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.

	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	$10^5 = 100,000$	$\pm 0.5\%$			
	Blue	6	$10^6 = 1,000,000$	±0.25%			
	Violet	7	$10^7 = 10,000,000$	±0.1%			
	Gray	8	$10^8 = 100,000,000$	$\pm 0.05\%$			
	White	9	$10^9 = 1,000,000,000$	-			
	Gold	-	$10^{-1} = 0.1$	±5%			
	Silver	-	$10^{-2} = 0.01$	$\pm 10\%$			
\geq	No Color	_	-	$\pm 20\%$			

Table D.1. Standard Resistor Color Code.

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-yellowgold*, as shown at left, would have nominal value $22 \times 10^4 = 220,000 \Omega$, or $220k\Omega$, but its actual value could be anything within $\pm 5\%$ (gold band) of this number ($209,000\Omega \le R \le 231,000\Omega$).

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

Five color bands

The five-band marking system is typically used for narrower tolerance ranges, such as $\pm 2\%$ or



system is typically used for harrower tolerance ranges, such as $\pm 2\%$ of 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 $122 \times 10^2 = 12,200 \Omega$, or $12.2k\Omega$, but its actual value could be anything within $\pm 1\%$ (brown band) of this number $(12,078\Omega \le R \le 12,322\Omega)$.

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.

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

Table D.2. EIA "E" Series	Table D.2.	EIA	"Е"	Series
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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 100 Ω . It would make little sense to produce a 105 Ω resistor, since 105 Ω falls within the ±10% tolerance range of the 100 Ω resistor. The next *reasonable* value is approximately 120 Ω , because the 100 Ω resistor with a 10% tolerance is expected to have a value somewhere between 90 Ω and 110 Ω , while a 120 Ω resistor would have a value ranging between 108 Ω and 132 Ω . 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, $100 \times 10^{1/12} \approx 121$, $100 \times 10^{2/12} \approx 147$, ..., $100 \times 10^{11/12} \approx 825$ 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 100 Ω and 1000 Ω . 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 $22M\Omega$.

E6	E12	E24	E48	E96	E192	E6	E12	E24	E48	E96	E192		E6	E12	E24	E48	E96	E192							
±20%	±10%	±5%	±2%	±1%	±0.5%	±20%	±10%	±5%	±2%	±1%	±0.5%		±20%	±10%	±5%	±2%	±1%	±0.5%							
	10/6							100						147							215				
				100	101					147	149						215	218							
			100	100		101				147		150					215		210						
												102	102					150	150						221
	100		.00		104			150			152				220			225							
		10							105	105					154	154						226	220		
			105	105	105	105		106				154		156					226		229				
					107	107					158	158						232	232						
	100							109		150				160			220				234				
										110	110					162	162						237	237	
		110			-	111				162	-	164					237	-	240						
				113	113				102	165	165					207	243	243							
			110	115	114			160		105	167				240		243	246							
				115	115			100		160	169				240		249	249							
				115	115	117				160	105	172					240	245	252						
			115	110	118				109	174	174					249	255	255							
100				110	120	150				1/4	176		220				255	258							
100				4.94	121	150				470	178		220				264	261							
				121	123					1/8	180						261	264							
			121		124				1/8		182					261		267							
				124	126					182	184						267	271							
		120			127			180			187				270			274							
				127	120					187	180						274	274							
			127		120				187		101					274		280							
				130	130					191	191						280	280							
	120				132		180				195			270				204							
							133	133					196	196						287	287				
			133		135				196		198					287		291							
					1	137	137					200	200						294	294					
		130	0		-		_	138			200			203				300		-	298				
				100				140	140					205	205						301	301			
			140		142				205		208					301		305							
			1.0	1/13	143				205	210	210					501	300	309							
				145	145					210	213						505	312							
E6	E12	E24	E48	E96	E192	E6	E12	E24	E48	E96	E192		E6	E12	E24	E48	E96	E192							
E6 ±20%	E12 ±10%	E24 ±5%	E48 ±2%	E96 ±1%	E192 ±0.5%	E6 ±20%	E12 ±10%	E24 ±5%	E48 ±2%	E96 ±1%	E192 ±0.5%		E6 ±20%	E12 ±10%	E24 ±5%	E48 ±2%	E96 ±1%	E192 ±0.5%							
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E6 ±20% 330	E12 ±10%	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402	E192 ±0.5% 316 320 324 328 332 336 340 344 348 352 357 367 365 357 365 370 374 379 374 379 383 388 388 392 397 407	E6 ±20% 470	E12 ±10% 470	E24 ±5% 470 510	E48 ±2% 464 487 511 536 562	E96 ±1% 464 475 487 487 511 523 536 536 549 562 576 590	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 536 542 549 556 542 549 556 556 562 569 576 583 597		E6 ±20% 680	E12 ±10%	E24 ±5% 680 750 820	E48 ±2% 681 715 750 787 825	E96 ±1% 681 698 715 732 750 768 787 806 825 845 866	E192 ±0.5% 681 698 706 715 723 741 750 759 768 777 759 768 806 816 825 835 845 845 845 856 866 866 876							
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E6 ±20% 330	E12 ±10%	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383 402	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412	E192 ±0.5% 316 320 324 328 332 336 340 344 348 352 357 361 365 370 374 365 370 374 379 383 388 399 383 388 397 402 407 417	E6 ±20% 470	E12 ±10% 470	E24 ±5% 470 510	E48 ±2% 464 487 511 536 562 590	E96 ±1% 464 475 487 499 511 523 536 536 549 562 576 570 604	E192 ±0.5% 464 470 475 481 487 499 505 511 517 523 530 536 549 556 562 569 556 562 569 556 562 569 556 562 569 576 604 402 597 604 612		E6 ±20% 680	E12 ±10%	E24 ±5% 680 750 820	E48 ±2% 681 715 750 787 825 866	E96 ±1% 681 698 715 732 750 768 787 806 825 845 866 887	E192 ±0.5% 681 698 706 715 723 732 741 750 759 768 806 816 816 825 835 845 835 845 856 866 876 8876							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383 402	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412	E192 ±0.5% 316 320 324 328 332 336 340 344 348 352 357 361 365 370 374 379 383 388 392 397 388 388 392 397 402 407 412 417	E6 ±20% 470	E12 ±10% 470	E24 ±5% 470 510	E48 ±2% 464 487 511 536 562 590	E96 ±1% 464 475 487 499 511 523 536 549 562 576 590 604	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 542 536 536 542 549 556 562 556 562 556 562 556 5576 583 590 597 604 619		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820	E48 ±2% 681 715 750 787 825 866	E96 ±1% 681 698 715 732 750 768 787 806 825 845 845 845 887	E192 ±0.5% 681 690 706 715 723 732 741 750 759 768 777 787 796 806 816 825 835 845 835 845 856 866 876 887 8909							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383 402	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412 422	E192 ±0.5% 316 320 324 328 332 336 340 344 348 352 357 367 367 367 367 367 367 367 367 374 379 383 388 388 392 397 402 407 412 417 412	E6 ±20% 470	E12 ±10% 470	E24 ±5% 470 510	E48 ±2% 464 487 511 536 562 590	E96 ±1% 464 475 487 499 511 523 536 549 562 576 590 604 619	E192 ±0.5% 464 475 481 487 493 505 511 517 523 530 536 542 549 556 542 549 556 552 569 576 583 590 597 604 612 612		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820	E48 ±2% 681 715 750 787 825 866	E96 ±1% 681 698 715 732 750 768 787 806 825 845 845 845 866 887	E192 ±0.5% 681 698 706 715 723 741 750 759 768 777 787 759 768 806 816 825 835 845 845 845 845 845 845 845 845 845 84							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383 402 422	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412 422	E192 ±0.5% 310 320 324 336 340 344 348 352 357 361 365 370 361 365 377 361 365 377 361 365 377 383 388 389 397 402 407 402 407 417 422 427	E6 ±20% 470	E12 ±10% 470	E24 ±5% 470 510 560	E48 ±2% 464 487 511 536 562 590 619	E96 ±1% 464 475 487 499 511 523 536 549 562 576 590 604 619	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 536 536 549 556 562 569 556 562 569 556 569 556 569 597 604 612 619 624		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820	E48 ±2% 681 715 750 787 825 866 909	E96 ±1% 681 698 715 732 750 768 806 825 845 866 887 909	E192 ±0.5% 681 690 706 715 723 732 741 750 759 768 777 787 787 796 806 816 816 825 835 835 845 845 845 845 845 845 845 845 845 84							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383 402 422	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412 412 422	E192 ±0.5% 310 320 324 328 332 336 340 344 348 352 357 361 365 370 374 365 370 374 379 383 388 392 397 402 407 412 412 412 412 427 422	<mark>€6</mark> ±20%	E12 ±10% 470	E24 ±5% 470 510 560	E48 ±2% 464 487 511 536 562 590 619	E96 ±1% 464 475 487 499 511 523 536 549 562 576 576 590 604 619 634	E192 ±0.5% 464 470 475 481 487 499 505 511 517 523 530 536 549 556 562 569 556 562 569 556 562 569 576 562 569 576 604 612 619 626 626 634		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820	E48 ±2% 681 715 750 787 825 866 909	E96 ±1% 681 698 715 732 750 768 787 806 825 845 866 887 909 931	E192 ±0.5% 681 699 706 715 723 732 741 750 759 768 806 816 825 835 845 835 845 835 845 856 866 866 876 887 899 920 920 920							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390	E48 ±2% 316 332 348 365 383 402 422	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 402 412 422 432	E192 ±0.5% 316 320 324 328 332 336 340 344 348 352 357 361 365 370 374 365 370 374 365 370 374 379 383 388 392 397 402 407 412 417 412 427 432	<mark>E6</mark> ±20% 470	E12 ±10% 470	E24 ±5% 470 510 560	E48 ±2% 464 487 511 536 562 590 619	E96 ±1% 464 475 487 499 511 523 536 549 562 576 576 590 604 619 634	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 542 542 542 542 549 556 562 556 5562 5569 576 583 590 597 604 612 612 612 612 612 612 612 612 612 612		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820 910	E48 ±2% 681 715 750 787 825 866 909	E96 ±1% 681 698 715 732 750 768 787 806 825 845 845 845 845 845 845	E192 ±0.5% 681 698 706 715 723 732 741 750 759 768 806 816 816 825 835 845 856 835 845 856 835 845 856 856 856 856 856 856 856 856 856 85							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390 430	E48 ±2% 316 332 348 365 383 402 422	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412 422 432	E192 ±0.5% 316 320 324 328 332 336 340 344 348 352 357 367 367 367 367 370 374 379 383 388 392 397 402 407 412 417 412 417 422 427 437	E6 ±20% 470	E12 ±10% 470 560	E24 ±5% 470 510 560	E48 ±2% 464 487 511 536 562 590 619	E96 ±1% 464 475 487 511 523 536 536 549 562 576 590 604 619 634	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 542 549 556 542 549 556 552 569 576 583 597 604 612 619 626 634 642 642 642 642		E6 ±20% 680	E12 ±10% 680 680 820	E24 ±5% 680 750 820 910	E48 ±2% 681 715 750 787 825 866 909	E96 ±1% 681 698 715 732 750 768 806 825 845 866 887 909 931 953	E192 ±0.5% 681 698 706 715 723 741 750 759 768 775 787 787 796 806 816 806 816 825 835 845 845 845 845 845 835 845 845 845 845 86 86 86 86 87 898 909 920 931 942 951							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390 430	E48 ±2% 316 332 348 365 383 402 422 442	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412 422 432	E192 ±0.5% 310 320 324 328 336 340 344 348 352 357 361 365 370 361 365 370 374 365 377 361 365 377 361 365 377 361 365 377 402 402 407 402 407 417 422 427 427 427 427	<mark>€6</mark> ±20%	E12 ±10% 470	E24 ±5% 470 510 560 620	E48 ±2% 464 487 511 536 562 590 619 649	E96 ±1% 464 475 487 511 523 536 549 562 576 590 604 619 634 639	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 549 556 562 562 569 556 562 569 576 583 590 597 604 612 619 626 638 612 619 626 634 642 649		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820 910	E48 ±2% 681 715 750 787 825 866 909 953	E96 ±1% 681 698 715 732 750 768 806 825 845 866 887 909 931 953	E192 ±0.5% 681 690 706 715 723 732 741 750 759 768 877 787 787 787 796 806 816 825 835 845 835 846 835 846 835 835 845 835 845 835 835 835 845 835 835 835 835 835 835 835 835 835 83							
E6 ±20% 330	E12 ±10% 330	E24 ±5% 330 360 390 430	E48 ±2% 316 332 348 365 383 402 422 442	E96 ±1% 316 324 332 340 348 357 365 374 383 392 402 412 422 432 432	E192 ±0.5% 310 320 324 328 332 336 340 344 348 352 357 361 365 370 374 365 370 373 361 365 370 374 379 383 388 392 397 402 407 412 407 412 412 407 412 412 412 427 432 432	<mark>€6</mark> ±20%	E12 ±10% 470 560	E24 ±5% 470 510 560 620	E48 ±2% 464 487 511 536 562 590 619 649	E96 ±1% 464 475 487 499 511 523 536 549 562 576 576 570 604 619 634 649 665	E192 ±0.5% 464 470 475 481 487 493 505 511 517 523 530 536 542 536 542 542 542 542 545 556 556 562 556 556 562 556 556 556 562 556 562 569 576 604 619 626 634 642 642 649 657 665		E6 ±20% 680	E12 ±10% 680	E24 ±5% 680 750 820 910	E48 ±2% 681 715 750 787 825 866 909 953	E96 ±1% 681 698 715 732 750 768 806 825 845 866 887 909 931 953 976	E192 ±0.5% 681 690 706 715 723 732 741 750 759 768 7759 768 806 816 825 835 845 835 845 835 845 835 845 835 845 835 845 835 845 835 845 835 845 835 845 825 835 845 825 835 845 825 835 845 825 835 845 85 866 866 876 876 876 876 876 876 876 876							

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

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 Tower Raings.							
Resistor Diame	Power Rating						
	1/16 "	1/4 W					
(]][]]	1/8 "	1/2 W					
	3/16 "	1 W					
	1/4 "	2 W					

Table D.4.	Resistor	Power	Ratings



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



or this:



or even this:

