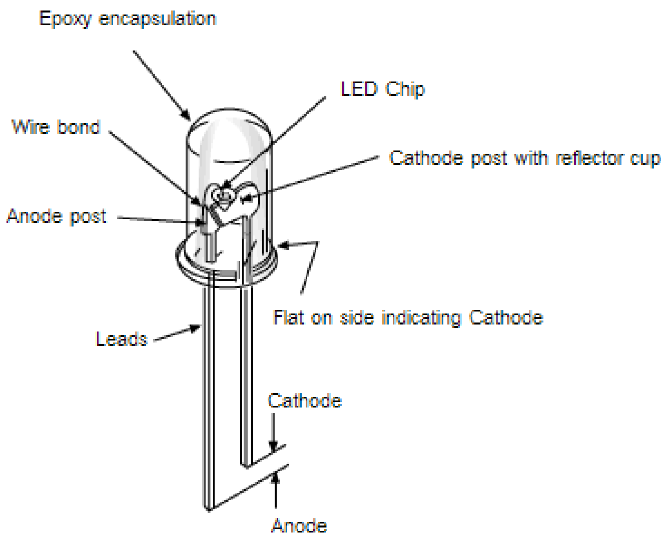
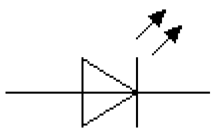
Optoelectronics

Optoelectronic components either convert current flow into light, or light into current flow. A component that converts one form of energy into another is called a transducer so therefore optoelectronic components are transducers.

Light Emitting Diodes

An LED is a type of diode that is capable of emitting light when a current flows through it. When the holes and electrons recombine in a signal or rectifier diode energy is released in the form of heat, in an LED however the energy is released predominantly in the form of light.

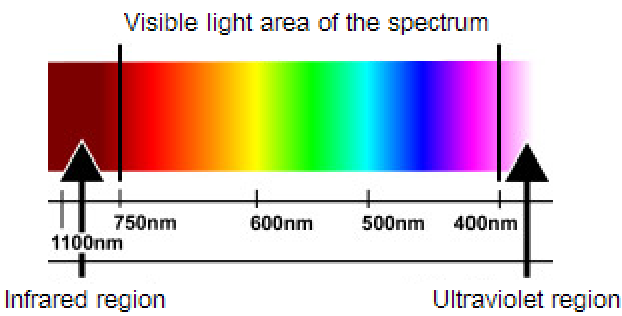




LED Schematic Symbol

LED characteristics

LEDs can are manufactured in a range of colours, the colour depending on the chemical composition of the semiconductor material. Light ranging all the way from the infrared region of the spectrum up to the ultraviolet region can be produced.



An LED is like any other diode, it only allows current to flow significantly in one direction only. Three things that must be considered when using LEDs:

The forward biased voltage drop is relatively high when compared to standard signal or rectifier diodes (0.7V), often in the order of 2.5V, although this varies on the colour and type of LED.

The reverse breakdown voltage of an LED is low, usually in the order of a few volts. LEDs are low power devices and the current flowing through them must be limited to prevent damage. The maximum current should usually be limited to around 20mA.

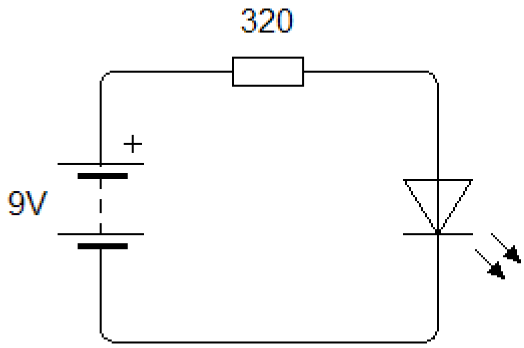
Limiting LED current

As mentioned on the previous page, the current through the diode must be limited to about 20mA. This is easily accomplished by inserting a resistor in series with the diode. The value of resistor required can be easily determined using Ohm's law:

Where V_S is the supply voltage, I_F is the forward current of the LED, and V_F is the forward voltage when I_F flows through the LED.

$$R = \frac{V_S - V_F}{I_F}$$

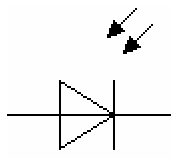
For example, if we have a supply voltage of 9V, an LED with a forward voltage of 2.5V when I_F=20mA, and we wish to limit the current to 20mA, the value of R will be:



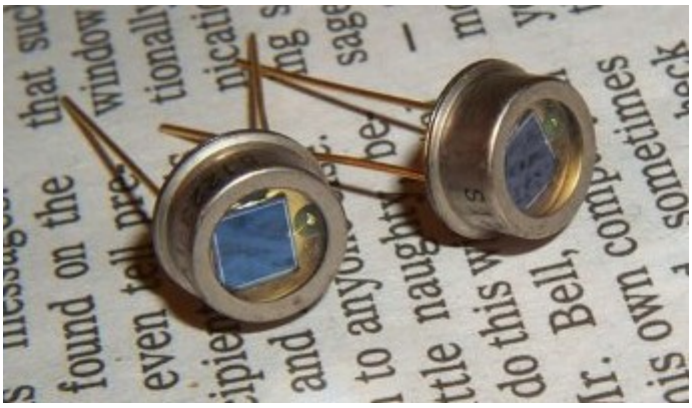
$$R = \frac{9 - 2.5}{20 \times 10^{-3}} = 325\Omega$$

Photodiodes

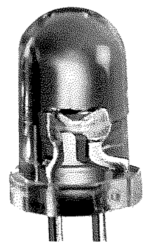
In appearance, most photodiodes look very similar to standard clear LEDs. A photodiode is basically just a PN junction diode with a large surface designed to capture as much light as possible. The PN junction is exposed to light through a transparent window or lens.



Photodiode symbol



High sensitivity photodiode

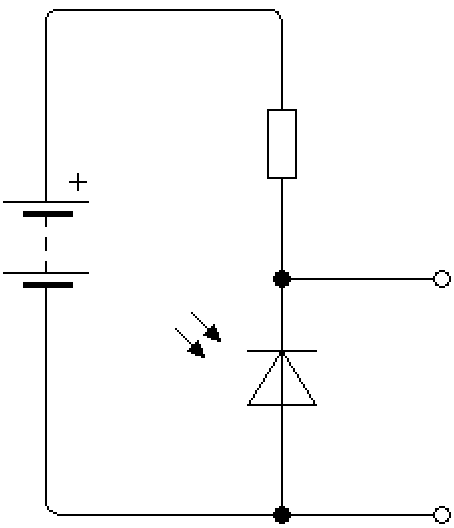


Standard photodiode

Photodiode Modes

Photodiodes are capable of converting light levels into current or voltage variations. There are two ways in which a photodiode can be operated:

- Photoconductive mode
- Photovoltaic mode



Photoconductive mode

In this mode of operation photodiodes are used in reverse bias mode; the amount of leakage current being proportional to the amount of light impinging on the PN junction.

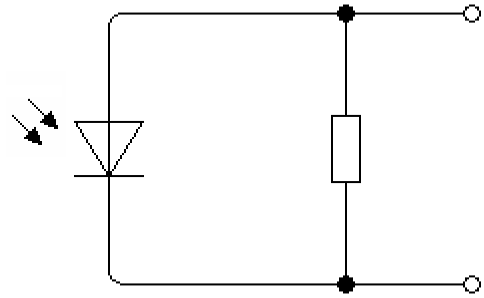
When in the dark the leakage current is low

When in light the leakage current increases

In the circuit shown above, the voltage developed at the cathode due to the leakage current is inversely proportional to the amount of light impinging on the photodiode.

Photovoltaic mode

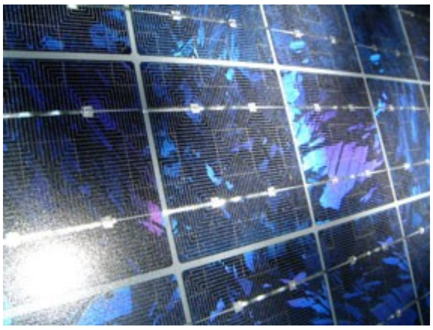
When light impinges on a PN junction a small potential is developed, this is the photovoltaic effect – light generating electricity. The voltage developed across the load resistor is therefore proportional to the light impinging on the diode, the brighter the light the higher the junction voltage. The anode of the photodiode develops a potential that is positive relative to the cathode.



Photodiode in PV mode

Photovoltaic operation is used in low light level situation but where speed of operation is not Important.

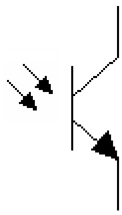
Solar panels use this principle to generate electricity, and basically consist of a large number of PN junctions connected in series and parallel to develop higher voltage and current supplies.



Photovoltaic solar panel

Phototransistors

A problem with photodiodes is that only very low signal levels can be created. These weak signals usually must be amplified by circuitry to make them usable by associated circuitry.

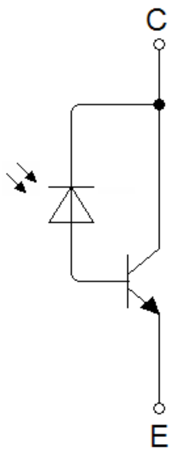


Phototransistor symbol

A phototransistor contains a photodiode in photoconductive mode and a transistor built on a single piece of silicon.

The circuit to the right shows the equivalent circuit.

A transistor has three legs: Base, Collector, & Emitter. The current flowing from collector to emitter is proportional to the current flowing though the base-emitter junction multiplied by an amplification factor (which is often in the region of 100 to >1000 times). The photocurrent generated by the photodiode is amplified by the transistor to provide a more substantial output signal when compared to that of a photodiode alone.



Phototransistor equivalent circuit

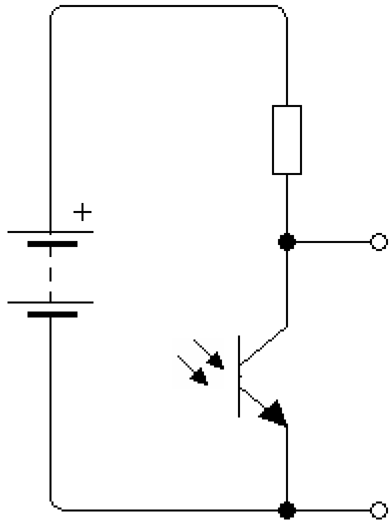
Phototranistors cont.

In the circuit shown on the right, the current flowing through the resistor is controlled by the amount of light impinging on the phototransistor.

The voltage at the collector is inversely proportional to the level light hitting the phototransistor

In low light levels little current flows and the output voltage from the collector is high

In higher light levels much more current flows and the voltage at the collector is pulled low.

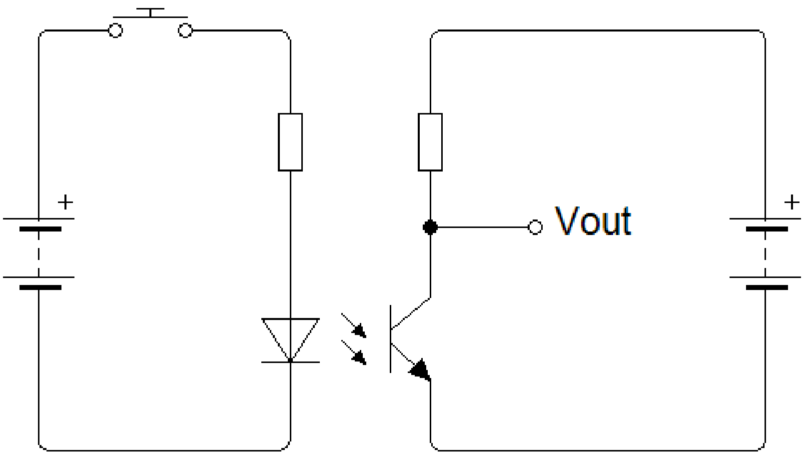


Phototransistor circuit

Optoisolators

An optoisolator allows two circuits two be electrically isolated from one another, it allows one circuit to influence another without having any physical electrical connection. A light transmissive, electrically insulating medium such as air or plastic allows light to be transmitted from an LED to a phototransistor.

In the circuit shown:



When the switch is open, no current flows through the LED and therefore it does not light up. Because of this, not light reaches the phototransistor, that will therefore be switched off and Vout will rise to the voltage of the battery.

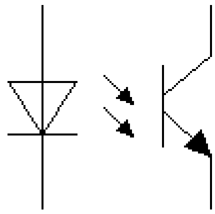
Optoisolators

Slotted optoisolators have many applications, such as:

- Determining the speed & position of rotating components (e.g motors, wheels etc)
- Position encoders in computer mice

A slotted optoisolator has a gap of air between the LED and the phototransistor, therefore a non-transmissive object placed between the gap will block the light that would otherwise reach the phototransistor.

Optoisolators can also be used to connect one circuit to another but avoiding any electrical contact. This is sometimes necessary to protect a microprocessor based system when interfacing to external peripherals.

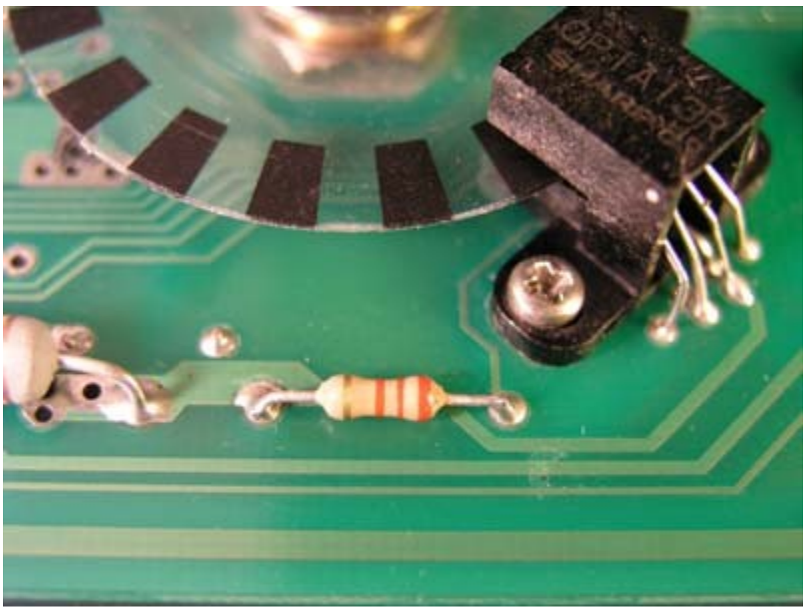


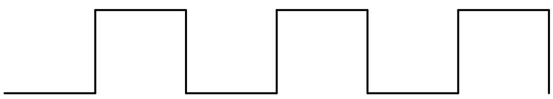
Optoisolator symbol

Slotted Optoisolatortor

Encased DIL optoisolator

As shown in the picture below, if a disc of clear plastic with black strips is placed on an axel as shown, the output of the phototransistor will produce a train of pulses as the disc rotates. The more pulses there are in a period of time, the faster the disc is rotating.





Train of pulses generated at the collector of the phototransistor when the disc is rotating at a steady speed.