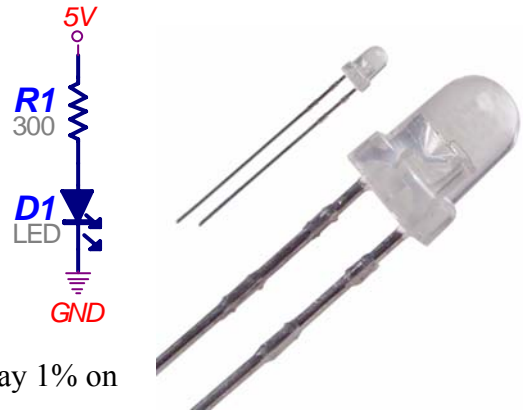


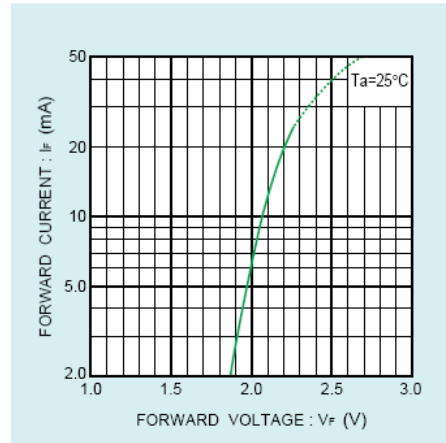
Things you should know about LED's:

The intensity of light that a LED produces is directly proportional to the current. Usually the current is set with a resistor. Ex: At 10mA the diode drops about 2.05V. With a 5V supply, this leaves 3V across the resistor. Therefore $R = 300\Omega$ ($3V/10mA$). Note: You don't need to know the exact voltage drop of the diode. If it's not bright enough lower the current limiting resistor. The maximum DC current should be listed in the data sheet. You may be able to pulse the LED with 10 times its rated current if the duty cycle is low enough (say 1% on time or less).

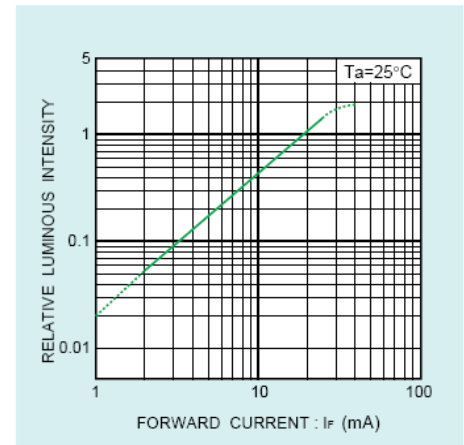


Interesting tidbits: Different color LED's drop different voltages (Red 1.7-2.5V, yellow 2.0-2.3V, green 2.0-2.6V, blue & white 3.1-3.7V). The LED voltage increases slightly with increasing current. The LED's lifetime varies exponentially with current. It may last 100,000 hours at 5mA, 10,000 hours at 20mA, and 100 hours at 100mA. The reverse voltage is very low (sometimes only a few volts) so don't put the LED in backwards.

Forward Current - Forward Voltage



Relative Luminous Intensity - Forward Current



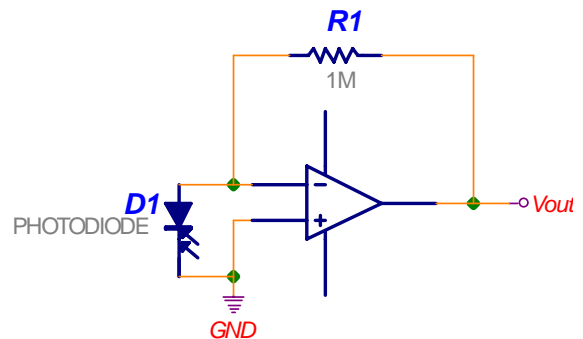
The LED data shown above is for a SLA-370LT3F (a random red LED).

Things you should know about photodiodes:

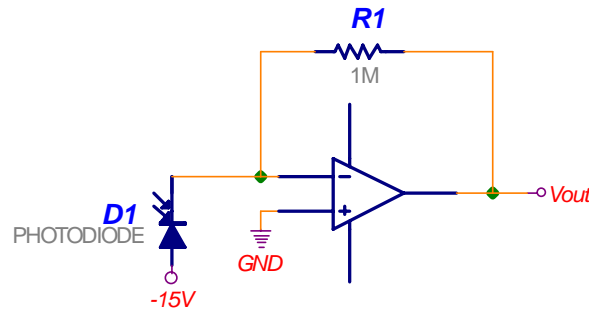
Photodiodes produce a leakage current that is directly proportional to the intensity of the light. This leakage current flows in the opposite direction to current in a normal diode or LED. Ex: As more photons hit the photodiode the current increases causing a voltage across R1. As the voltage across the diode (and resistor) increases the linearity decreases.



A current to voltage converter (or transimpedance amplifier) is an easy way to convert the photodiode current to a voltage and keep the diode voltage at zero (circuit to the right). The output current vs. incident light can be linear over 6-9 orders of magnitude. When light hits the photodiode a current is generated that flows through R1 to the output (no current flows into the op-amp). Note: The output voltage will be negative. If the diode polarity is reversed the output voltage will be positive.



By reverse biasing a PIN photodiode (shown to the right) its capacitance is decreased and therefore it can respond faster. The speed of the transimpedance amplifier to the right will be faster than the one above. Note: In this case the output will be positive since the polarity of the diode is the opposite of the above circuit. The diode capacitance in parallel with the input capacitance of the op-amp and the feedback resistor limits the response time. The op-amp tries to keep the input pins at the same voltage independent of the light input. It does this by adjusting V_{out} which sources or draws current from the input capacitance through the feedback resistor. This RC time constant limits the speed at which the amplifier can respond. Ex: If the photodiode has 10pf of capacitance when reverse biased with -15V and the op-amp input capacitance is 10pf and the feedback resistors is 1M Ω the response time would be on the order of $(10\text{pf}+10\text{pf}) * 1\text{M}\Omega = 20\mu\text{s}$.



Photodiodes (and diodes in general) aren't perfect. When reverse biased a small leakage current flows (an ideal diode has no current in the reverse direction). In the case of a photodiode this leakage current is called the dark current (the current the photodiode produces with no light hitting the diode). The dark current is both temperature dependent and voltage dependent. Increasing temperature and/or increasing reverse bias increases the dark current.

How to read a photodiode datasheet:

Dark current (I_D): Explained above

Breakdown Voltage (V_{BR}): The maximum reverse voltage that can be applied to the diode

Noise Equivalent Power (NEP): The photon intensity required to equal the noise at a given reverse bias

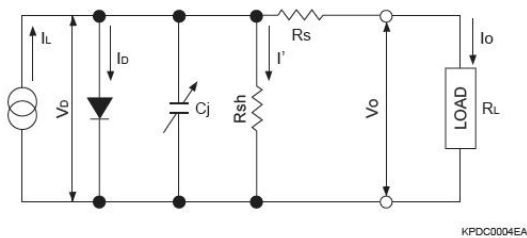
Response time (t_r): How fast the diode can respond to a step input in light at a given reverse bias

Junction Capacitance (C_j): The capacitance of the diode at a given reverse bias

Short circuit current (I_{SC}): With the diode pins shorted, the current that flows at a given light intensity

Shunt resistance (R_{SH}): Used to estimate the thermal noise when no reverse bias is applied. It's the ratio of voltage to current near $V=0$ (Ex: $R_{SH} = 10\text{mV}/I_D$)

Figure 2-1 Photodiode equivalent circuit



- I_L : Current generated by the incident light (proportional to the amount of light)
- I_D : Diode current
- C_j : Junction capacitance
- R_{sh} : Shunt resistance
- R_s : Series resistance
- I' : Shunt resistance current
- V_D : Voltage across the diode
- I_o : Output current
- V_o : Output voltage