D: The Resistor Color Code and Standard Values

Resistor values are determined by reading the color bands from left to right. Depending on position, each band can represent a digit, a multiplier, or a tolerance.

Table D.1. Standard Resistor Color Code.

Color		Digit	Multiplier	Tolerance
	Black	0	$10^0 = 1$	-
	Brown	1	$10^1 = 10$	±1%
	Red	2	$10^2 = 100$	±2%
	Orange	3	$10^3 = 1{,}000$	-
	Yellow	4	$10^4 = 10{,}000$	-
	Green	5	$10^5 = 100{,}000$	±0.5%
	Blue	6	$10^6 = 1{,}000{,}000$	±0.25%
	Violet	7	$10^7 = 10{,}000{,}000$	±0.1%
	Gray	8	$10^8 = 100{,}000{,}000$	±0.05%
	White	9	$10^9 = 1{,}000{,}000{,}000$	-
	Gold	-	$10^{-1} = 0.1$	±5%
	Silver	-	$10^{-2} = 0.01$	±10%
	No Color	-	-	±20%

There are two marking systems in common use:

Four color bands

The first two bands represent digits and the third is the multiplier. The fourth band is the tolerance of the resistor value in percent. For example, a resistor with four-band marking *red-red-yellow-gold*, as shown at left, would have nominal value $22\times10^4 = 220{,}000\ \Omega$, or 220kΩ, but its actual value could be anything within ±5% (gold band) of this number $\left(209{,}000\,\Omega \le R \le 231{,}000\,\Omega\right)$.

If a resistor appears to have only three bands, the fourth band is "no color," indicating a tolerance of ±20%.

Five color bands

The five-band marking system is typically used for narrower tolerance ranges, such as ±2% or smaller. The first three bands represent digits and the fourth is the multiplier. The fifth band is the tolerance of the resistor value in percent.

For example, a resistor with five-band marking *brown-red-red-red-brown*, as shown at left, would have nominal value 122×10^2 = 12,200 Ω, or 12.2kΩ, but its actual value could be anything within ±1% (brown band) of this number $\left(12,078\Omega \le R \le 12,322\Omega\right)$.

Resistors can have only a specific set of standard values within each decade. These values are determined by the tolerance, and they repeat through each decade. This "preferred value" system was developed by the Electronic Industries Alliance (EIA), and has its origins in the early years of the 20th century at a time when most resistors were carbon-graphite with relatively poor manufacturing tolerances. The EIA "E" series specifies the preferred values for various tolerances, and the number following the "E" specifies the number of steps per decade.

Table D.2. EIA "E" Series.

Series	Description
E3	50% tolerance (obsolete)
6	20% tolerance (seldom used)
E12	10% tolerance
E24	5% tolerance (and usually 2% tolerance)
E48	2% tolerance (also for inventory cost control in place of E96)
E96	1% tolerance
E192	0.5%, 0.25%, 0.1% and smaller tolerances

The rationale is simple: values are selected for components based on the tolerances with which they can be manufactured. Using 10% tolerance devices as an example, suppose that the first preferred value is 100Ω. It would make little sense to produce a 105Ω resistor, since 105Ω falls within the ±10% tolerance range of the 100Ω resistor. The next *reasonable* value is approximately 120Ω, because the 100Ω resistor with a 10% tolerance is expected to have a value somewhere between 90Ω and 110Ω, while a 120Ω resistor would have a value ranging between 108Ω and 132Ω. The spacing between values is actually a logarithmic pattern based on the multiplier $10^{1/n}$, where n is the number of values within a decade. For example, the E12 scale (used for ±10% tolerance resistors) should include the values 100, $100\times10^{1/12}\approx121$, $100\times10^{2/12}\approx147$, …, $100\times10^{11/12}\approx825$ in the decade between 100 and 1000. These are, for historical reasons, rounded slightly to the values 100, 120, 150, …, 820, shown in Table D.3. This table is normalized for the decade between 100Ω and 1000Ω. The values in any other decade range can be determined by merely dividing or multiplying the table entries by the appropriate power of 10.

It is important to note that, although the 4-band color code allows for all resistor values that are multiples of 10 in the decade from 100-990 (90 combinations), not all of these values are available. For example, 100 is available in all of the series listed in Table D.3. However, the next value in the 5% tolerance range is 110 (24 of the 90 are valid in series E24), the next value in the 10% tolerance range is 120 (12 of the 90 are valid in series E12), and the next value in the 20% tolerance range is 150 (6 of the 90 are valid in series 6).

The largest resistance value commercially available is 22MΩ.

Table D.3. Standard EIA Resistor Values for the Decade $100\Omega \le R \le 1000\Omega$.

E6	E12	E24	E48	E96	E192
±20%	±10%	±5%	±2%	±1%	±0.5%
100	100	100	100	100	100
					101
				102	102
					104
			105	105	105
					106
				107	107
					109
		110	110	110	110
					111
				113	113
					114
			115	115	115
					117
				118	118
					120
	120	120	121	121	121
					123
				124	124
					126
			127	127	127
					129
				130	130
					132
		130	133	133	133
					135
				137	137
					138
			140	140	140
					142
				143	143
					145

E6	E12	E24	E48	E96	E192
±20%	±10%	±5%	±2%	±1%	±0.5%
150	150	150	147	147	147
					149
				150	150
					152
			154	154	154
					156
				158	158
					160
		160	162	162	162
					164
				165	165
					167
			169	169	169
					172
				174	174
					176
	180	180	178	178	178
					180
				182	182
					184
			187	187	187
					189
				191	191
					193
		200	196	196	196
					198
				200	200
					203
			205	205	205
					208
				210	210
					213

E6	E12	E24	E48	E96	E192
±20%	±10%	±5%	±2%	±1%	±0.5%
220	220	220	215	215	215
					218
				221	221
					223
			226	226	226
					229
				232	232
					234
		240	237	237	237
					240
				243	243
					246
			249	249	249
					252
				255	255
					258
	270	270	261	261	261
					264
				267	267
					271
			274	274	274
					277
				280	280
					284
		300	287	287	287
					291
				294	294
					298
			301	301	301
					305
				309	309
					312

E6	E12	E24	E48	E96	E192
±20%	±10%	±5%	±2%	±1%	±0.5%
330	330	330	316	316	316
					320
				324	324
					328
			332	332	332
					336
				340	340
					344
		360	348	348	348
					352
				357	357
					361
			365	365	365
					370
				374	374
					379
	390	390	383	383	383
					388
				392	392
					397
			402	402	402
					407
				412	412
					417
		430	422	422	422
					427
				432	432
					437
			442	442	442
					448
				453	453
					459

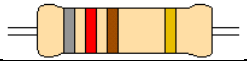
E6	E12	E24	E48	E96	E192
±20%	±10%	±5%	±2%	±1%	±0.5%
470	470	470	464	464	464
					470
				475	475
					481
			487	487	487
					493
				499	499
					505
		510	511	511	511
					517
				523	523
					530
			536	536	536
					542
				549	549
					556
	560	560	562	562	562
					569
				576	576
					583
			590	590	590
					597
				604	604
					612
		620	619	619	619
					626
				634	634
					642
			649	649	649
					657
				665	665
					673

E6	E12	E24	E48	E96	E192
±20%	±10%	±5%	±2%	±1%	±0.5%
680	680	680	681	681	681
					690
				698	698
					706
			715	715	715
					723
				732	732
					741
		750	750	750	750
					759
				768	768
					777
			787	787	787
					796
				806	806
					816
	820	820	825	825	825
					835
				845	845
					856
			866	866	866
					876
				887	887
					898
		910	909	909	909
					920
				931	931
					942
			953	953	953
					965
				976	976
					988

Power Rating

Another important consideration when using resistors is their power handling capability, or power "rating." The diameter of the resistor cylinder clearly indicates the power rating as shown in Table D.4.

Table D.4. Resistor Power Ratings.

Resistor Diameter		Power Rating
	1/16 "	1/4 W
	1/8 "	1/2 W
	3/16 "	1 W
	1/4 "	2 W

Be careful! Failure to observe and respect the power rating of a resistor can result in this:

or this:

or even this: