

# **www.mbsm.pro , Practical Electronics for Inventors, Fourth Edition**

written by mahdi miled | 23 November 2017

**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

Book Details

Title: Practical Electronics for Inventors, Fourth Edition

Publisher: McGraw-Hill Education: New York, Chicago, San Francisco, Athens, London, Madrid, Mexico City, Milan, New Delhi, Singapore, Sydney, Toronto

Copyright / Pub. Date: 2016 McGraw-Hill Education

ISBN: 9781259587542

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

features new instruction on programmable logic, semiconductors, operational amplifiers, voltage regulators, power supplies, digital electronics, and more. Coverage includes:

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

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FOURTH EDITION

# PRACTICAL ELECTRONICS FOR INVENTORS

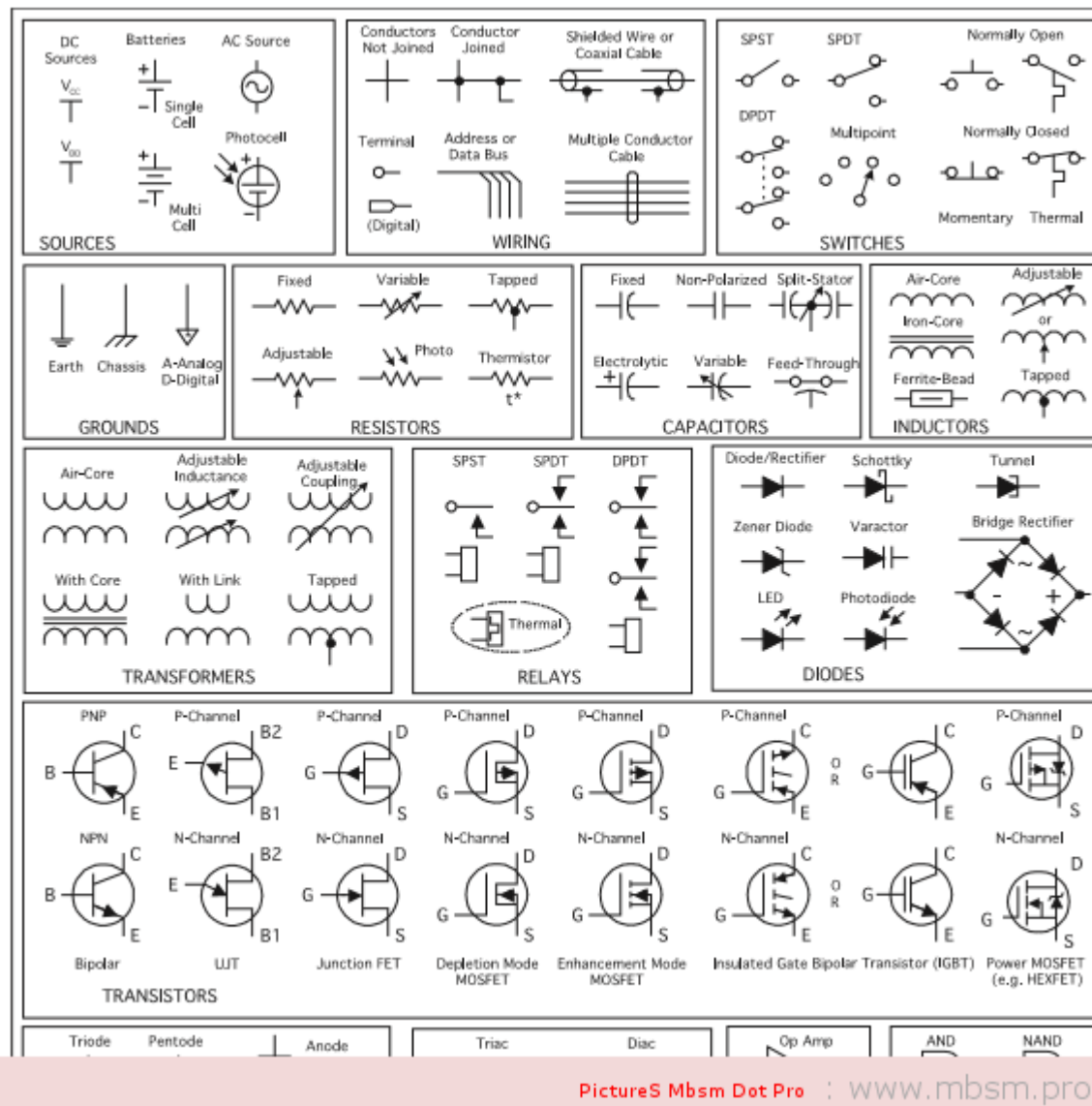


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### Resistor Labels

#### Conversion Calculator

$k = 1,000$ ;  $M = 1,000,000$   
 $1M\Omega = 1,000,000 \Omega = 1 \times 10^6 \Omega$   
 $1k\Omega = 1,000 \Omega = 1 \times 10^3 \Omega$

#### Examples:

$3.3 k\Omega = 3,300 \Omega = 3.3 \times 10^3 \Omega$   
 $22 k\Omega = 22,000 \Omega = 22 \times 10^3 \Omega$   
 $2 M\Omega = 2,000,000 \Omega = 2 \times 10^6 \Omega$   
 $1.68 M\Omega = 1,680,000 \Omega = 1.68 \times 10^6 \Omega$

#### 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 replacing such resistors; don't

### 4-Band Resistor Code (Most Common)

**Label Meaning**  
 $20 \times 1,000 = 20k \Omega \pm 5\%$

First Digit: Black, Second Digit: Orange, Multiplier (# of zeros): Gold, % Tolerance: Gold

### 5-Band Resistor Code (3-digit)

**Label Meaning**  
 $675 \times 10 = 6750 \Omega \pm 1\%$

First Digit: Purple, Second Digit: Blue, Third Digit: Green, Multiplier (# of zeros): Brown, % Tolerance: Brown

### 5-Band Resistor Code (Reliability)

**Label Meaning**  
 $47 \times 100,000 = 4.7 M\Omega \pm 10\%$

First Digit: Yellow, Second Digit: Purple, Third Digit: Green, Multiplier (# of zeros): Silver, Reliability: Brown

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

### 6-Band Resistor Code

**Label Meaning**  
 $276 \times 1 = 276\Omega \pm 1\%$

First Digit: Purple, Second Digit: Red, Third Digit: Black, Multiplier: Blue, % Tolerance: Brown, Temp. Coeff.: Red

Color	Temp. Coeff. (ppm)
Brown	100
Red	50

### Surface Mount Resistor Code

#### 3-digit Label

**Label Meaning**

101	10 and 1 zero = 100 $\Omega$
105	10 and 5 zeros = 1,000,000 $\Omega$
224	22 and 4 zeros = 220,000 $\Omega$
1R0	1.0 and no zeros = 1 $\Omega$
22R	22.0 and no zeros = 22 $\Omega$
R10	0.1 and no zeros = 0.1 $\Omega$

The first two digits represent significant figures; the last digit specifies the multiplier. For values under 100  $\Omega$ , 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 $\Omega$
22R0	22.0 and no zeros = 22 $\Omega$

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

#### Tolerance Label

**Label Meaning**

Label	Tolerance
101F	100 $\Omega \pm 1\%$
D	$\pm 0.5\%$
F	$\pm 1.0\%$

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<p><b>an Labels</b></p> <p>International          100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>an Color Code</b></p> <p>0 1 2 3 4 5 6 7 8 9</p> <p>Black Brown Red Orange Yellow Green Blue Violet Grey White</p> <p><b>an Color</b></p> <p>Black 0          Brown 1          Red 2          Orange 3          Yellow 4          Green 5          Blue 6          Violet 7          Grey 8          White 9</p>	<p><b>4-Band Resistor Code (Most Common)</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>5-Band Resistor Code (3-digits)</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>3-Band Resistor Code (Potentiometer)</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>6-Band Resistor Code</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p>	<p><b>Surface Mount Resistor</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>4-digit code</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>5-digit code</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p>
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<p><b>an Labels</b></p> <p>International          100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>an Color Code</b></p> <p>0 1 2 3 4 5 6 7 8 9</p> <p>Black Brown Red Orange Yellow Green Blue Violet Grey White</p> <p><b>an Color</b></p> <p>Black 0          Brown 1          Red 2          Orange 3          Yellow 4          Green 5          Blue 6          Violet 7          Grey 8          White 9</p>	<p><b>4-Band Resistor Code (Most Common)</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>5-Band Resistor Code (3-digits)</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>3-Band Resistor Code (Potentiometer)</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>6-Band Resistor Code</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p>	<p><b>Surface Mount Resistor</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>4-digit code</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p> <p><b>5-digit code</b></p> <p>100 ohms <math>10^2 \Omega</math>          10 ohms <math>10^1 \Omega</math>          1 ohm <math>10^0 \Omega</math>          0.1 ohm <math>10^{-1} \Omega</math>          0.01 ohm <math>10^{-2} \Omega</math>          0.001 ohm <math>10^{-3} \Omega</math></p>
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# Capacitor Markings

## Capacitance Conversion Calculator

$1 \text{ F} = 1 \times 10^6 \mu\text{F} = 1 \times 10^9 \text{ nF} = 1 \times 10^{12} \text{ pF}$   
 $1 \mu\text{F} = 1 \times 10^{-6} \text{ F} = 1 \times 10^3 \text{ nF} = 1 \times 10^6 \text{ pF}$   
 $1 \text{ nF} = 1 \times 10^{-9} \text{ F} = 1 \times 10^{-3} \mu\text{F} = 1 \times 10^3 \text{ pF}$   
 $1 \text{ pF} = 1 \times 10^{-12} \text{ F} = 1 \times 10^{-6} \mu\text{F} = 1 \times 10^{-3} \text{ nF}$   
 $\text{F} = \text{Farad}, \mu = \text{micro}, \text{n} = \text{nano}, \text{p} = \text{pico}$

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

## Tantalum

**Label meaning 1**

1st significant figure in  $\mu\text{F}$   
2nd significant figure in  $\mu\text{F}$   
Multiplier  
Voltage (See table)

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 $\mu\text{F}$ , 16 V

## Mylar (Polyester Film)

## Polypropylene

## Dipped Mica

**Label meaning**

Marking	Actual
104K	0.001 $\mu\text{F}$ , $\pm 10\%$
104K	0.1 $\mu\text{F}$ , $\pm 10\%$
22J	0.22 $\mu\text{F}$ , $\pm 5\%$
472K	0.0047 $\mu\text{F}$ , $\pm 10\%$
221J	220 pF, $\pm 5\%$
470J	47 pF, $\pm 5\%$
102J	1000 pF, $\pm 5\%$
103F	0.01 $\mu\text{F}$ , $\pm 1\%$
223F	0.022 $\mu\text{F}$ , $\pm 1\%$

Voltage Rating

## Ceramic Disc Capacitors

22 pF  $\pm 20\%$   
1000V

Temp. Char.  
Z5U  
.0033  $\pm 20\%$   
-56% to +22% variation from +10°C to +85°C

1Z  
100V  
0.1 $\mu\text{F}$   
-20% to +80%  
100V

Temperature Coefficient  
Color Code  
Tolerance  
1st Digit  
2nd Digit  
Decimal Point  
Multiplier

121K  
120 pF  $\pm 10\%$

4R7D  
4.7 pF  $\pm 0.5\text{pF}$

X7R  
10K  
1 kV  
10 pF  $\pm 10\%$   
 $\pm 15\%$  variation from -55°C to +125°C  
1000V

K5U  
474M  
0.47 $\mu\text{F}$   $\pm 20\%$   
+22% to -70% variation from +25°C to +85°C

20  $\pm 20\%$   
50V AC  
400V DC  
20 pF  $\pm 20\%$   
50V AC  
400V DC

Z5P  
2200 K  
2200 pF  $\pm 10\%$   
 $\pm 10\%$  variation from +10°C to +85°C

200 nZ  
12V  
200 nF -20°C to +80°C  
12V DC

N2200  
47 pF  $\pm 20\%$   
Neg. Temp. Coeff. of 2200 ppm/°C

**Label:**  
Varies widely according to manufacturer. Usually given in pF (see multiplier code table) but may be given in  $\mu\text{F}$  when there is a decimal before digits. See other tables for temperature and tolerance markings.

## Ceramic Disc (European Markings)

**Label Meaning**

Marking	Actual	Marking	Actual
47p			
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

1st Digit 2nd Digit Multiplier

Color	S.F.	Tolerance	Temp. Coeff. ppm/°C
Black	0	$\pm 20\%$	>10pF
Brown	1	$\pm 1\%$	<10pF
Red	2	$\pm 2\%$	
Orange	3	$\pm 3\%$	
Yellow	4	$\pm 4\%$	
Green	5	$\pm 5\%$	
Blue	6		
Violet	7		
Gray	8		
White	9		

Temp. Coeff. Tolerance

## Surface Mount Capacitors

## Multiplier Code

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

## EIA Capacitor Tolerance Codes

Letter	$\leq 10 \text{ pF}$	$\geq 10 \text{ pF}$
B	$\pm 0.1 \text{ pF}$	-
C	$\pm 0.25 \text{ pF}$	-
D	$\pm 0.5 \text{ pF}$	-
E	-	$\pm 25\%$
F	$\pm 1 \text{ pF}$	$\pm 1\%$
G	-	$\pm 2\%$
H	-	$\pm 2.5\%$
J	-	$\pm 5\%$
K	-	$\pm 10\%$
M	-	$\pm 20\%$
P	-	-0 to +100%
S	-	-20 to +50%
W	-	-0 to +200%
X	-	-20 to +40%
Z	-	-20 to +80%

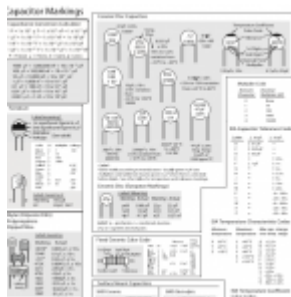
## EIA Temperature Characteristic Codes

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

## EIA Temperature Coefficient

PictureS Mbsm Dot Pro : [www.mbsm.pro](http://www.mbsm.pro)

www-mbsm-pro-Practical-Electronics-for-Inventors-Fourth-Edition4.png (178 KB)



### Superscript Markings

**Supplementary Information:**  
 Table S1: Summary of the data used in the study.  
 Table S2: Summary of the results of the study.  
 Table S3: Summary of the results of the study.  
 Table S4: Summary of the results of the study.  
 Table S5: Summary of the results of the study.

