Resistor Color Code, Tutorial

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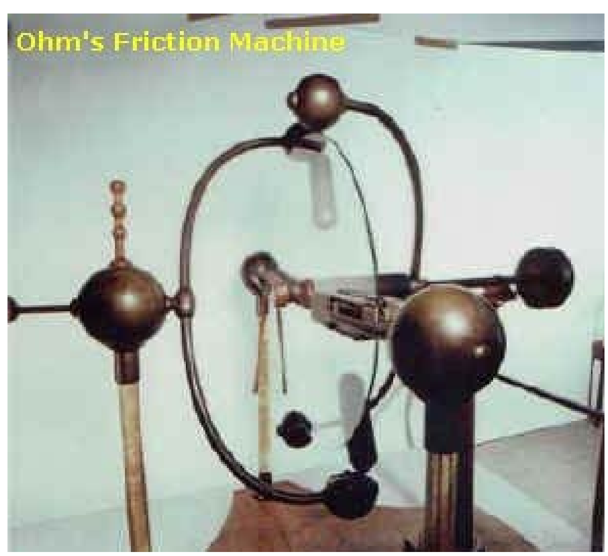
First the history and development of the resistor as we now now it. Georg Simon Ohm was born on March 16, 1789 in the city of Erlangen in Bavaria, which is now Germany. He died on July 6, 1854 in Munich, Bavaria, Germany. Ohm came from a protestant family. His father, Johann Wolfgang Ohm, was a locksmith while his mother, Maria Elizabeth Beck, was the daughter of a tailor. Although his parents had not been formally educated, Ohm's father was a rather remarkable man who had educated himself to a high level and was able to give his sons and excellent education through his own teachings. Had Ohm's brothers and sisters all survived he would have been one of a large family but, as was common in those times, several of the children died in their childhood. Of the seven children born to Johann and Maria Ohm only three survived, Georg, his brother Marin who went on to become a well-known mathematician, and his sister Elizabeth Barbara.

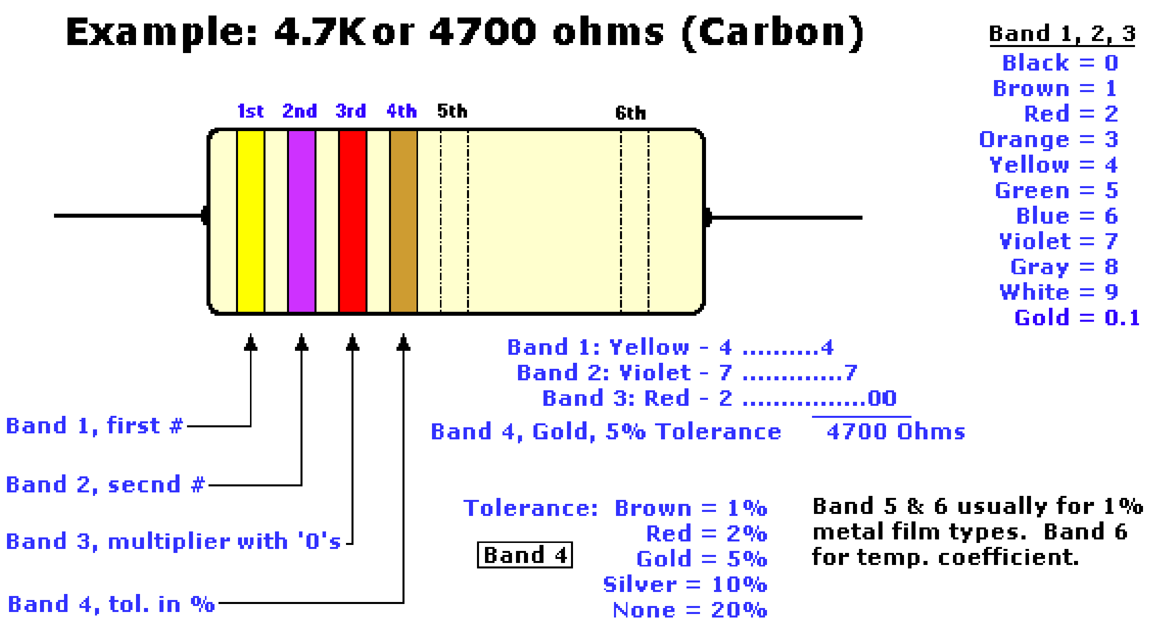
While children, Georg and Martin were taught by their father who brought them to a high standard in mathematics, physics, chemistry and philosophy. This was in stark contrast to their school education. Georg Simon entered Erlangen Gymnasium at the age of eleven but there he received little by the way of scientific training. In fact, his formal part of his schooling was uninspired stressing learning by rote and interpreting texts. This contrasted strongly with the inspired instruction that both Georg Simon and Martin received from their farther who brought them to a level in mathematics which led the professor at the University of Erlangen, Karl Christian von Langsdorf, to compare them to the Bernoulli Family. It is worth stressing again the remarkable achievement of Johann Wolfgang Ohm, an entirely self-taught man, to have been able to give his sons such a fine mathematical and scientific education.



In 1805 Ohm entered the University of Erlangen but he became rather carried away with student life. Rather than concentrate on his studies, he spent much time dancing, ice skating and playing billiards. Ohm's father, angry that his son was wasting the educational opportunity that he himself had never been fortunate enough to experience, demanded that Ohm leave the university after three semesters. Ohm was sent to Switzerland where, in September 1806, took up a post as a mathematics teacher in a school in Gottstadt bei Nydau.

Ohm continued working for several other Universities throughout Bavaria and published several papers. In two important papers in 1826, Ohm gave a mathematical description of conduction in circuits modeled of Fourier's study of heat conduction. These papers continue Ohm's deduction of results from experimental evidence and, particularly in the second paper, he was able to propose laws which went a long way to explaining results of others working on galvanic electricity. This second paper certainly was a first step in a comprehensive theory which Ohm was able to give in his famous book published in the following year called "Die Galvanische Kette, mathematisch bearbeitet" (1827) which means "The Galvanic Chain, Mathematically worked" and contained what is now know as the 'Ohm Laws' and they are for voltage: **E=IxR**, current: **I=E/R**, resistance: **R=E/I**, power: **$P=E^2/R$**, also **$P=I^2*R$** or **P=E*I**
At the time Ohm started to write his papers (8) he was on a one year sabbatical doing his research at the Jesuit Gymnasium of Cologne.

In 1849 Ohm took up a post in Munich as curator of the Bavarian Academy's physical cabinet and began to lecture at the University of Munich. Only in 1852, two years before his death, did ohm achieve his lifelong ambition of being appointed to the chair of physics at the University of Munich.



Another example for a Carbon 22000 Ohms or 22 Kilo-Ohms also known as 22K at 5% tolerance:

Band 1 = Red, 1st digit
Band 2 = Red, 2nd digit
Band 3 = Orange, 3rd digit, multiply with zeros, in this case 3 zero's
Band 4 = Gold, Tolerance, 5%

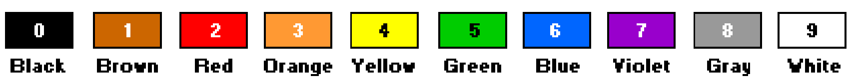
Example for a Precision Metal Film 19200 Ohms or 19.2 KiloOhms also known as 19K2 at 1% tolerance:

Band 1 = Brown, 1st digit
Band 2 = White, 2nd digit
Band 3 = Red, 3rd digit
Band 4 = Red, 4th digit, multiply with zeros, in this case 2 zero's
Band 5 = Brown, Tolerance, 1%
Band 6 = Blue, Temperature Coefficient, 6

If you are a bit serious about the electronics hobby I recommend learning the "Color-Code". It makes life a lot easier. The same color code is used for everything else, like coils, capacitors, rf-chokes, etc. Again, just the color code associated with a number, like: black=0 brown=1 red=2, etc, etc.

If you are interested in learning the code by memory, try the steps below to help you 'Learn the Color-code'.
Make sure you add the number to the color, like: 0 is black, 1 is brown, 2 is red, etc. etc.
Do not proceed to step **3** until you know the color-code backwards, forwards, and inside-and-out (trust me!)

Can you *'create'*
your own resistors? Sure thing, and not difficult. Here is how to do it: Draw a line on a piece of paper with a soft pencil, HB or 2HB will do fine. Make the line thick and about 2 inches (5cm) long. With your multimeter, measure the ohm's value of this line by putting a probe on each side of the line, make sure the probes are touching the carbon from the pencil. The value would probably be around the 800K to 1.5M depending on your thickness of the line and what type of pencil lead is used. If you double the line the resistance will drop considerably, if you erase some of it (length-wise obviously!) the resistance will increase. You can also use carbon with silicon glue and when it dries measure the resistance, or gypsum with carbon mixed, etc. The reason for mentioning these homebrew resistors is that this method was used in World War II to fix equipment when no spare parts were available. My father, who was with the Dutch resistance during WWII, at that time made repairs like this on many occasion.

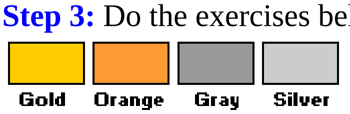


Step 1: Learn the colors

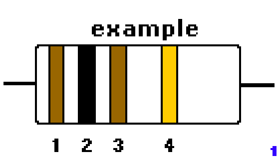
The color 'Gold' is not featured in the above table. If the 3rd band is gold it means multiplying by 0.1. Example, 1.2 ohm @ 5% would be brown-red-gold-gold. 12 multiplied by 0.1 gives 1.2 Don't get confused by gold as a resistance or a tolerance value. Just watch the location/posistion of the band.

Step 2: Learn the tolerances.

Step 3: Do the exercises below. (Cheating gets you nowhere :-))



Colors I used for 'Gold, Orange, Gray, and Silver'




```
1st band, denominator: Brown (1)
2nd band, denominator: Black (0)
3rd band, how many zeros (1)
4th band, tolerance in %: gold (5)
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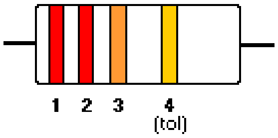
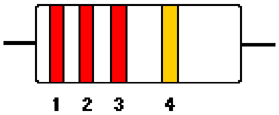
(tol)

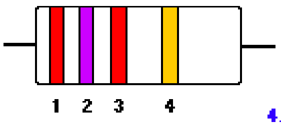
Answer: 1 0 1 = 100 ohm, 5% tolerance



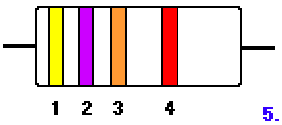
2\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



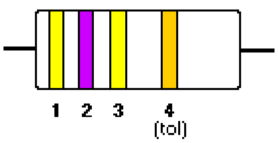
3\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



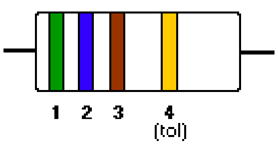
4\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



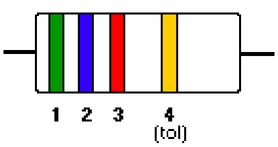
5\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



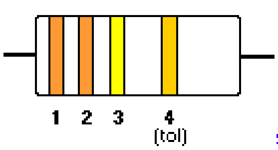
6\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



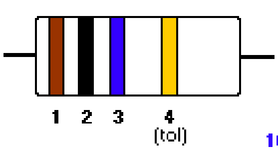
7\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



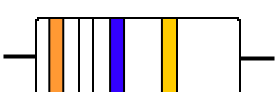
8\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



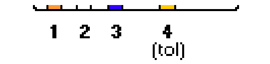
9\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



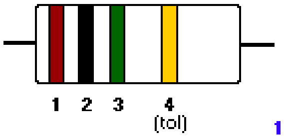
10\.
1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ______________________



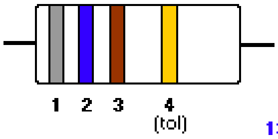
1st band: ______
2nd band: ______



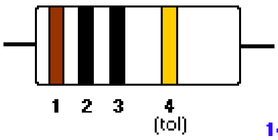
11. 3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



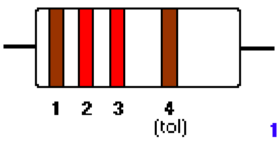
12. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



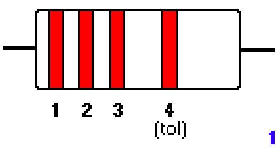
13. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



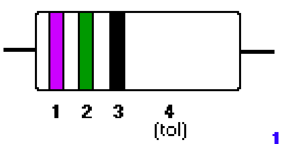
14. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



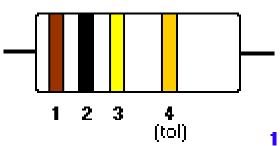
15. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



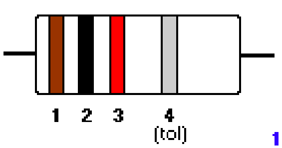
16. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



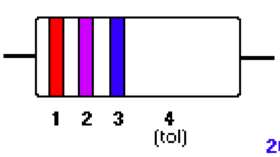
17. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



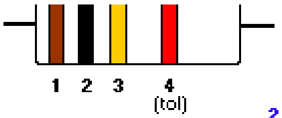
18. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



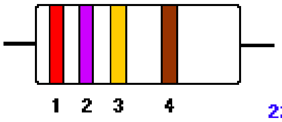
19. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



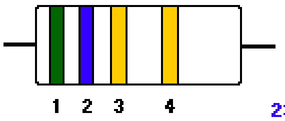
20. 1st band: ______
2nd band: ______
3rd band: ______
4th band, tolerance in %: ______
Answer: ____________________



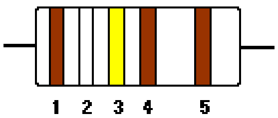
21. 1st band: brown (1)
2nd band: black (0)
3rd band: gold (0.1)
4th band, tol. in %: red (1-0-0.1 = 1 ohm, 2%)



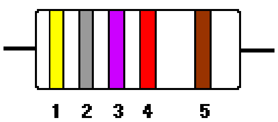
22. 1st band:
2nd band:
3rd band:
4th band, tolerance in %:
Answer: ____________________



23. 1st band:
2nd band:
3rd band:
4th band, tolerance in %:
Answer: ____________________



24. 1st band: brown (1)
2nd band: white (9)
3rd band: yellow (4)
4th band: brown (0)
5th band, tol.in %: brown (1940 ohm = 1.94K, Precision type.)



25. 1st band:
2nd band:
3rd band:
4th band:
5th band, tolerance in %:
Answer: ____________________

To get familiarized with abreviations in values, I used below 4700 or 4K7, 1000 or 1K, which is all the same. Every thousand (1000) is called a 'K' which stands for 'Kilo'. The 'M' stands for 'Mega' (million). 1 Mega is 1000K or 1000 000 ohms. So 4K7 means 4 thousand and 7 hundred or 4700 ohms. 6K8 means 6 thousand and 8 hundred or 6800 ohm. One more example, 1M2 means 1million and 200.000 or 1.200000 ohms. Here are a couple more: 1K92=1.92K=1920 ohms, 100E=100 ohms, 19K3=19.3K=19300 ohms, 1M8=1.8M, etc., etc. These abreviations you find everywhere in the industry, schematics, diagrams and whatever. It is normal and takes a bit of time to get used to.

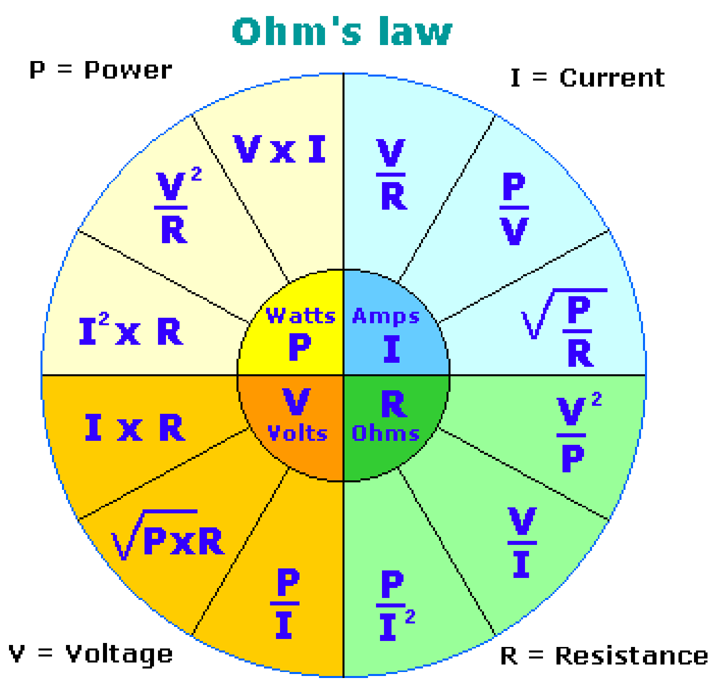
4700 ohm, 5% = yellow violet red, gold	**100 ohm, 2% = brown black brown, red**
1000 ohm, 5% = brown black red, gold	**22 ohm, 1% = red red black, brown**
150 ohm, 5% = ________________________	270 ohm, 5% = ________________________
3300 ohm, 5% = ________________________	10 ohm, 1% = ________________________
470 ohm, 2% = ________________________	6800 ohm, 10% = ________________________
3K3, 5% = ________________________	1K, 5% = ________________________
150 ohm, 1% = ________________________	2M9, 10% = ________________________
10M, 10% = ________________________	1 Mega Ohm, 5% = ________________________
1 ohm, 1% = ________________________	3M9, 20% = ________________________
1200 ohm, 5% = ________________________	1K2, 5% = ________________________
220 ohm, 1% = ________________________	3300 ohm, 2% = ________________________

47 ohm, 5% =	______________________	390 ohm, 5% =	______________________
3900 ohm, 2% =	______________________	100.000 ohm, 5% =	______________________
10K, 5% =	______________________	10.000 ohm, 5% =	______________________
1500 ohm, 2% =	______________________	56K, 5% =	______________________
1M, 10% =	______________________	470K, 1% =	______________________
1.8 ohm, 2% =	______________________	2.2 ohm, 1% =	______________________
2K76, 1% =	______________________	94.1K, 2% =	______________________

This should get you started. If it looks difficult to you, don't worry. It is easy. Whenever you have a spare moment practise the color code in your head. It's like learning to ride a bicycle, once you know how to do it you never forget. I, and many others who learned electronics in the 60's and up to the 80's, were taught a little sentence to remember the sequence of the resistor colors like Black, Brown, Red, Orange, Yellow, Green, Blue, Violet, Gray, and White, which refers to: "**B**ad **B**eer **R**ips **O**ur **Y**oung **G**uts **B**ut **V**odka **G**ives **W**ell". As you will agree this saying no longer applies to the society we live in today for obvious offending reasons. And I'm hessitant to even mention it but fact is, it was part of our 'learning' for decades and so I decided to mention it for reference purposes only.
Good luck my friends!

Just in case, here are the >>> Answers <<< to all the questions above.

Resistor Formulas



$R = \frac{V}{I}$ **Ohm's Law. R is Resistance, V is Volt, I is Current.**

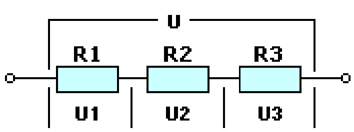
$R = \rho \frac{1}{A}$ $\quad (\rho = \frac{1}{4} \pi d^2)$ $\quad \rho$ is called 'Rho'

What exactly is rho you ask? Ohm's Law is not a fundamental law like Newton's Laws or the laws of thermodynamics, but an empirical description of a property shared by many electrical materials. This property of electrical materials is called conductivity. The inverse of that is called **resistivity**, which where **'Rho'** comes in. Just in case you are a bit rusty with your basic math, inverse means that the mathematical relation between the two items, say A and B is: A = 1/B

This is also called the reciprocal. B is the reciprocal of A, so that A*B = 1.

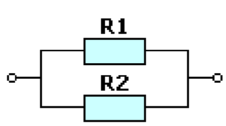
The relationship between conductivity and resistivity is: conductivity = 1/resistivity

Resistivity, represented by the greek letter *Rho*, (see above), is related to resistance, one of the items in the equation of Ohm's law. Resistance is not just found in resistors, but also in conductors. Wires are conductors. We try to make wires with as little resistance as possible, that is, with as much conductivity as possible. This can be done by decreasing the length of the wire and by increasing the diameter of the wire, and by choosing a material with as much conductivity as possible. These variables, L (length of conductor), A(cross sectional area of conductor) and (symbol for the conductivity of the material) together spell the resistance of the conductor. That is: R = L/(A)
In plain English words, resistance, R, is the ratio of the length (L) of the conductor wire divided by the constant conductivity (the greek sigma) and by the cross sectional area (A). This formula is used to calculate how much resistance will be present in a wire conductor. You will find that it is important to reduce the resistance in the conductors in circuits. This is because resistance generates heat, and, for many circuits, heat is not desireable. So this formula shows us that one way to do this is to keep the length of conductors to a minimum. That also saves money. Reducing the length of conductors in a circuit will reduce the heat radiated which will keep nearby electronics components from overheating [thus helping them to last longer] and reduce power requirements [== save a little money over time]. Wow! All that information is derived from that one little formula. Formulas are powerful tools.
(Tony's note: The Rho explanation was taken from "BASIC ELECTRONICS ENGINEERING TECHNOLOGY 4.1" and is used with permission from Jairo Moreno).



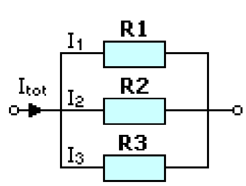
$$R_s = R_1 + R_2 + R_3$$

Resistors in series; just count them up!



$$R_p = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

Two resistors in parallel



$$I_{tot} = I_1 + I_2 + I_3$$

$$I_{tot} = I_1 + I_2 + I_3 = \frac{1}{R_p} : \frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3}$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Multiple resistors in parallel

I forgot to mention a very important thing, there are two resistor *body* colors which you should know what they are if you are thinking of repairing electronic circuits. These body colors are white, and blue (and sometimes composite green depending on where you live) and are used to indicate non-flammable and/or fusible resistor types. It is important to know **NOT** to replace these with ordinairy type resistors. The non-flamable types are there for a reason (they don't burn when overheated) and just replacing it with a normal type resistor may create a fire-hazard or worse. The fusible types are usually white with one black band in the middle of the body. So if you ever are looking for the 'fuses' check these out. They are less than 0.1 ohm, carbon.

In the case of surface mount resistors; since they are so tiny they feature the same coding as on capacitors. For example, if it says 103 this means 10 Kilo-ohm (10 + 3 zeros), 104 means 10 + 4 zeros (100K), 222 means 22 + 2 zeros (2K2). Easy huh?

E24 Standard Series Values (5%)

1.0	10	100	1.0K (1K0)	10K	100K	1.0M(1M0)	10M
1.1	11	110	1.1K (1K1)	11K	110K	1.1M(1M1)	11M
1.2	12	120	1.2K (1K2)	12K	120K	1.2M(1M2)	12M
1.3	13	130	1.3K (1K3)	13K	130K	1.3M(1M3)	13M
1.5	15	150	1.5K (1K5)	15K	150K	1.5M(1M5)	15M
1.6	16	160	1.6K (1K6)	16K	160K	1.6M(1M6)	16M
1.8	18	180	1.8K (1K8)	18K	180K	1.8M(1M8)	18M
2.0	20	200	2.0K (2K0)	20K	200K	2.0M(2M0)	20M
2.2	22	220	2.2K (2K2)	22K	220K	2.2M(2M2)	22M
2.4	24	240	2.4K (2K4)	24K	240K	2.4M(2M4)	
2.7	27	270	2.7K (2K7)	27K	270K	2.7M(2M7)	
3.0	30	300	3.0K (3K0)	30K	300K	3.0M(3M0)	
3.3	33	330	3.3K (3K3)	33K	330K	3.3M(3M3)	
3.6	36	360	3.6K (3K6)	36K	360K	3.6M(3M6)	
3.9	39	390	3.9K (3K9)	39K	390K	3.9M(3M9)	
4.3	43	430	4.3K (4K3)	43K	430K	4.3M(4M0)	
4.7	47	470	4.7K (4K7)	47K	470K	4.7M(4M7)	
5.1	51	510	5.1K (5K1)	51K	510K	5.1M(5M1)	
5.6	56	560	5.6K (5K6)	56K	560K	5.6M(5M6)	
6.2	62	620	6.2K (6K2)	62K	620K	6.2M(6M2)	
6.8	68	680	6.8K (6K8)	68K	680K	6.8M(6M8)	
7.5	75	750	7.5K (7K5)	75K	750K	7.5M(7M5)	
8.2	82	820	8.2K (8K2)	82K	820K	8.2M(8M2)	
9.1	91	910	9.1K (9K1)	91K	910K	9.1M(9M1)	

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