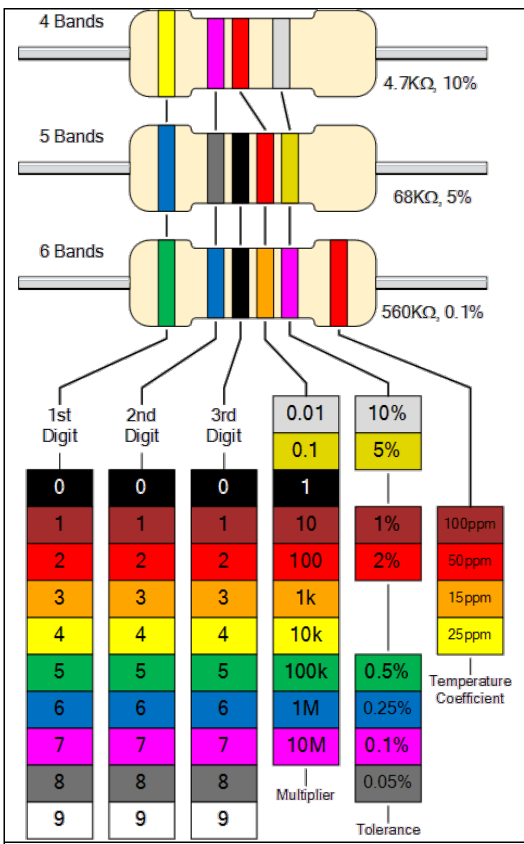
Resistor Color Codes

Resistors are available in a range of different resistance values from fractions of an Ohm (Ω) to millions of Ohms. Obviously, it would be impractical to have available resistors of every possible value for example, 1Ω, 2Ω, 3Ω, 4Ω etc, because millions of different resistors would need to exist to cover all the possible values. Instead, resistors are manufactured in what are called "preferred values" with their resistance value printed onto their body in colored ink.

Figure 1. A resistor with four colored bands

The resistance value, tolerance, and wattage rating are printed onto the body of the resistor as numbers or letters when the resistors body is big enough to read the print, such as large power resistors. But when the resistor is small such as a 1/4W carbon or film type, these specifications are shown as colored painted bands to indicate both their resistive value and their tolerance with the physical size of the resistor indicating its wattage rating. The resistor color code markings are read one band at a time starting from the left to the right, with the larger width tolerance band oriented to the right side. The color of each band is associated with a number in the digit column of the color chart or table below.



Color	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		± 0.05%
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

Figure 2 The Standard Resistor Color Code Chart and Table.

Calculating Resistor Values

The **Resistor Color Code** system is read left to right with the "left-hand" or the most significant colored band being nearest to a connecting lead as shown in Figure 1. The colors are then interoperated as;

Digit, Digit, Multiplier = Color, Color x 10^{color} in Ohm's (Ω's)

For example, a resistor has the following colored markings;

Yellow Violet Red = 4 7 2 = 4 7 x 10^2 = 4700Ω or 4k7.

The fourth and fifth bands are used to determine the percentage tolerance of the resistor. Resistor tolerance is a measure of the resistors variation from the specified resistive value and is a consequence of the manufacturing process and is expressed as a percentage of its "nominal" or preferred value.

Typical resistor tolerances for film resistors range from 1% to 10% while carbon resistors have tolerances up to 20%. Resistors with tolerances lower than 2% are called precision resistors with the or lower tolerance resistors being more expensive.

Most five band resistors are precision resistors with tolerances of either 1% or 2% while most of the four band resistors have tolerances of 5%, 10% and 20%. The color code used to denote the tolerance rating of a resistor is given as;

Brown = 1%, Red = 2%, Gold = 5%, Silver = 10 %

If a resistor has no fourth tolerance band then the default tolerance would be at 20%.

It is sometimes easier to remember the resistor color code by using mnemonics or phrases that have a separate word in the phrase to represent each of the Ten + Two colors in the code. Once such saying is: "**B**etter **B**e **R**ight **O**r **Y**our **G**reat **B**ig **V**enture **G**oes **W**est".

Tolerances, E-series & Preferred Values

Resistors are manufactured in what are commonly known as **preferred values**. Instead of sequential values of resistance from 1Ω and upwards, certain values of resistors exist within certain tolerance limits. The tolerance of a resistor is the maximum difference between its actual value and the required value and is generally expressed as a plus or minus percentage value. For example, a 1kΩ ±20% tolerance resistor may have a maximum and minimum resistive value of.

Maximum Resistance Value

1kΩ or 1000Ω + 20% = 1,200Ω's

Minimum Resistance Value

1kΩ or 1000Ω – 20% = 800Ω's

Then using the example above, a 1kΩ ±20% tolerance resistor may have a maximum value of 1200Ω's and a minimum value of 800Ω's resulting in a difference of some 400Ω's!! for the same value resistor.

In some electrical or electronic circuits this large 20% tolerance of the same resistor is not a problem. For precision applicators such as high accuracy circuits, filters, or oscillators etc, then higher tolerance resistor needs to be used. For these cases a 20% tolerance resistor could not generally be used to replace 2% or even a 1% tolerance type.

The five and six band resistor color code is more commonly associated with the high precision 1% and 2% film types while the common garden variety 5% and 10% general purpose types tend to use the four band resistor color code. Resistors come in a range of tolerances but the two most common are the E12 and the E24 series.

The E12 series comes in twelve resistance values per decade, (A decade representing multiples of 10, i.e. 10, 100, 1000 etc), while the E24 series comes in twenty four values per decade and the E96 series ninety six values per decade. A very high precision E192 series is now available with tolerances as low as ± 0.1% giving a massive 192 separate resistor values per decade.

Tolerance and E-series Table.

E6 Series at 20% Tolerance – Resistors values in Ω's

1.0, 1.5, 2.2, 3.3, 4.7, 6.8

E12 Series at 10% Tolerance – Resistors values in Ω's

1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2

E24 Series at 5% Tolerance – Resistors values in Ω's

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, 7.2, 8.2, 9.1

E96 Series at 1% Tolerance – Resistors values in Ω's

1.00, 1.02, 1.05, 1.07, 1.10, 1.13, 1.15, 1.18, 1.21, 1.24, 1.27, 1.30, 1.33, 1.37, 1.40, 1.43, 1.47, 1.50, 1.54, 1.58, 1.62, 1.65, 1.69, 1.74, 1.78, 1.82, 1.87, 1.91, 1.96, 2.00, 2.05, 2.10, 2.15, 2.21, 2.26, 2.32, 2.37, 2.43, 2.49, 2.55, 2.61, 2.77, 2.74, 2.80, 2.87, 2.94, 3.01, 3.09, 3.16, 3.24, 3.32, 3.40, 3.48, 3.57, 3.65, 3.74, 3.83, 3.92, 4.02, 4.12, 4.22, 4.32, 4.42, 4.53, 4.64, 4.75, 4.87, 4.99, 5.11, 5.23, 5.36, 5.49, 5.62, 5.76, 5.90, 6.04, 6.19, 6.34, 6.49, 6.65, 6.81, 6.98, 7.15, 7.32, 7.50, 7.68, 7.87, 8.06, 8.25, 8.45, 8.66, 8.87, 9.09, 9.31, 9.53, 9.76

Then by using the appropriate E-series value for the percentage tolerance required for the resistor, adding a multiplication factor to it, any ohmic value of resistance within that series can be found. For example, take an E-12 series resistor, 10% tolerance with a preferred value of 3.3, then the values of resistance for this range are:

Value x Multiplier = Resistance

3.3 x 1 = 3.3Ω

3.3 x 10 = 33Ω

3.3 x 100 = 330Ω

3.3 x 1,000 = 3.3kΩ

3.3 x 10,000 = 33kΩ

3.3 x 100,000 = 330kΩ

3.3 x 1,000,000 = 3.3MΩ

The mathematical basis behind these preferred values comes from the square root value of the actual series being used. For example, for the E6 20% series there are six individual resistors or steps (1.0 to 6.8) and is given as the sixth root of ten (6√10), so for the E12 10% series there are twelve individual resistors or steps (1.0 to 8.2) and is therefore given as the twelfth root of ten (12√10) and so on for the remaining E-series values.

The tolerance series of **Preferred Values** shown above are ranges of resistor values chosen so that at maximum or minimum tolerance any one resistor overlaps with its neighboring value. For example, take the E24 range of resistors with a 5% tolerance. Its neighboring resistor values are 47 and 51Ω's respectively.

47Ω + 5% = 49.35Ω's, and 51Ω – 5% = 48.45Ω's, an overlap of just 0.9Ω's.

Surface Mount Resistors

4.7kΩ SMD Resistor

Surface Mount Resistors or SMD Resistors are very small rectangular shaped metal oxide film resistors designed to be soldered directly onto the surface, hence their name, of a circuit board. Surface mount resistors generally have a ceramic substrate body onto which is deposited a thick layer of metal oxide resistance.

The resistive value of the resistor is controlled by increasing the desired thickness, length or type of deposited film being used and highly accurate low tolerance resistors, down to 0.1% can be produced. They also have metal terminals or caps at either end of the body which allows them to be soldered directly onto printed circuit boards.

Surface Mount Resistors are printed with either a 3 or 4-digit numerical code which is similar to that used on the more common axial type resistors to denote their resistive value. Standard SMD resistors are marked with a three-digit code, in which the first two digits represent the first two numbers of the resistance value with the third digit being the multiplier, either x1, x10, x100 etc. For example:

"103" = 10 × 1,000 ohms = 10 kiloΩ´s

"392" = 39 × 100 ohms = 3.9 kiloΩ´s

"563" = 56 × 1,000 ohms = 56 kiloΩ´s

"105" = 10 × 100,000 ohms = 1 MegaΩ

Surface mount resistors that have a value of less than 100Ω's are usually written as: "390", "470", "560" with the final zero representing a 10 x^o multiplier, which is equivalent to 1. For example:

"390" = 39 × 1Ω = 39Ω´s or 39RΩ

"470" = 47 × 1Ω = 47Ω´s or 47RΩ

Resistance values below ten have a letter "R" to denote the position of the decimal point as seen previously in the BS1852 form, so that 4R7 = 4.7Ω.

Surface mount resistors that have a "000" or "0000" markings are zero-Ohm (0Ω) resistors or in other words shorting links, since these components have zero resistance.