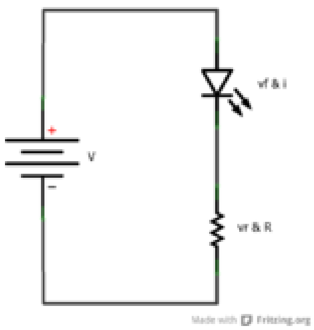
## Designing an LED Circuit

In this section, we will consider the scenario of powering a single LED at its nominal current rating from a dedicated voltage source, and picking the best resistor to match. To do this, we need to do the following:

1. Find the forward voltage drop of the desired LED
2. Find the operating current of the desired LED
3. Find or set the voltage of the power supply being used
4. Calculate the value of the series resistor used to limit the LED current
5. Calculate the necessary power rating of the resistor

For the case of a single LED, we will be analyzing the following circuit:




### Process for a Single LED

For a given LED, we will have a forward drop voltage $v_f$, an operating current $i$. We also have a power supply voltage $V$.

#### Calculate Resistor Value

The first thing we calculate is the resistor value. To do this, we need to know how much of a voltage drop there is across the resistor. Since we are given the voltage source $V$ and the forward drop voltage $v_f$, the voltage drop across the resistor can be found using Kirchhoff's Voltage Law (KVL) as

$$v_r = V - v_f$$

Now that we know $v_r$, we can calculate the resistor value that will yield the desired operating current. This is a simple application of Ohm's Law, $V = I \cdot R$, or, more useful to us now,

$$R = \frac{V}{I}$$

Finally, the resistor value necessary is

$$R = \frac{v_r}{i}$$

#### Calculate Resistor Minimum Power Rating

Since we know the resistor value, $R$, the current through the resistor, $i$, and the voltage drop across the resistor, $v_r$, we can calculate the power dissipated through the resistor as either

$$P = \frac{V^2}{R} = \frac{v_r^2}{R}$$

or

$$P = V \cdot I = v_r \cdot i$$

**NOTE:** $P$ is the *minimum* power rating necessary for the resistor. Any rating larger than this is acceptable. Any rating smaller than this could damage the circuit, and may start a fire from overheating!

### Example 1 - Red LED

For this example, we will design a circuit around a common hobby LED, such as this one from SparkFun. This LED has two important parameters:

- 1.8-2.2 VDC forward drop
- Suggested current 16-18mA

First, we will assume that $v_f = 2V$, $i = 16mA$, and the power supply voltage $V = 5V$. We can calculate the voltage drop across the resistor as

$$v_r = V - v_f = 5V - 2V = 3V$$

Next we can calculate the resistor value necessary:

$$R = \frac{v_r}{i} = \frac{3V}{0.016A} = 187.5\Omega$$

You can either try to make a $187.5\Omega$ resistor by cleverly placing resistors in series, or you can use any resistor of a *larger* value, at the expense of some current. The closest standard 5% resistor is $200\Omega$, and will result in a current draw of

$$i = \frac{v_r}{R} = \frac{3V}{200\Omega} = 0.015A = 15mA$$

which is pretty close!

Finally we can calculate the power rating necessary for the resistor as

$$P = v_r \cdot i = 3V \cdot 0.015A = 0.045W = 45mW$$

Most common hobby resistors are at least $0.25W = 250mW$, so just about any resistor would be able to dissipate the heat generated with this circuit (but double check!).

### Example 2 - IR LED

For this example, we will design a circuit around a more powerful infrared LED, such as this one from DigiKey. The parameters of this LED are:

- Forward voltage drop of $v_f = 1.3V$
- Current usage of $i = 100mA$

**IMPORTANT: Do not try to use this LED directly from an Arduino, such as in the digital output tutorial. Arduino pins are capable of sourcing at *most* 40mA of current. Drawing more *will* damage your Arduino. Consider using a transistor instead!**

As in Example 1, we will assume that $V = 5V$. The voltage drop across the resistor is

$v_r = V - v_f = 5V - 1.3V = 3.7V$

The resistor value is

$$R = \frac{v_r}{i} = \frac{3.7V}{0.1A} = 37\Omega$$

The closest standard 5% resistor is $39\Omega$, and will result in a current draw of

$$i = \frac{v_r}{R} = \frac{3.7V}{39\Omega} \approx 0.095A = 95mA$$

Finally we can calculate the power rating necessary for the resistor as

$$P = v_r \cdot i = 3.7V \cdot 0.095A = 0.3515W \approx 352mW$$

For this LED, we will need to step up to the next power level of resistors, which is $0.5W = 500mW$

## Designing an LED Array

[In Progress]

## Common LED/Resistor Combinations

| Description | Supply Voltage | LED Forward Voltage | # LEDs in Series | Desired Current | Closest Resistor |
|---|---|---|---|---|---|
| Red SMD | 5V | 1.8V | 1 | 2mA | 1.6kΩ 1/10W |
| Red SMD | 5V | 1.8V | 2 | 2mA | 750Ω 1/10W |
| Blue SMD | 5V | 2.85V | 1 | 5mA | 430Ω 1/10W |
| Yellow SMD | 5V | 1.8V | 1 | 2mA | 1.6kΩ 1/10W |
| Yellow SMD | 5V | 1.8V | 2 | 2mA | 750Ω 1/10W |
| Green SMD | 5V | 1.7V | 1 | 2mA | 1.8kΩ 1/10W |
| Green SMD | 5V | 1.7V | 2 | 2mA | 820Ω 1/10W |
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