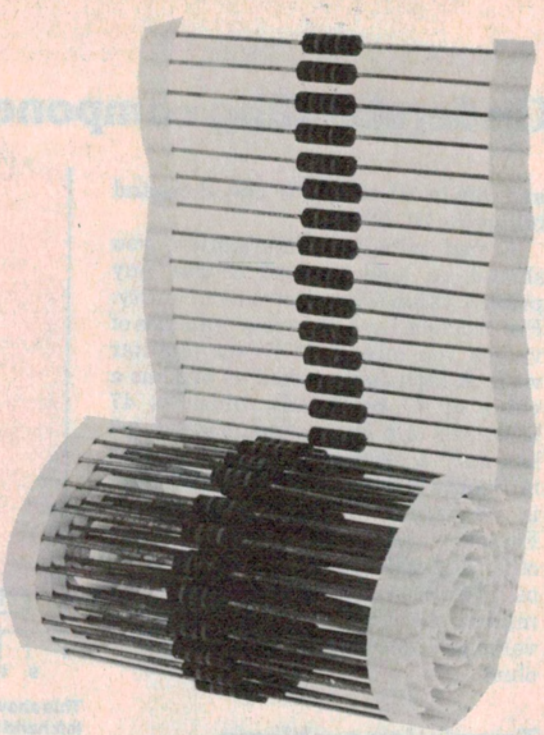
0·001µ 100n 0R1 120,150,180
4R7 6p8 1k02
33, 47, 56, 68, 82, 100

Understanding component values



To the beginner in electronics, and to quite a few not-so-beginners, the values and units given to electronic components such as resistors, capacitors and RF chokes seem confusing. This article should clarify things for you.

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THE DECIMAL point has been almost abolished in electronics. The little dot was so small it often disappeared when things were printed, and in any case not everybody recognises its meaning. The French, who invented the decimal system, use a comma instead, and so do most Europeans. Other countries use commas for different purposes, like separating hundreds from thousands in large numbers. So when you see a number written 1,500 you don't immediately know whether it's meant to be fifteen hundred or one-and-a-half to three decimal places! When engineers from all over the world sat down to decide on a standard international numbering system, they decided that the best thing to do with the decimal point/comma was to get rid of it altogether.

It has been replaced by a letter. To show where the decimal point was, any letter would do. For example, you might write one-and-a-half as 1a5 or 1b5 or 1c5, or you could use a capital letter, say 1P5 or 1Q5.

Normally in electronics you're not dealing with pure numbers. You're dealing with numbers of *somethings* — so many volts, so many watts, amps, ohms and so forth. Most of these quantities have letters that are used as abbreviations for them. 5 V means 5 volts, for example, 5 A means 5 amps, 5 W means 5 watts. When you want to express fractional amounts of these quantities, you use the abbreviation letter in place of the decimal point, like this: 5V6, 1A5, 3W7. You don't have much trouble seeing that these last three mean 5-point-6 volts, 1-point-5 amps and 3-point-7 watts. Unfortunately, there isn't a letter of our alphabet that stands for ohms, but we're all quite used to seeing a capital R for resistance, so we use that to indicate ohms, like this: 4R7, 2R2, 100R. These mean of course 4-point-7 ohms, 2-point-2 ohms and 100 ohms.

Mini and maxi units

Lots of things aren't commonly or conveniently measured in the standard size units. Capacitors, for example, are never measured in Farads, because a whole Farad is an enormous capacitance. Practical capacitors have values measured in thousandths, millionths and even smaller fractions of a Farad. At the other extreme, resistors often have values of thousands and millions of ohms. Now it's obviously inconvenient and confusing to write 0F000001 for one microfarad or 100 000R for one hundred kilohms, so what you do is alter the decimal-point-indicating letter to show the size of the units you are using. For example, 1k5. Clearly this means one-and-a-half somethings and from kilograms and kilometres everyone knows that the little letter 'k' indicates a thousand. So 1k5 must mean one-and-a-half thousand, that is 1500. Similarly, 4k7 means 4700, 2k2 means 2200 and so forth. It's usually clear enough from the context whether you're talking about resistance or capacitance or frequency or whatever, so you don't need to write ohms or anything afterwards.

As well as k for one thousand, there are a number of other letters that stand for multiples of the basic unit. Here they are:

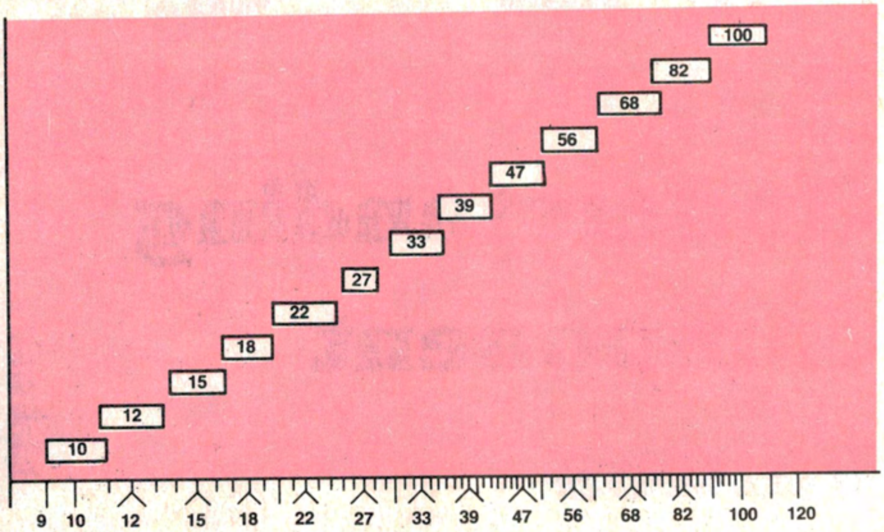
G (Giga) = 1 000 000 000 (one thousand million, 10^{9})
M (Mega) = 1 000 000 (one million, 10^{6})
k (kilo) = 1 000 (one thousand, 10^{3})
m (milli) = 1/1000 (one thousandth, 10^{-3})
u (micro) = 1/1 000 000 (one millionth, 10^{-6})
n (nano) = 1/1 000 000 000 (one thousand millionth, 10^{-9})
p (pico) = 1/1 000 000 000 000 (one billionth, 10^{-12})

Occasionally you'll come across *tera* (T) which is one million million (10^{12}) ▶

Understanding component values

and *femto* (f) which is one thousand billionth (10^{-15}).

Armed with this information, you should be able to read almost any printed value of an electronic quantity. For practice, here are a few examples of values you might not be too familiar with. A capacitor marked as 47p has a value of 47 picofarads, which is 47 billionths of a Farad. One marked 4p7 has only a tenth the value, 4-point-7 billionths of a Farad. A 100n capacitor is 100 nanofarads or 100÷1 000 000 000 Farads = 1/10 000 000 Farad. At the other end of the scale, a resistor marked as 15M has a value of 15 Megohms, i.e: 15 million ohms; one marked 1M5 has a value ten times less at 1-point-5 million ohms.



This shows the tolerance extremes of all the values in the E12 series, represented by a horizontal bar. The left hand end and right hand ends of each bar represent, respectively, the lower limit and the upper limit of the value. Most overlap, you will note.

Translation problems

The standard international numbering system makes everything simple as long as everybody sticks to it, but unfortunately there are still some occasions when you come across values written in an older style and you have to translate them into the new style. This mainly happens with capacitors.

The first problem is that the old symbol for 'micro' was different. It was a Greek letter called mu, which is pronounced like the noise a pussycat makes, and looks like this: μ. This symbol caused some confusion in the past, because it sometimes got mistaken for m, which has always meant 'milli', a thousand times larger. So μ was officially replaced by 'u'. If you see a capacitor marked, for example, 10μ, you can translate that directly into 10u and know that it means 10 microfarads. Nevertheless, μ is still widely used.

Another confusing thing is the still common practice of marking or specifying capacitor values in *fractions* of a microfarad, like 0.001μ (1000p, or better, 1n). To convert fractions of a microfarad into modern values, you have to multiply by 1000 to get the answer in nanofarads, or multiply by 1 000 000 and get the answer in picofarads. Don't panic! To save you trouble, here is a list of typical old-style values and how they translate into new style. From this list you should be able to work out very quickly the new-style version of any old-style capacitor value.

0.1μ = 100n	0.47μ = 470n
0.01μ = 10n (10 000p!)	0.047μ = 47n
0.001μ = 1n (1000p!)	0.0047μ = 4n7
0.0001μ = 100p	0.00047μ = 470p

Small resistances

Resistors with small values sometimes cause difficulties. Because small resistances are not very commonly used, most people are not accustomed to thinking in terms of milliohms (thousandths of an ohm), so the little letter 'm' isn't used for resistors. A resistance of one-tenth of an ohm is not written 100m (for one hundred milliohms), but 0R1 (for one-tenth of an ohm). As usual, the letter R indicates the position of the decimal point and shows that the unit of measurement is whole ohms. In the same way, 2R2 means 2-point-2 ohms, 5R6 means 5-point-6 ohms and so forth. Even smaller values are still written as fractions of an ohm, but the 0 before the decimal-point-indicating letter is usually omitted. For instance, R01 means point-01 ohms (one hundredth of an ohm), R001 means point-001 ohms (one thousandth of an ohm), R33 means 33/100ths of an ohm and R068 means 68/1000ths of an ohm.

Zeroes

Some component values are written with a zero before or after the multiplier character to indicate the value quite unambiguously. For example, a 1000 pF capacitor, rather than being written '1n' may be written 1n0. Or a point-1 (0.1) ohm resistor, rather than being written R1, may be written 0R1.

Preferred values

Why is it that resistors and capacitors only seem to come in certain values? You almost never see a 25R resistor, only 22R or 27R ones. 600k resistors are likewise as rare as hens' teeth, but there are any number of 560k and 680k ones. For one thing, manufacturers can't make every possible value of resistor. If they made resistors in every whole number of ohms between 1R and 10M, they'd be making ten million different products and selling only a few of each. Very capital inefficient, as they say. Resistors would be ridiculously expensive and manufacturers would go bankrupt. Obviously, only a restricted number of values can be produced.

But why these peculiar values that actually are produced? What's so special about 4k7 or 56R or 820R? Why not stick to simple numbers? The reason is that these particular values allow the *least* number of different values to be made. How come? Well, resistors are not made with absolute accuracy — that costs too much and isn't usually necessary. Most circuits will accept a variation of 10% in resistor values without problems. So resistors are made with values that are anything up to 10% higher or lower than their marked value. This is called a tolerance of 10% and such a resistor is usually called a 10% resistor. For example, a 100R, 10% resistor might have a value anywhere between 90R and 110R. Given this amount of variation, there would obviously be no point in also making 10% resistors with nominal values like 94R or 107R, because these values are already covered by the ±10% spread of the 100R resistor.

So in a series of 10% resistors, what should be the next highest value above 100R? A value of, say, 111R would be too low, because the 111R resistor would also have a tolerance of 10%, so its possible values would spread down to below

100R, completely overlapping the upper range of variation of the 100R resistor. To avoid this kind of overlap, the next highest value 10% resistor needs to be about 120R. A 120R 10% resistor has its possible values spread between 108R and 132R. There's still a small overlap, but to get rid of the overlap completely without leaving a gap you'd need a value of one hundred and twenty two and two ninths ohms (work it out for yourself if you like algebra), which is rather an awkward number. 120R is a nice round number, so that's the 'preferred value' next in the series. By similar reasoning, the next value in the series of 10% resistors is 150R, then 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R and then 1k. It doesn't take much to see that the obvious next preferred value after 1k must be 1k2, then 1k5, 1k8 and so on. In other words, the same sequence of values keeps repeating, multiplied by ten at each repetition. This series of preferred values is known as the *E12 series*, because there are 12 values in the series. For reference, here are two 'decades' of the E12 series:

10	**100**
12	**120**
15	**150**
22	**220**
27	**270**
33	**330**
39	**390**
47	**470**
56	**560**
68	**680**
82	**820**

Even though resistors are nowadays more commonly made with a tolerance of 5%, the old E12 series of preferred values is still the most widely used. There is a similar series, called E24, which is worked out in just the same way as the E12 series, except that a tolerance of only 5% is assumed.

For closer tolerances, there's the E48 series (2%) and E96 series (1%) with, respectively, 48 and 96 values per decade.

Capacitors are made to wider tolerances than resistors — 20% is not at all uncommon, so they are usually supplied in a restricted range of preferred values. The significant figures in this series are 10, 15, 22, 33, 47 and 68. As there are only six values per decade, it is called the E6 series.

Close tolerance values are written in the same way as we've described previously, so if you come across a 1k02 resistor or a 34p8 capacitor you'll know you're dealing with close tolerance components. In the first case, you have a 1020 ohm resistor, in the second case you have a 34.8 pF capacitor. ●

Preferred numbers in a decade for the E6, E12, E24 & E96 series

E6 20%	E12 10%	E24 5%	E96 1% and 2%						
10	10	10	10.0	10.2	10.5	10.7			
		11	11.0	11.3	11.5	11.8			
	12	12	12.1	12.4	12.7				
		13	13.0	13.3	13.7	14.0	14.3	14.7	
15	15	15	15.0	15.4	15.8				
		16	16.2	16.5	16.9	17.4	17.8		
	18	18	18.2	18.7	19.1	19.6			
		20	20.0	20.5	21.0	21.5			
22	22	22	22.1	22.6	23.2	23.7			
		24	24.3	24.9	25.5	26.1	26.7		
	27	27	27.4	28.0	28.7	29.4			
		30	30.1	30.9	31.6	32.4			
33	33	33	33.2	34.0	34.8	35.7			
		36	36.5	37.4	38.3				
	39	39	39.2	40.2	41.2	42.2			
		43	43.2	44.2	45.3	46.4			
47	47	47	47.5	48.7	49.9				
		51	51.1	52.3	53.6	54.9			
	56	56	56.2	57.6	59.0	60.4			
		62	61.9	63.4	64.9	66.5			
68	68	68	68.1	69.8	71.5	73.2			
		75	75.0	76.8	78.7	80.6			
	82	82	82.5	84.5	86.6	88.7			
		91	90.9	93.1	95.3	97.6			

Tolerance extremities for the E6, E12 and E24 preferred value series

−20%	−10%	−5%	nominal value	+5%	+10%	+20%
8	9	9.5	10	10.5	11	12
		10.5	11	11.6		
	10.8	11.4	12	12.6	13.2	
		12.4	13	13.7		
12	13.5	14.3	15	15.8	16.5	18
		15.2	16	16.8		
	16.2	17.1	18	18.9	19.8	
		19.0	20	21.0		
17.6	19.8	20.9	22	23.1	24.2	26.4
		22.8	24	25.2		
	24.3	25.7	27	28.4	29.7	
		28.5	30	31.5		
26.4	29.7	31.4	33	34.7	36.3	39.6
		34.2	36	37.8		
	35.1	37.1	39	41.0	42.9	
		40.9	43	45.2		
37.6	42.3	44.7	47	49.4	51.7	56.4
		48.5	51	53.6		
	50.4	53.2	56	58.8	61.6	
		58.9	62	65.1		
54.4	61.2	64.6	68	71.4	74.8	81.6
		71.3	75	78.8		
	73.8	77.9	82	86.1	90.2	
		86.5	91	95.6		
E6	E12	E24		E24	E12	E6
← lower extremities					upper extremities →	