Electrical Resistor Values

TN-021-ResistorValues

Dr John S Glover*

01 March 2020

1 Introduction

With the ubiquitous use of integrated circuits (ICs) and surface mounted devices there is still a need for the use of discrete components within electronic circuits. For discrete resistors a colour coding system is used to specify the value of the resistor and this colour coding also includes a tolerance marking. The fabrication of all resistor values is not practical therefore a number of series of resistors have been specified depending on the overall tolerance of the resistor series.

This short technical note firstly outlines the resistor band colour scheme which is used to define the resistor value, §2. The values of resistors, as defined by a number of series of preferred values, is presented in §3, together with an illustration of the use of resistor value tolerance and how this applies to the defined series.

2 Resistor Band Colour Scheme

For an axial resistor, the value of its resistance is denoted by a series of coloured bands around the body[1], either:

- four bands (three providing the value and one for the tolerance);
- five bands (four providing the value and one for the tolerance);
- six bands (four providing the value, one for the tolerance and one for the temperature coefficient).

The colour of each band denotes either a significant digit or the number of zeroes which form the value. The bands denoting the value of the resistor are usually grouped together with the tolerance band or tolerance and temperature coefficient being separate. Additionally, the tolerance band utilises a different set of colours. Only three bands are mandatory, the three providing a resistance value. Bands for tolerance, increased precision and temperature coefficient are optional.

The IEC (International Electrotechnical Commission) standard covers the colour banding is IEC 60062, [2].

The values and number of zeroes associated with each colour are detailed in Table 1.

The tolerance associated with each colour are detailed in Table 2.

*email: *jsglover@zetnet.co.uk*

[1] other schemes do exist, for example, writing the value on the resistor, often in short form, but this note focusses only on the colour schemes

Colour	Value	Multiplier
Silver		0.01
Gold		0.1
Black	0	1
Brown	1	10
Red	2	100
Orange	3	1,000
Yellow	4	10,000
Green	5	100,000
Blue	6	1,000,000
Violet	7	10,000,000
Grey	8	
White	9	

Table 1: Resistor value colour coding.

Colour	Tolerance (%)
Silver	10
Gold	5
Red	2
Brown	1
Green	0.5
Blue	0.25
Violet	0.1
Grey	0.05

Table 2: Tolerance value colour coding.

2.1 Resistors - Four band

Using the four band resistor illustrated in Figure 1 the value is given by:

Yellow - 4

Violet - 7

Orange - 1,000

Silver - 10%

Value - 47 kΩ ± 10%

2.2 Resistors - Five band

Using the five band resistor illustrated in Figure 2 the value is given by:

Yellow - 4

Grey - 8

Violet - 7

Orange - 1,000

Silver - 10%

Value - 487 kΩ ± 10%

Figure 1: Illustration of colour bands for a four band resistor.

Figure 2: Illustration of colour bands for a five band resistor.

2.3 Resistors - Six band

Using the six band resistor illustrated in Figure 3 the value is given by:

Yellow - 4

Grey - 8

Violet - 7

Orange - 1,000

Orange - 15 ppm/K

Silver - 10%

Value - 487 kΩ ± 10% 15 ppm/K

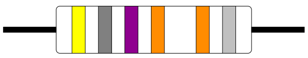

Figure 3: Illustration of colour bands for a six band resistor.

3 Resistor Values

To produce resistors for all possible values is impractical, not only would this mean a large number of resistors to be manufactured but the ability to form resistors to specific values is expensive. An approach has been developed whereby resistors are produced in sets, or to be more precise *series*. Each series is based on the tolerance of the series; 20%, 10% etc. The values of the E6, E12, E24 and E48 series are detailed in Table 3. The series are more fully explained in IEC 60063, [1]

Tolerance	20% E6	10% E12	5% E24	2% E48
	10	10	10	100
				105
			11	110
				115
		12	12	121
				127
			13	133
				140
	15	15	15	147
				154
			16	162
				169
		18	18	178
				187
			20	196
				205
	22	22	22	215
				226
			24	237
				249
		27	27	261
				274
			30	287
				301
	33	33	33	316
				332
			36	348
				365
		39	39	383
				402
			43	422
				442
	47	47	47	464
				487
			51	511
				536
		56	56	562
				590
			62	619
				649
	68	68	68	681
				715
			75	750
				787
		82	82	825
				866
			91	909
				953

Table 3: Resistor values per tolerance range.

3.1 What is tolerance?

Since manufacturing every resistor value is not a practical proposition they are manufactured in series with a given level of precision; 20% E6, 10% E12 etc. with preferred values, [1]. A resistor's tolerance, expressed as a percentage, is the maximum difference between the resistor's actual value and the resistor's defined value.

So for a nominal 1 kΩ resistor with a 20% tolerance, i.e. a resistor from the E6 series

Maximum possible value $1,000\Omega + 20\% = 1,200\Omega$

Minimum possible value $1,000\Omega - 20\% = 800\Omega$

The full range for the E6 series is elaborated in Table 4 and the spread of resistances for the E6 series is illustrated in Figure 4.

Minimum (Ω)	Nominal (Ω)	Maximum (Ω)
800	1,000	1,200
1,200	1,500	1,800
1,760	2,200	2,640
2,640	3,300	3,960
3,760	4,700	5,640
5,440	6,800	8,160

Table 4: Resistor values for E6 (20%) tolerance (base value 1kΩ).

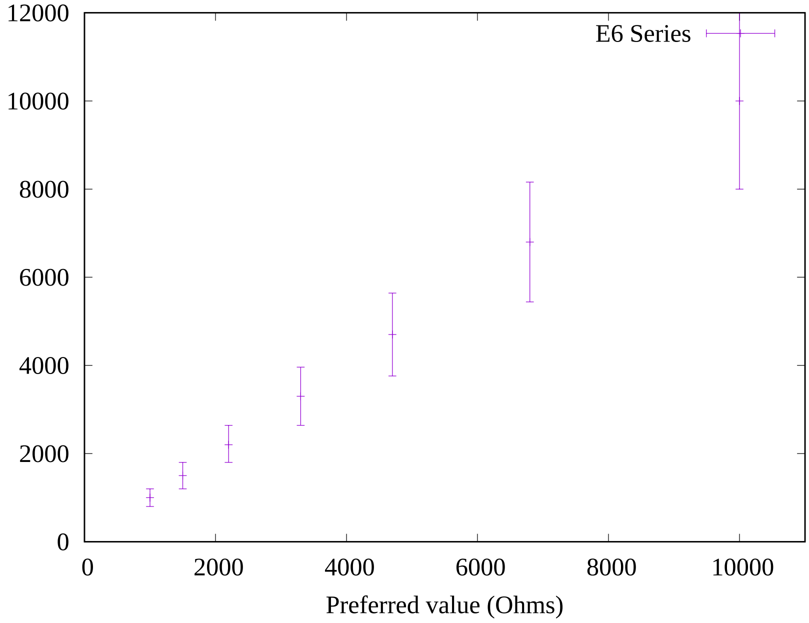

Figure 4: E6 preferred values and tolerance range.

3.2 What is the temperature coefficient?

The temperature coefficient for a resistor represents the stability of its resistance value as temperature of the resistor varies. When a current passes through a resistor power is dissipated over time as heat energy. The amount of power dissipated is a product of the current and resistor value, for DC this is given by:

$$P = I^2.R \tag{1}$$

where

P Power in Watts (W),

I Current in Amps (A),

R Resistance in Ohms (Ω).

As illustrated in Figure 3, §2, the temperature coefficient is indicated by Band 6 on a six band resistor. The respective values for the temperature colours is displayed in Table 5.

Colour	Temperature Coefficient (ppm/K)
Black	250
Brown	100
Red	50
Orange	15
Yellow	25
Green	20
Blue	10
Violet	5
Grey	1

Table 5: Resistor temperature coefficient colour coding.

The sophistication of design, manufacturing materials and production techniques leads to improved temperature stability and, usually, increased cost.

4 Summary

This short note has explained the colour coding schemes used for resistors (four, five and six band), the standard series for resistors and explained their derivation based on the tolerance to which they are produced.

To reiterate, although the colour coding scheme for resistors has been described in this technical note, this is not the only mechanism for labelling resistance values. Other schemes exist, for example, writing the resistance value on the device in a short form, 5K6[2] is a 5.6 kΩ.

References

[1] IEC. *Preferred number series for resistors and capacitors.* Number 60063. 03 2015.

[2] IEC. *Marking codes for resistors and capacitors.* Number 60062. 07 2016.

[2] Note, the use of an upper case K and the omission of the units of measure (Ω).