RESISTOR & CAPACITOR DATA

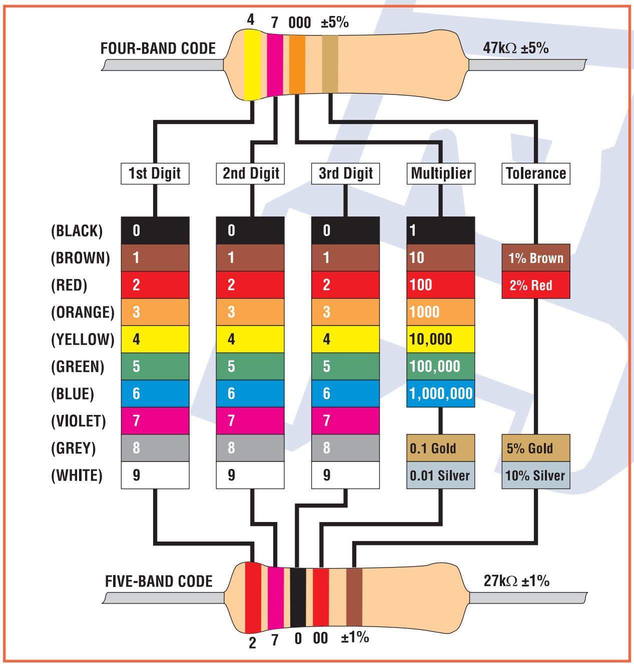
Resistors

Many resistors are so small that it would be difficult to print their value and % tolerance on their body in digits. To overcome this, a coding system based on bands of distinctive colours was developed to assist in identification. Learning this 'colour code' is not as necessary as it used to be (thanks to accurate, low cost digital multimeters!), but it's not hard to learn and it's quite useful knowledge anyway.

The first thing to know is that in each decade of resistance — i.e., from 10 - 100Ω, 100 - 1kΩ, 1k - 10kΩ, etc — there are only a finite number of different nominal values allowed. Most common resistors have values in the 'E12' series, which only has 12 allowed values per decade. Normalised these are 1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8 and 8.2. Multiples of these values are simply repeated in each decade — e.g., 10, 12, 15, 18 and so on. Note that the 'steps' between these values are always very close to 20%, because the E12 series dates from the days of resistors with ±10% tolerance.

To allow greater accuracy in circuit design, modern 1% tolerance resistors are made in a larger range of values: the 'E24' series, which has 12 *additional* allowed values per decade as shown in the table. As before, these nominal values are simply repeated in each decade. The table at right shows both the E12 and E24 allowed values for comparison.

The next thing to know is that there are **two** different resistor colour coding systems in use: one using a total of 4 colour bands, and the other 5. The 5-band system is generally used for 2% and closer tolerance resistors, even though the 4-band system is quite capable of handling any resistors with E12 or E24 values. Both systems use the same band colours to represent the various digits; the main difference is that 5-band resistors have an additional 'third band', which is almost always BLACK to represent a third digit of '0'. Here's how both systems work in practice:



4-band resistors will almost always have values in the E12 series, while 5-band resistors can have any value in the E24 series. This is worth remembering, because depending on the resistor's body colour, some of the band colours may not be easy to distinguish. Blue (6) and grey (8) sometimes look very similar, as do red (2), brown (1) and orange (3). So if you're in doubt, check the apparent coded value against the allowed E12 or E24 values to see if it's 'legal' — or check with a digital multimeter, just to make sure.

Preferred Resistor Values (within each decade)

E12 Series	E24 Series
10	10
	11
12	12
	13
15	15
	16
18	18
	20
22	22
	24
27	27
	30
33	33
	36
39	39
	43
47	47
	51
56	56
	62
68	68
	75
82	82
	91

Capacitors

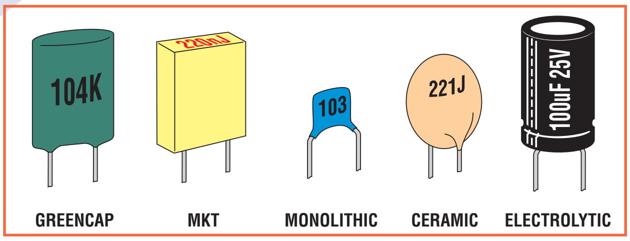
Virtually all of the capacitors stocked by Jaycar have their electrical values printed directly on their body, in digits and letters. However there's often still a coding system, which can make it a bit tricky to work out the capacitance, voltage rating, tolerance and so on until you know how it works. This is explained below.

Incidentally, so-called 'greencaps' (which can actually be brown, dark red or even blue!) are one type of metallised polyester film capacitor, like the 'MKT' type — which tends to be smaller, and in a more tightly controlled rectangular package. Similarly the 'monolithic' type is a type of multilayer ceramic capacitor, designed to combine high capacitance with very low self-inductance.

Plastic film, Ceramic & Monolithic Capacitors

Most of these types have their nominal value either printed directly on them or use the 'EIA' coding system, which is a bit like resistor colour coding, but in digits: the first two digits followed by a 'multiplier' showing the number of zeroes. With this code the value is generally given in picofarads (pF), which you'll need to divide by either one million or one thousand (respectively) if you want the value in microfarads (μF) or nanofarads (nF).

Hence a capacitor marked '104' has a value of 10 with 4 zeroes after it, or 100,000pF (which is the same as 100nF, or 0.1μF). Similarly '681' means 68 with a single zero, or 680pF, while '472' means 47 with two zeroes, or 4700pF (which is the same as 4.7nF).



Alternatively the value may be given directly in nanofarads, with three significant digits but the third generally '0'. In this case there's generally also a small 'n', which can be used in place of a decimal point. So '220n' means a 220nF capacitor, which is the same as 0.22µF, while '3n3' means 3.3nF (= 3300pF).

Many of these capacitors also have a capital letter to indicate their tolerance rating, according to the following coding system:

Capacitor Tolerance Marking Codes

F	G	J	K	M	Z
±1%	±2%	±5%	±10%	±20%	-20%, +80%

Examples: 104K = 0.1µF ± 10%; 4n7J = 4.7nF ±5%

Material Codes for Plastic Film Capacitors

Capacitors which use a plastic film dielectric are identified using the following codes:

MKT	Metallised Polyester (PETP)
KS	Polystyrene film/foil
MKC	Metallised Polycarbonate
KP	Polypropylene film/foil
KT	Polyester film/foil
MKP	Metallised polypropylene

Ceramic Capacitor Colour coding for Temperature Coefficient

Capacitors which use a plastic dielectric have a very low *temperature coefficient* (tempco) — i.e., their capacitance scarcely varies with temperature, and can generally be regarded as 'stable'. However this isn't true with many ceramic-dielectric types. Many of the ceramic materials produce a negative tempco, where capacitance *decreases* with temperature, while a few give a positive tempco where capacitance increases with temperature.

By careful mixing of materials, manufacturers can produce a ceramic which gives a tempco very close to zero, but the resulting dielectric constant is also quite low. That is why such 'NP0' capacitors are normally only available in relatively low values — less than about 200pF, typically.

The following colour bands are used on ceramic capacitors to indicate their tempco. Note that 'P' indicates a positive tempco and 'N' a negative one, with the number indicating parts per million per degree C.

P100	Red/Violet	**NP0**	Black
N033	Brown	**N075**	Red
N150	Orange	**N220**	Yellow
N330	Green	**N470**	Blue
N750	Violet	**N1500**	Orange/Orange

Electrolytic Capacitors

Electrolytic capacitors take advantage of the ability of some metal oxides to act as an excellent insulator (at low voltages) and also form a dielectric material with a very high dielectric constant 'K'. Most common electrolytic capacitors use aluminium oxide as the dielectric, but special-purpose and low leakage types generally use tantalum oxide.

The main shortcoming of electrolytic capacitors is that the insulating and dielectric properties of the metallic oxides are polarity sensitive — so most electrolytic capacitors must be connected into circuit so that voltage is always applied to them with the correct polarity (which is marked on their body). The only exception is 'non polarised' or *bipolar* (BP) electrolytics, which are effectively two electrolytics in series back-to-back.

Because the oxide dielectric layer in electrolytic capacitors is extremely thin, these capacitors are more prone to breakdown at higher voltages. So all electrolytics are clearly marked in terms of their safe maximum operating voltage.

In most cases electrolytics also have their capacitance value shown directly on the case as well.

The three most common types of aluminium electrolytic in current use are the axial-lead or RT type, the radial-lead or RB type (for vertical mounting on PC boards) and the chassis-mounting or RG type. There's also a variation on the RB type called the RP, with a third lead for orientation and added support.

The most common type of tantalum electrolytic in current use is the solid or TAG tantalum type, where the tantalum oxide dielectric is formed on the surface of a solid block of sintered tantalum granules. These capacitors provide low leakage and very high capacitance in a very small volume, but are limited to quite low voltages — typically less than 33V.