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Practical Electronics for Inventors, Fourth Edition

by: Paul Scherz, Dr. Simon Monk

Abstract: A fully updated, no-nonsense guide to electronics. Advance your electronics knowledge and gain the skills necessary to develop and construct your own functioning gadgets. Written by a pair of experienced engineers and dedicated hobbyists, Practical Electronics for Inventors, Fourth Edition, lays out the essentials and provides step-by-step instructions, schematics, and illustrations. Discover how to select the right components, design and build circuits, use microcontrollers and ICs, work with the latest software tools, and test and tweak your creations. This easy-to-follow book features new instruction on programmable logic, semiconductors, operational amplifiers, voltage regulators, power supplies, digital electronics, and more. Coverage includes:

- Resistors, capacitors, inductors, and transformers
- Diodes, transistors, and integrated circuits
- Optoelectronics, solar cells, and phototransistors
- Sensors, GPS modules, and touch screens
- Op amps, regulators, and power supplies
- Digital electronics, LCDs, and logic gates
- Microcontrollers and prototyping platforms
- Combinational and sequential programmable logic
- DC motors, RC servos, and stepper motors
- Microphones, audio amps, and speakers
- Modular electronics and prototypes

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Authors:

Paul Scherz is a Systems Operation Manager who received his B.S. in physics from the University of Wisconsin. He is an inventor/hobbyist in electronics, an area he grew to appreciate through his experience at the University's Department of Nuclear Engineering and Engineering Physics and Department of Plasma Physics.

Dr. Simon Monk has a bachelor's degree in cybernetics and computer science and a Ph.D. in software engineering. He spent several years as an academic before he returned to industry, co-founding the mobile software company Momote Ltd. He has been an active electronics hobbyist since his early teens and is a full-time writer on hobby electronics and open-source hardware. Dr. Monk is author of numerous electronics books, including Programming Arduino, Hacking Electronics, and Programming the Raspberry Pi.

Description: A fully updated, no-nonsense guide to electronics. Advance your electronics knowledge and gain the skills necessary to develop and construct your own functioning gadgets. Written by a pair of experienced engineers and dedicated hobbyists, Practical Electronics for Inventors, Fourth Edition, lays out the essentials and provides step-by-step instructions, schematics, and illustrations. Discover how to select the right components, design and build circuits, use microcontrollers and ICs, work with the latest software tools, and test and tweak your creations. This easy-to-follow book

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1. <https://www.amazon.com/Practical-Electronics-Inventors-Fourth-Scherz/dp/1259587541> [back]

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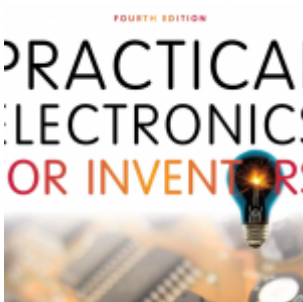
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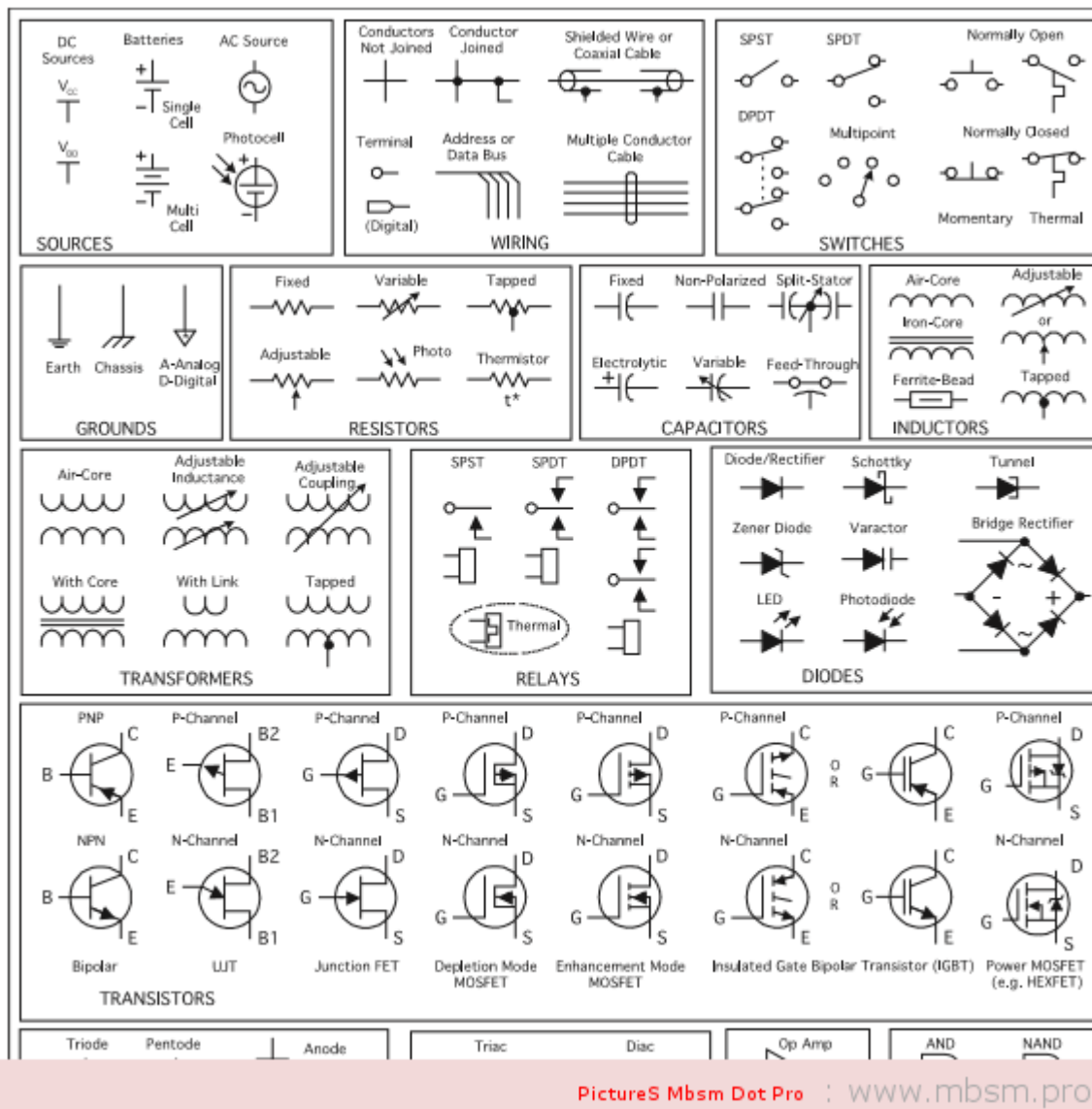


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Resistor Labels

Conversion Calculator

k = 1,000 ; M = 1,000,000

1MΩ = 1,000,000 Ω = 1 x 10⁶Ω

1kΩ = 1,000 Ω = 1 x 10³Ω

Examples:

3.3 kΩ = 3,300 Ω = 3.3 x 10³Ω

22 kΩ = 22,000 Ω = 22 x 10³Ω

2 MΩ = 2,000,000 Ω = 2 x 10⁶Ω

1.68 MΩ = 1,680,000 Ω = 1.68 x 10⁶Ω

Resistor Color Code

Color	Sig. Fig.	Decimal Multiplier	Tolerance (%)
Black	0	1	-
Brown	1	10	1
Red	2	100	2
Orange	3	1,000	-
Yellow	4	10,000	-
Green	5	100,000	0.5
Blue	6	1,000,000	0.25
Purple	7	10,000,000	0.1
Gray	8	100,000,000	-
White	9	1,000,000,000	-
Gold	-	0.1	5
Silver	-	0.01	10
No Color	-	-	20

Body Color

The body color of a resistor typically doesn't carry meaning, except in some instances where it may specify temperature coefficient. However, if you find resistors within a circuit that are white/gray or blue in color, they may be non-flammable or fusible resistors. Care must be taken when entering such resistors.

4-Band Resistor Code (Most Common)

Label Meaning

Red Black Orange Gold
20 x 1,000 = 20k Ω ± 5%

First Digit Second Digit Multiplier (#of zeros) % Tolerance

5-Band Resistor Code (3-digit)

Label Meaning

Purple Blue Green Brown Brown
675 x 10 = 6750 Ω ± 1%

First Digit Second Digit Third Digit Multiplier (#of zeros) % Tolerance

5-Band Resistor Code (Reliability)

Label Meaning

Yellow Purple Green Silver Brown
47 x 100,000 = 4.7 MΩ ± 10%

1% Reliability/1000 Hr — Brown

Color	Reliability (%/1000 Hr)
Brown	1
Red	0.1
Orange	0.01
Yellow	0.001

First Digit Second Digit Multiplier (#of zeros) Reliability % Tolerance

6-Band Resistor Code

Label Meaning

Purple Red Blue Black Brown Red
276 x 1 = 276Ω ± 1%

TC of 50 ppm — Red

Color	Temp. Coeff.
Brown	100 ppm
Red	50 ppm

First Digit Second Digit Third Digit Multiplier (#of zeros) Temp. Coeff. % Tolerance

Surface Mount Resistor Code

3-digit Label

Label Meaning

101 10 and 1 zero = 100 Ω

105 10 and 5 zero = 1,000,000 Ω

224 22 and 4 zeros = 220,000 Ω

1R0 1.0 and no zeros = 1 Ω

22R 22.0 and no zeros = 22 Ω

R10 0.1 and no zeros = 0.1 Ω

The first two digits represent significant figures; the last digit specifies the multiplier. For values under 100 Ω, the letter R is substituted for one of the significant digits and represents a decimal point.

4-digit Label

Label Meaning

1001 100 and 1 zero = 1000 Ω

22R0 22.0 and no zeros = 22 Ω

The first three digits represent significant figures; the last digit specifies the multiplier. R represents a decimal point.

Tolerance Label

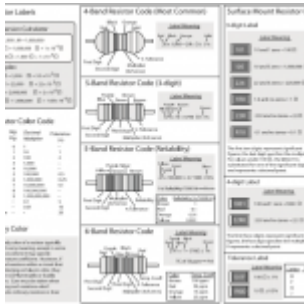
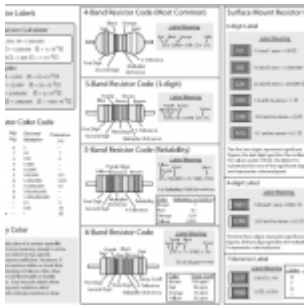
Label Meaning

101F 100 Ω ± 1%

Letter	Tolerance
D	±0.5 %
F	±1.0 %
G	±2.0 %
J	±5.0 %
K	±10.0 %
M	±20.0 %
P	±1.0 %
R	±0.5 %
S	±0.25 %
T	±0.1 %
Z	±20.0 %

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Capacitor Markings

Capacitance Conversion Calculator

$1 \text{ F} = 1 \times 10^6 \mu\text{F} = 1 \times 10^9 \text{ nF} = 1 \times 10^{12} \text{ pF}$
 $1 \mu\text{F} = 1 \times 10^{-6} \text{ F} = 1 \times 10^3 \text{ nF} = 1 \times 10^6 \text{ pF}$
 $1 \text{ nF} = 1 \times 10^{-9} \text{ F} = 1 \times 10^{-3} \mu\text{F} = 1 \times 10^3 \text{ pF}$
 $1 \text{ pF} = 1 \times 10^{-12} \text{ F} = 1 \times 10^{-6} \mu\text{F} = 1 \times 10^{-9} \text{ nF}$

F = Farad, μ = micro, n = nano, p = pico

$1000 \mu\text{F} = 1,000,000 \text{ nF} = 10 \times 10^8 \text{ pF}$
 $100 \mu\text{F} = 100,000 \text{ nF} = 10 \times 10^7 \text{ pF}$
 $10 \mu\text{F} = 10,000 \text{ nF} = 10 \times 10^6 \text{ pF}$
 $1 \mu\text{F} = 1,000 \text{ nF} = 10 \times 10^5 \text{ pF}$
 $0.1 \mu\text{F} = 100 \text{ nF} = 10 \times 10^4 \text{ pF}$
 $0.01 \mu\text{F} = 10 \text{ nF} = 10 \times 10^3 \text{ pF}$
 $0.001 \mu\text{F} = 1 \text{ nF} = 10 \times 10^2 \text{ pF}$

Tantalum

Label meaning 1

1st significant figure in μF
 2nd significant figure in μF
 Multiplier (See table)
 Voltage

Color	S.F.	Multiple	Voltage
Black	0	1	10V
Brown	1	10	
Red	2	100	
Orange	3	1000	
Yellow	4		6.3V
Green	5		16V
Blue	6		20V
Violet	7		
Gray	8	0.01	25V
White	9	0.1	3V
Pink			35V

Label meaning 2

Marking	Actual
22	22 μF , 16 V

Mylar (Polyester Film)
Polypropylene
Dipped Mica

Label meaning

Marking	Actual
.001K*	0.001 μF , $\pm 10\%$
104K	0.1 μF , $\pm 10\%$
22J*	0.22 μF , $\pm 5\%$
472K	0.0047 μF , $\pm 10\%$
221J	220 pF, $\pm 5\%$
470J	47 pF, $\pm 5\%$
102J	1000 pF, $\pm 5\%$
103F	0.01 μF , $\pm 1\%$
223F	0.022 μF , $\pm 1\%$

Ceramic Disc Capacitors

Temperature Coefficient Color Code

Color	Temp. Coeff. (ppm/°C)
Black	±20
Brown	±25
Red	±50
Orange	±75
Yellow	±100
Green	±150
Blue	±200
Violet	±250
Gray	±300
White	±400

Multiplier Code

Numeric Character	Decimal Multiplier (pF)
0	None
1	10
2	100
3	1000
4	10,000

EIA Capacitor Tolerance Codes

Letter	≤ 10 pF	≥ 10 pF
B	± 0.1 pF	-
C	± 0.25 pF	-
D	± 0.5 pF	-
E	-	± 25%
F	± 1 pF	± 1%
G	-	± 2%
H	-	± 2.5%
J	-	± 5%
K	-	± 10%
M	-	± 20%
P	-	-0 + 100%
S	-	-20 + 50%
W	-	-0 + 200%
X	-	-20 + 40%
Z	-	-20 + 80%

EIA Temperature Characteristic Codes

Minimum temperature	Maximum temperature	Max cap. change over temp. range
X -55°C	2 +45°C	A ± 1.0%
Y -35°C	4 +65°C	B ± 1.5%
Z +10°C	5 +85°C	C ± 2.2%
	6 +105°C	D ± 3.3%
	7 +125°C	E ± 4.7%
		F ± 7.5%
		P ± 10%
		R ± 15%
		S ± 22%
		T -33% + 22%
		U -56% + 22%
		V -82% + 22%

Ceramic Disc (European Markings)

Label Meaning

Marking	Actual	Marking	Actual
p68	0.68 pF	22p	22 pF
1p0	1.0 pF	n10	0.1 nF
4p7	4.7 pF	n27	0.27 nF

Label: p = picofarads, n = nanofarads; location of p or n signifies decimal point.

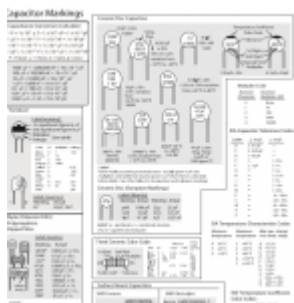
Fixed Ceramic Color Code

Color	S.F.	Tolerance	Temp. Coeff. ppm/°C
Black	0	± 20%	>10pF <10pF
Brown	1	± 1%	0
Red	2	± 2%	-50
Orange	3	± 3%	-100
Yellow	4	± 4%	-150
Green	5	± 5%	-200
Blue	6	± 6%	-250
Violet	7	± 7%	-300
Gray	8	± 8%	-350
White	9	± 9%	-400

Surface Mount Capacitors

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Capacitor Markings

Capacitor markings are used to identify the value, tolerance, and other characteristics of a capacitor. The markings are usually printed on the capacitor's body or on a label.

The following table shows the most common capacitor markings and their meanings:

Capacitor Markings

Marking	Value	Tolerance
100	100 pF	±20%
1000	1000 pF	±20%
10000	10000 pF	±20%
100000	100000 pF	±20%
1000000	1000000 pF	±20%
10000000	10000000 pF	±20%
100000000	100000000 pF	±20%
1000000000	1000000000 pF	±20%

Capacitor Markings

Marking	Value	Tolerance
100	100 pF	±20%
1000	1000 pF	±20%
10000	10000 pF	±20%
100000	100000 pF	±20%
1000000	1000000 pF	±20%
10000000	10000000 pF	±20%
100000000	100000000 pF	±20%
1000000000	1000000000 pF	±20%

The diagram illustrates various capacitor markings and their meanings. It includes a table of markings and values, a section for capacitor types (CERAMIC, ALUMINUM ELECTROLYTIC, TANTALUM ELECTROLYTIC), and a section for capacitor values and tolerances.

Marking	Value	Tolerance
100	100 pF	±20%
1000	1000 pF	±20%
10000	10000 pF	±20%
100000	100000 pF	±20%
1000000	1000000 pF	±20%
10000000	10000000 pF	±20%
100000000	100000000 pF	±20%
1000000000	1000000000 pF	±20%

Capacitor Types

- CERAMIC
- ALUMINUM ELECTROLYTIC
- TANTALUM ELECTROLYTIC

Capacitor Values and Tolerances

Value	Tolerance
100 pF	±20%
1000 pF	±20%
10000 pF	±20%
100000 pF	±20%
1000000 pF	±20%
10000000 pF	±20%
100000000 pF	±20%
1000000000 pF	±20%