of solid-state lighting for the replacement of the incandescent light bulb. Since the LED life expectancy was estimated at about 50 to 100 times that of incandescent bulbs and the LED luminous efficacy at about 20 lumens per watt surpassed that of the incandescent light bulbs, rigorous work begun in the development of solid-state lighting. Today the luminous efficacy of LEDs is at about 100 to 135 lumens per watt. Thus, it is possible to think of substituting the fluorescent light bulb also with LEDs, since the best fluorescent light bulbs have luminous efficacies of about 100 lumens per watt. This substitution, apart from conserving energy resources, will also eliminate hazardous materials such as mercury and phosphors from contaminating landfill sites due to discarded fluorescent light bulbs.

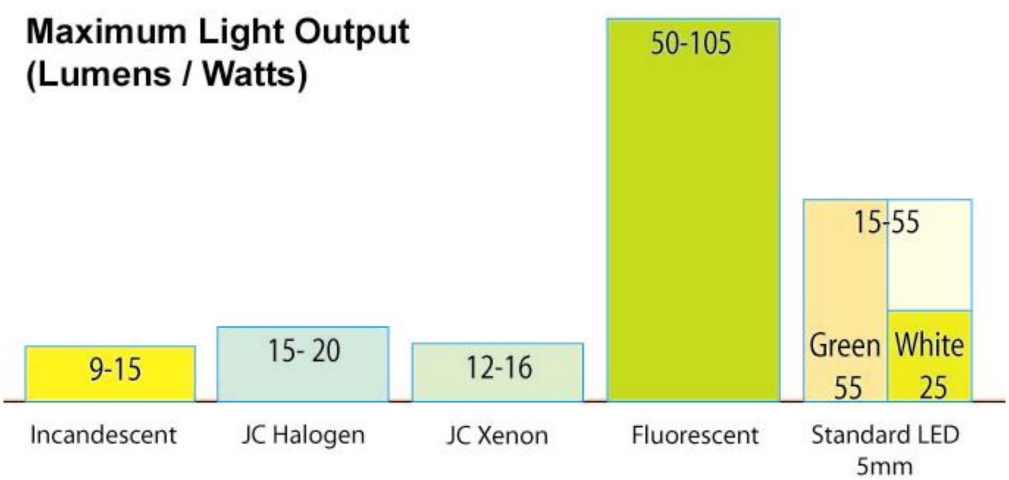
An additional benefit from this substitution is that the light of the LED's will not drop in cold weather applications, as is the case with fluorescent light sources.

Another advantage of LEDs, over conventional light sources, is that they are rough and can withstand, without breakage, the rough handling during transportation with minimal packaging.

The future of solid-state lighting based on LEDs is also promising. The IEEE (Institute of Electrical and Electronics Engineers) Spectrum magazine has reported recently that the theoretical maximum efficacy of the LED is in the order of several hundred lumens per watt and it is expected to be achieved in the next decade. When this happens the LED will surpass in luminous efficacy even the HID (high intensity discharge) lamps use for outdoor area lighting.

As a result of these endeavors, companies have come up with a line of LED lights geared to a wide range of requirements and applications. Intelligent technology together with state-of-the-art workmanship, high light efficiency and a long working life are few of the biggest advantages of LEDs. LED has several advantages as follows.

- Long working life (last up to 100,000 hours)
- Low heat emission
- Shock resistance
- Low energy consumption (decrease of electric costs by up to 90%)
- No maintenance costs
- Great range of temperatures
- Wide range of voltage applications
- Variety of colors available



As can be seen from the graphic above, the light flux of LEDs is not as good as the fluorescent light. Thanks to some clever people, this problem has now been solved. The light flux of LEDs has been optimized and ways have been found to produce white light as well. Even before these new developments, the LEDs have strong points / advantages. These properties, together with the new developments, have now made them suitable for entirely new applications, where they are superior to conventional incandescent bulbs.

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Why Does an LED Emit Light?

Here we need some theory. An LED is an electronic semiconductor component that emits light when charged with an electric current. In this process, light is not produced by heating a coil, as in the conventional incandescent bulb, but by electronic reactions inside the semiconductor. However, the light issued by the LED only comes from a narrow range of the entire spectrum, i.e., only a small section of the theoretically available light radiation is actually produced.

LED technology is now bright enough to enable LED lighting in the entertainment industry. Lighting solutions for film studios, theatres, stage lights, disco lighting and theme parks like colored spotlights, flood lighting, color changing lighting, wall wash lighting, cove lighting and column lighting are all deployed. All areas have the challenge that controllable dynamic colors are needed to make a real difference. LEDs are the perfect solution for these applications. They combine color capabilities with safety, long life, and enable more innovative and smaller light solutions.

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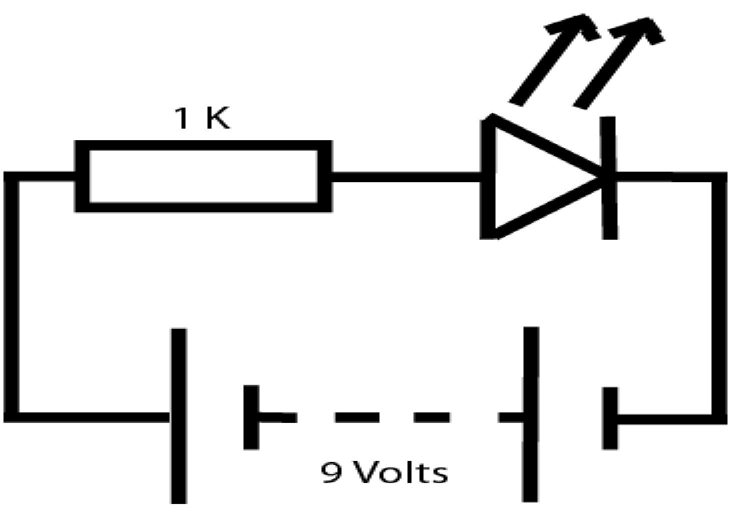
Testing an LED

Never connect an LED directly to a battery or power supply! It will be destroyed almost instantly because too much current will pass through and will burn it out.



LEDs must have a resistor in series to limit the current to a safe value, for quick testing purposes a 1kΩ resistor is suitable for most LEDs if your supply voltage is 12V or less. **Remember to connect the LED in the correct way.**

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Calculating an LED Resistor Value

Remember again, an LED must have a resistor connected in series to limit the current through the LED, otherwise it will probably burn out almost instantly. The resistor value, **R** is given by:

$$R = (V_S - V_L) / I$$

V_S = Supply Voltage
V_L = LED Voltage (usually 2V, but sometimes, might be 4V for blue and white LEDs)
I = LED Current (e.g., 20mA), this must be less than the maximum permitted

If the calculated value is not available choose the nearest standard resistor value which is **greater** than your calculated value, so that the current will be a little less than you chose. In fact you may wish to choose a greater resistor value to reduce the current (or, to increase battery life for example) but this will make the LED less bright.

For example:

Suppose the Supply Voltage (V_S) = 9V, and you have a Red LED (V_L = 2V), requiring a Current (I) = 20mA = 0.020A, then, the Resistor will be:

R = (9V - 2V) / 0.02A = **350Ω**,

So, choose 390Ω (the nearest standard value which is greater).

TIP:

If you want to work out the LED Resistor formula using Ohm's law, the Ohm's law says that the resistance of the Resistor will be:

R = V/I, where:

V = Voltage across the Resistor (=$V_S - V_L$ in this case)
I = the Current through the Resistor

So, $R = (V_S - V_L) / I$

Really, the result will be the same that we had before. For more information on the calculations, please, see the Ohm's Law over any website.

In the next topic, we have a table with recommended Resistor value for different Power Supplies and colors of LEDs and an automatic “LED-Calculator” to get an accurate LED Resistor value.

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Reading a Table of Technical Data for LEDs

Suppliers' catalogues usually include tables of technical data for components such as LEDs. These tables contain a good deal of useful information in a compact form but they can be difficult to understand if you are not familiar with the abbreviations used.

The table below shows typical technical data for some 5mm diameter round LEDs with “Water Clear” packages (plastic bodies). Only three columns are important and these are shown in bold.

Colors	**I_F Maximum**	**I_F Typical**	**V_F Typical**	**V_F Range**	**V_R Maximum**	**Wavelength**
Blue	30mA	**20mA**	**3.2V**	3.0-3.4V	10V	470nm
Green	30mA	**20mA**	**2.8V**	2.4-3.3V	30V	520nm
Orange	30mA	**20mA**	**2.2V**	1.8-2.5V	35V	615nm
Red	30mA	**20mA**	**2.0V**	1.8-2.2V	30V	660nm
Yellow	30mA	**20mA**	**2.1V**	1.9-2.2V	25V	590nm
White	30mA	**20mA**	**3.4V**	3.0-3.8V	5V	X:0.28, Y:0.28
InfraRed	50mA		**1.6V**			700–1200 nm
UltraViolet	35mA		**3.5V**			300–400 nm

I_F Maximum	Maximum Forward Current, forward just means with the LED connected correctly
I_F Typical	This is the typical current for the most LEDs
V_F Typical	Typical Forward Voltage, V_L in the LED Resistor calculation
V_F Range	Range for Forward Voltage
V_R Maximum	Maximum Reverse Voltage You can ignore this for LEDs connected in the correct way.
Wavelength	The peak wavelength of the light emitted, this determines the color of the LED. ====> nm = nanometer

For an approximately Resistor value, please, see the table below with recommended Resistor value for different Power Supplies and colors of LEDs.

Recommended Resistor Values for the LEDs

SUPPLY VOLTAGE	LED COLOR					
	RED	YELLOW	ORANGE	GREEN	BLUE	WHITE
3 V	56 OHM			*not recommended*		
5 V	150 OHM			82 -100 OHM		
6 V	180 OHM			120 OHM		
9 V	390 OHM			330 OHM		
12 V	470 OHM			390 OHM		
13.8 V(auto)	560 OHM			510 OHM		

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Connecting LEDs in series

If you wish to have several LEDs on at the same time it may be possible to connect them in series. This prolongs battery life by lighting several LEDs with the same current as just one LED.

All the LEDs connected in series pass the **same current** so it is best if they are all the same type. The power supply must have sufficient voltage to provide about 2V (approximately for Red, Yellow and Orange LEDs) for each LED (or, 3V for Green LED, or 4V for Blue and White, approximately) plus at least another 2V for the Resistor. To work out a value for the Resistor you must add up all the LED voltages and use this for $\mathbf{V_L}$.

Example calculations:

Figure out the total estimate voltage for a Red, a Yellow and a Green LED in series:

$\mathbf{V_L}$ (Red) = 2V
$\mathbf{V_L}$ (Yellow) = 2V
$\mathbf{V_L}$ (Green) = 3V
TOTAL $\mathbf{V_{LEDs}}$ = 7V (the three LED voltages added up)
Plus 2V for the Resistor, at least
New TOTAL = 9V (need a supply voltage)
So, a **9V battery** would be ideal.

If the Supply Voltage (V_S) is 9V and the Current (I) must be 15mA = 0.015A, then, the Resistor will be:

$R = (V_S - V_L) / I = (9 - 7) / 0.015 = 2 / 0.015 = 133.3\,\Omega$, so choose $R = 139\,\Omega$ (the nearest standard value which is greater).

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LED-Calculator (Series)

Use the link "LED-Calculator" below for get an accurate LED Resistor value and power.

LED-Calculate

NOTE: If the results for Resistor value and power are a negative number, probably the value that you entered for the "**Source Voltage**" is less than the total for "**Number of LEDs x LED Voltage(FV)**". In this case, we recommend you to increase the Source Voltage up to over until you get a positive value for Resistor and Power.

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Standard Resistors Values and Wattages

Standard Resistor Values up to 100K (values in Ohms)										
0.10	0.15	0.22	0.33	0.47	0.62	0.68	0.75	0.82	0.91	1.0
1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.7	3.0
3.3	3.6	3.9	4.3	4.7	5.1	5.6	6.2	6.8	7.5	8.2
9.1	10	11	12	13	15	16	18	20	22	24
27	30	33	36	39	43	47	51	56	62	68
75	82	91	100	110	120	130	150	160	180	200
220	240	270	300	330	360	390	430	470	510	560
620	680	750	820	910	1.0K	1.1K	1.2K	1.3K	1.5K	1.6K
1.8K	2.0K	2.2K	2.4K	2.7K	3.0K	3.3K	3.6K	3.9K	4.3K	4.7K
5.1K	5.6K	6.2K	6.8K	7.5K	8.2K	9.1K	10K	11K	12K	13K
15K	16K	18K	20K	22K	24K	27K	30K	33K	36K	39K
43K	47K	51K	56K	62K	68K	75K	82K	91K	100K	

Note:

1) Values in Blue color are easier to find in any store.
2) Sometimes you cannot find the EXACT value, for example, 147 Ohms, but you can find the value 150 Ohms, and it will work as well.

Standard Resistor Wattages up to 5 Watts (values in Watts)			
1/16 = 0.0625 Watts	1/10 = 0.1 Watts	1/8 = 0.125 Watts	1/4 = 0.25 Watts
0.33 Watts	0.4 Watts	1/2 = 0.5 Watts	0.6 Watts
1 Watts	2 Watts	3 Watts	5 Watts

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