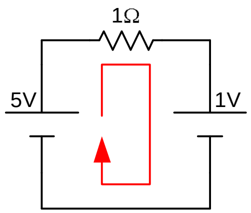
CARE AND FEEDING OF LEDs

1

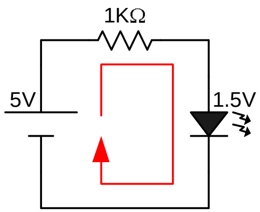


An LED can be thought of in the same way as a battery, i.e. as a fixed voltage device. In the example shown above, there is a 4V difference between the two batteries and 1Ω of resistance between them so 4A of current flows (Direction not shown as electron flow!):

(5V-1V)/1Ω = 4A

Remember however that unlike a battery, an LED will generally not operate as a voltage source, however when exposed to a photon flux, all diodes will generate a current flow, the best example being a diode optimized to do so: ***A solar cell***.

2



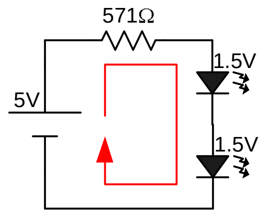
For an LED, the math is exactly the same, where the resistor is chosen to get the current you want:

(5V-1.5V)/3.5mA = 1KΩ

This is also why you never want to hook an LED right to a voltage source. If for instance you have 0.1Ω of wire between your voltage and your LED and in this case, every color of LED will be RED for a few milli-seconds!:

(5V-1.5V)/0.1Ω = 35A!!!

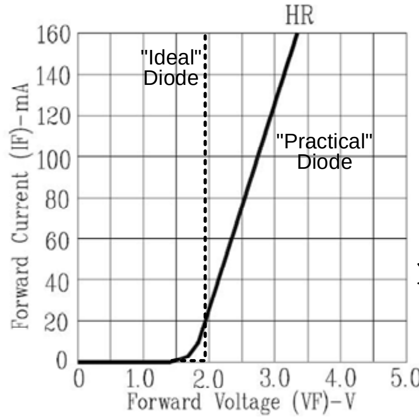
3

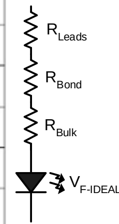


If you need to run two LEDs at once, and the voltage is high enough, connecting them in series can save on parts and furthermore can guarantee that each LED gets EXACTLY the same current, because every element in a series circuit will, by definition, see the same current:

(5V-1.5V-1.5V)/3.5mA = 571Ω

This is how backlighting in modern phone displays is done, as well as traffic lights and LED light bulbs. In phones, there may be up to 10 LEDs and LED light bulbs can have dozens. Since LED output is a function of current, this ensures each one in the string (If from the same device family) will be equally as bright.



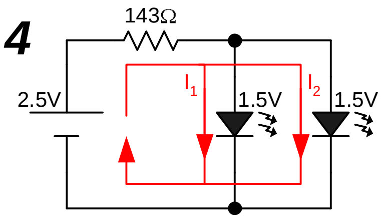


Like any other diode, an LED draws little current below its typical forward voltage and then a lot of current above its forward voltage. For the example graph above, this LED would be spec'd as having a V_F of 1.95V @ 20mA. Below 1.5V it could be considered "Off", but what is happening above 2V? Any diode can be thought of comprising the components shown to the right, where the linear current change for an increasing voltage is the input voltage minus the IDEAL diode voltage divided by the sum of all the resistances, i.e. a linear increase in current for an increase in voltage. (R_{Bulk} is the resistance of the semiconductor material.) The actual value of the total resistance component of a diode (Or LED) can be computed from the linear portion of its graph. For the example above, for a voltage change of 3.8V-1.9V the current changes by 160mA-20ma:

R_{Total} = (3.8V-1.9V)/(160mA-20mA) = 13.6Ω

The very fact that this number is not zero is why an actual LED (vs its Ideal equivalent) abused by a constant voltage source without the protection of a current limiting resistor may not die instantly but instead slowly cook itself to death. The power that goes into an LED that does not come out as light gets turned into heat, and that heat which causes thermal stress is the primary cause of failure in this any any other type of device.

4

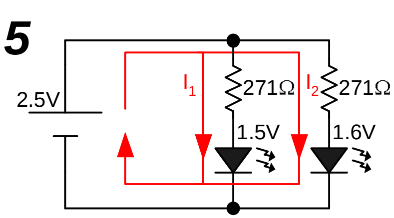


This example is where the problem starts and comes into play when the battery voltage is not high enough to support the LEDs all in series, i.e. 2.5V< (1.5V+1.5V). In a perfect world where both LEDs had exactly the same voltage, they would share the current equally:

(2.5V-1.5V)/7mA = 143Ω, $I_1 = I_2$ = 3.5mA

Unfortunately, no two LEDs are exactly alike so the lowest voltage device "Hogs" all of the available current until it's own voltage rises (Because of internal resistances) and the higher voltage device starts to get an un-equal share. If the lower voltage LED is not driven hard enough to rise to the voltage of the higher voltage LED, the higher voltage LED gets no current. (You can buy LEDs with matched voltages tested at the factory; VERY expensive!)

5



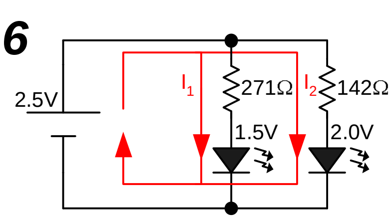
To balance the current between two LEDs in parallel, each one gets its own resistor which helps to negate the variations that exist between even LEDs from the same wafer. In fact, these are called "Balancing resistors" for that very reason. The value of the resistor is chosen so that the average LED voltage within a family is satisfied, or the different voltages of the LEDs used when say a Red and a Green are used together:

(2.5V-1.55V)/3.5mA = 271Ω, $I_1 = I_2$ = 3.5mA

For the LEDs used in the this example with a single resistor, the two currents would be calculated as shown below, keeping in mind that as with any diode, generally no current flows until the input voltage is greater than the forward voltage of the diode:

(2.5V-1.5V)/7mA = 143Ω, I_1 = 7mA, I_2 = 0mA

6



For different LED types, such as a RED and a GREEN led used together, the calculations would be the same but done separately for each LED. This would also hold true for LEDs of roughly the same type with different specs or two LEDs in series that are in parallel with a third LED. For the example shown above:

(2.5V-1.5V)/3.5mA = 271Ω, I_1 = 3.5mA
(2.5V-2.0V)/3.5mA = 142Ω, I_2 = 3.5mA

Generally speaking, the voltage dropped across the "Current Limiting" resistor should be approximately ten times the expected variation of V_F (Due to such things as temperature variation and the like) to limit the change in current due to that variation: A change of 10% of the voltage across the resistor will cause a 10% change in the resistors, and therefore the LEDs, current.