Basic Electronics Series

Capacitor Markings and Identification

Capacitor Values

- Capacitors are passive electronic components that have the ability to store energy in an electric field.
- Capacitors generally consist of two insulated plates (or sets of plates) separated by an insulating material called a *dielectric* material.
- That ability to store energy in an electric field is called *capacitance.*

Capacitor Values

- Capacitance is measured in units called *farads.*
- The farad is an extremely large unit, an we therefore normally work with units called *microfarads (µF), nanofarads (nF),* or *picofarads (pF).*
- In the past, picofarads were called *micro-microfarads.*

Capacitor Values

- The actual sizes of these common units are as follows:
  - 1 μF = 1 x 10^{-6} F = 0.000001 F
  - 1 nF = 1 x 10^{-9} F = 0.000000001 F
  - 1 pF = 1 x 10^{-12} F = 0.000000000001 F
- Unit conversion is done by moving the decimal point in accordance with the direction and distance of the conversion

Capacitor Values

- Capacitors also have additional characteristics that need to be considered when discussing capacitor values:
  - Tolerance
  - Dielectric material
  - Temperature range and stability
- These values are sometimes marked or coded on the body of a capacitor

Capacitor Polarity

- Some capacitors are polarized, and therefore must be inserted into the circuit in the proper orientation with respect to the polarity of the capacitor.
  - Electrolytic capacitors are usually marked to indicate the negative lead.
  - Tantalum capacitors are usually marked to indicate the positive lead.

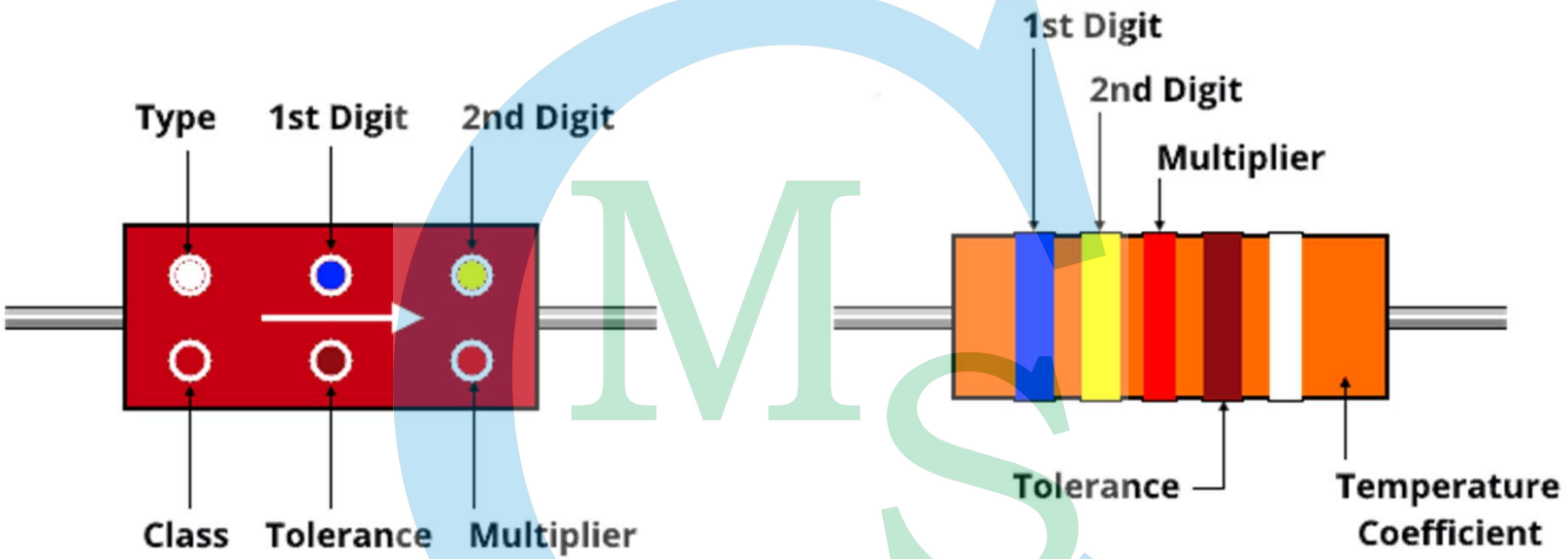
Capacitor Value Codes

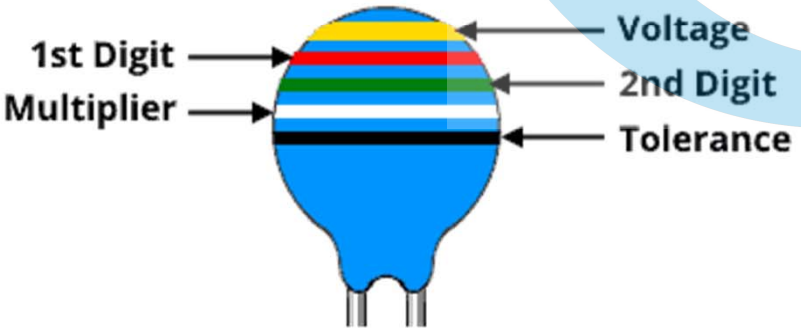
- Over the years, different marking schemes have been used to identify capacitor values
  - Color codes
    - Uses standard electronics color code scheme
  - Numeric codes
    - Uses a three-digit code to indicate the value
  - Direct value marking
    - The capacitor is marked with the actual value

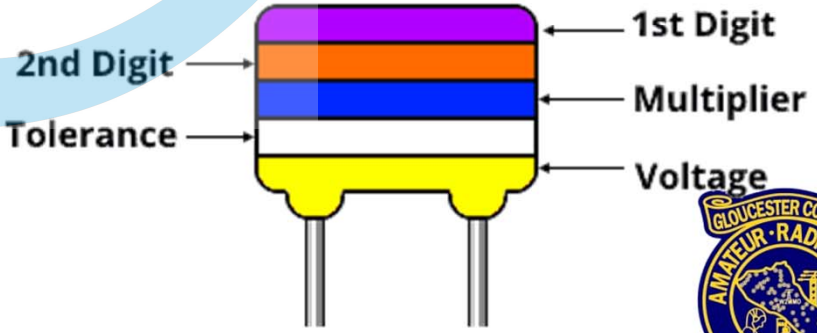
Color Codes

- Color codes were used in both stripe and dot patterns to convey capacitor values.
- Each successive stripe or dot indicates a separate aspect of the component's value.
- Stripes are found on capacitors of several different types.
- Dots are most common on mica and silver mica capacitors.

Color Codes







Color Meanings

Band Colour	Digit A	Digit B	Multiplier D	Tolerance (T) > 10pf	Tolerance (T) < 10pf	Temperature Coefficient (TC)
Black	0	0	x1	± 20%	± 2.0pF	
Brown	1	1	x10	± 1%	± 0.1pF	-33×10^{-6}
Red	2	2	x100	± 2%	± 0.25pF	-75×10^{-6}
Orange	3	3	x1,000	± 3%		-150×10^{-6}
Yellow	4	4	x10,000	± 4%		-220×10^{-6}
Green	5	5	x100,000	± 5%	± 0.5pF	-330×10^{-6}
Blue	6	6	x1,000,000			-470×10^{-6}
Violet	7	7				-750×10^{-6}
Grey	8	8	x0.01	+80%,-20%		
White	9	9	x0.1	± 10%	± 1.0pF	
Gold			x0.1	± 5%		
Silver			x0.01	± 10%		

Color Meanings

- Certain capacitor types will sometimes use specific colors in specific locations to indicate some non-standard property such as capacitor type or class.
- In many cases, the color of the body of the capacitor is also a part of the color code and must be taken into consideration when determining type and value of a capacitor.

Numeric and Alpha Codes

- It is very common for capacitors, especially ceramic types, to be marked with a numeric or numeric/alphabetic code to indicate the capacitor value and tolerance.
- Three-digit numeric codes provide only the value information.
- An alphabetic suffix to the numeric code provides tolerance information.

Numeric Code System

- In the numeric code, the first and second digits are the significant digits of the value, while the third digit is the multiplier.
- The value coded is a picofarad value.
  - Example: 473 has the following meaning:
    - 1st significant digit … 4
    - 2nd significant digit… 7
    - Multiplier… 3, meaning x1,000
    - Therefore, the value is 47,000pF, or 0.047µF

Values and Numeric Codes 1

Value (pF)	Value (nF)	Value (µF)	Code	Value (pF)	Value (nF)	Value (µF)	Code
10	0.010	0.00001	100	330	0.330	0.00033	331
15	0.015	0.000015	150	470	0.470	0.00047	471
22	0.022	0.000022	220	560	0.560	0.00056	561
33	0.033	0.000033	330	680	0.680	0.00068	681
47	0.047	0.000047	470	750	0.750	0.00075	751
100	0.100	0.0001	101	820	0.820	0.00082	821
120	0.120	0.00012	121	1,000	1	0.001	102
130	0.130	0.00013	131	1,500	1.5	0.0015	152
150	0.150	0.00015	151	2,000	2	0.002	202
180	0.180	0.00018	181	2,200	2.2	0.0022	222
220	0.220	0.00022	221	3,300	3.3	0.0033	332

Values and Numeric Codes 2

Value (pF)	Value (nF)	Value (µF)	Code	Value (pF)	Value (nF)	Value (µF)	Code
4,700	4.7	0.0047	472	150,000	150	0.15	154
5,000	5	0.005	502	200,000	200	0.2	204
5,600	5.6	0.0056	562	220,000	220	0.22	224
6,800	6.8	0.0068	682	330,000	330	0.33	334
10,000	10	0.01	103	470,000	470	0.47	474
15,000	15	0.015	153	680,000	680	0.68	684
22,000	22	0.022	223	1,000,000	1,000	1	105
33,000	33	0.033	333	1,500,000	1,500	1.5	155
47,000	47	0.047	473	2,000,000	2,000	2	205
68,000	68	0.068	683	2,200,000	2,200	2.2	225
100,000	100	0.1	104	3,300,000	3,300	3.3	335

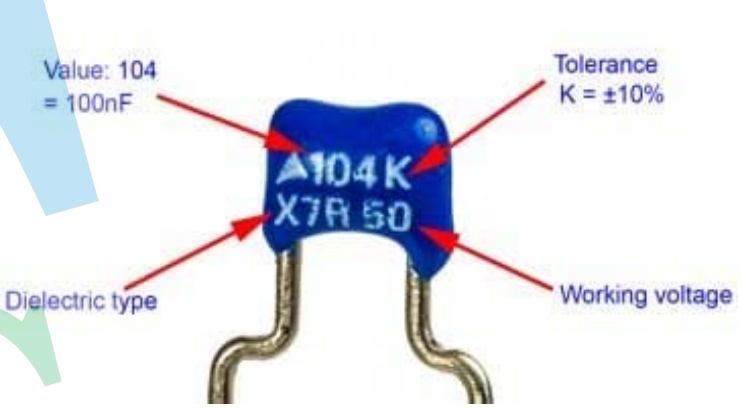
Tolerance Codes

- Alpha codes are used for tolerance, and may be either ± a fixed number of picofarads, or may be ± a fixed percentage.
- When the nominal value is less than 10pF, the tolerance is a fixed number of picofarads more or less than the nominal value.
- When the nominal value is greater than 10pF, the tolerance is ± a given percentage of the nominal value.

	LETTER	B	C	D	F	G	J	K	M	Z
Tolerance ± pF or ±% based on value	C <10pF ±pF	0.1	0.25	0.5	1	2				
	C >10pF ±%			0.5	1	2	5	10	20	+80/-20

Ceramic Marking Overview

- At right is a somewhat well-marked monolithic ceramic capacitor.



- This capacitor is marked with its capacitance, tolerance, dielectric type, and the working voltage for which the capacitor is designed.
- Not all capacitors are so well marked!

Dielectric Marking

- On some capacitors, particularly ceramic types, the type of dielectric used in construction of the capacitor may also be marked on the body of the capacitor.
- It may be on the opposite side from the value code or marking.
- It will usually be a dielectric code such as C0G, NP0, X7R, Y5V, Z5U, and so forth.
  - This abbreviation is the industry standard code for the dielectric type or class.

Ceramic Capacitor Classes

CLASS	DESCRIPTION	COMMON TYPES
Class 1	Class 1 ceramic capacitors offer a high level of stability and exhibit low loss levels, and they are ideal for use in resonant circuits.	NP0, P100, N33, N75, etc.
Class 2	Class 2 ceramic capacitors offer high volumetric efficiency, i.e. large capacitance for a given volume for smoothing, by-pass, coupling and decoupling applications.	X7R, X5R, Y5V, Z5U, etc.
Class 3	Class 3 ceramic capacitors offer higher volumetric efficiency than the class 2 ceramic capacitors, but their temperature stability is not nearly so good. A typical performance for the change of capacitance with temperature is −22% to +56% over a range of 10°C to 55°C.	Only available as leaded components. No longer standardised.

Class 1 Capacitor Codes

- To define the performance of a ceramic capacitor dielectric a three character code is used which is specific to ceramic capacitor class 1 dielectrics.
  - The first character is a letter which gives the significant figure of the change in capacitance over temperature in ppm/°C.
  - The second character is numeric and gives the multiplier.
  - The third character is a letter and gives the maximum error in ppm/°C.

Class 1 Capacitor Codes

FIRST CHARACTER		SECOND CHARACTER		THIRD CHARACTER	
LETTER	SIG FIGS*	DIGIT	MULTIPLIER (10^X)	LETTER	TOLERANCE *
C	0.0	0	-1	G	+/-30
B	0.3	1	-10	H	+/-60
L	0.8	2	-100	J	+/-120
A	0.9	3	-1000	K	+/-250
M	1.0	4	+1	L	+/-500
P	1.5	6	+10	M	+/-1000
R	2.2	7	+100	N	+/-2500
S	3.3	8	+1000		
T	4.7				
V	5.6				
U	7.5				

The tolerance values relate as the capacitor value change from its nominal value in ppm/°C.

Class 2 Capacitor Codes

- A three code is used to define the performance of ceramic capacitor dielectric.
  - The first character is a letter. This gives the low-end operating temperature.
  - The second is numeric and indicates the high-end operating temperature.
  - The third character is a letter which indicates the capacitance change over the temperature range

Class 2 Capacitor Codes

FIRST CHARACTER		SECOND CHARACTER		THIRD CHARACTER	
LETTER	LOW TEMP	DIGIT	HIGH TEMP	LETTER	CHANGE
X	-55C (-67F)	2	+45C (+113F)	D	+/-3.3%
Y	-30C (-22F)	4	+65 (+149F)	E	+/-4.7%
Z	+10C (+50F)	5	+85 (+185F)	F	+/-7.5%
		6	+105 (+221F)	P	+/-10%
		7	+125 (+257F)	R	+/-15%
				S	+/-22%
				T	+22% / -33%
				U	+22% / -56%
				V	+22% / -82%

Direct Value Marking

- Some capacitors, particularly polarized types, will have certain values marked on the body of the capacitor:
  - Capacitance value, usually in microfarads;
  - Maximum working voltage, usually a DC level;
  - Maximum operating temperature in degrees Celsius (usually on electrolytics); and
  - The polarity of the capacitor.

Capacitor Packages

- Capacitors are made in numerous different packages or form factors.
- The capacitor type can often be recognized simply by the appearance of the capacitor, though details like dielectric types will not be so evident.
- Capacitors are made in both leaded and surface-mount varieties.

Surface Mount Markings

- Many surface-mount capacitors will use the standard three-digit value designator, while others – especially polarized types – will be marked directly with the value and working voltage.
- A good number of surface-mount (SMT) capacitors will not be marked at all!
  - Their values must then be determined by measurement or via the device schematic.

Surface Mount Markings

- There are three basic EIA schemes for SMT capacitor marking…
  - 3-digit EIA system – uses three alpha-numeric characters;
  - 4-digit EIA system – uses four alpha-numeric characters; and
  - EIA-198 system – uses two characters, one alphabetic and one numeric.

3-Digit EIA Code

- Three characters are used, mostly numeric
- The first digit is the first significant digit of the value.
- The second digit is the second significant digit of the value.
- The third digit is the multiplier.
- When an “R” is the second digit, the third digit is the second significant digit and the value is less than 10pF.

4-Digit EIA Code

- The first digit is the first significant digit of the value.
- The second digit is the second significant digit of the value.
- The third digit is the multiplier.
- The fourth digit is the tolerance.
- When an “R” is the second digit, the third digit is the second significant digit and the value is less than 10pF.

EIA-198 Code

- In this code, the first digit is a numeric character and it represents the value of the capacitor.
- The second digit is an alphabetic character and it represents the multiplier.
- There are 33 numeric characters assigned and 10 alphabetic characters assigned.

EIA-198 Value Codes

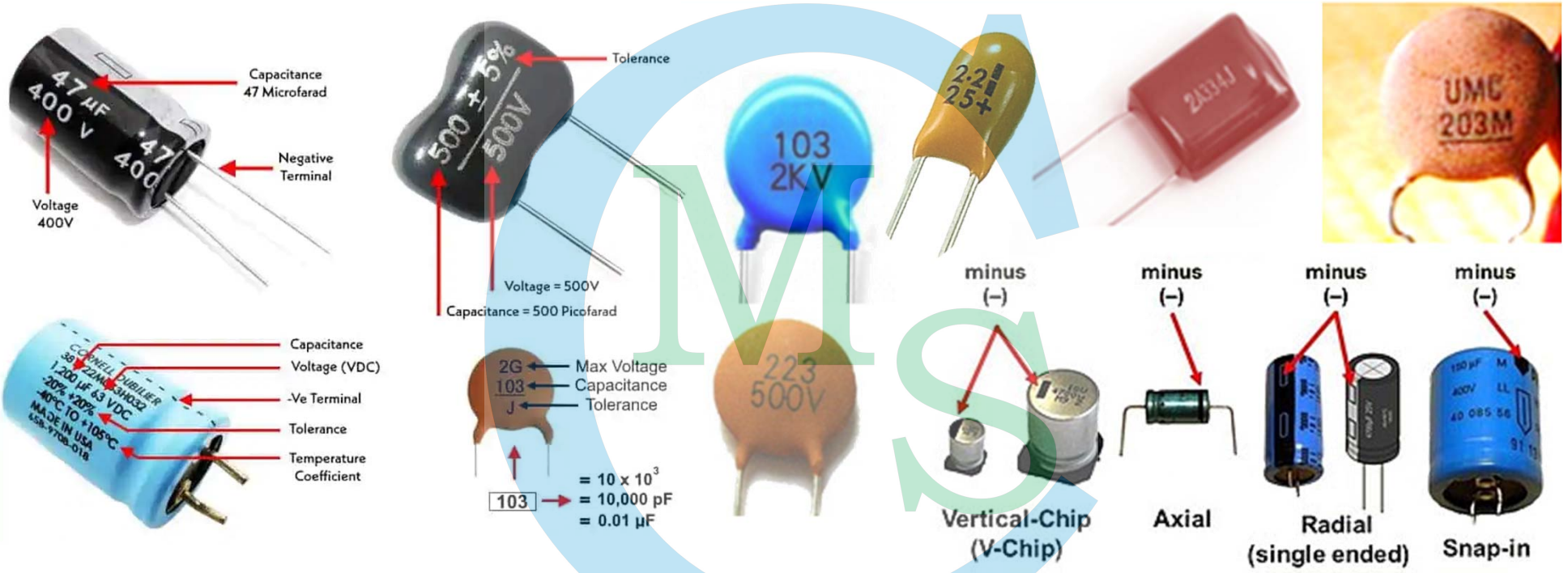
Code	Value		Code	Value		Code	Value
A	1.0		L	2.7		T	5.1
B	1.1		M	3.0		U	5.6
C	1.2		N	3.3		M	6.0
D	1.3		B	3.5		V	6.2
E	1.5		P	3.6		W	6.8
F	1.6		Q	3.9		N	7.0
G	1.8		D	4.0		X	7.5
H	2.0		R	4.3		T	8.0
J	2.2		E	4.5		Y	8.2
K	2.4		S	4.7		Y	9.0
a	2.6		f	5.0		Z	9.1

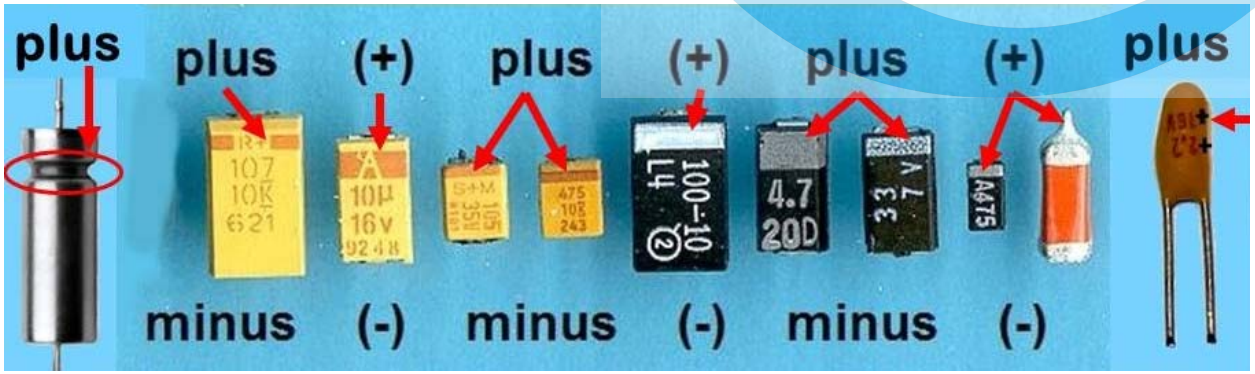
EIA-198 Multiplier Codes

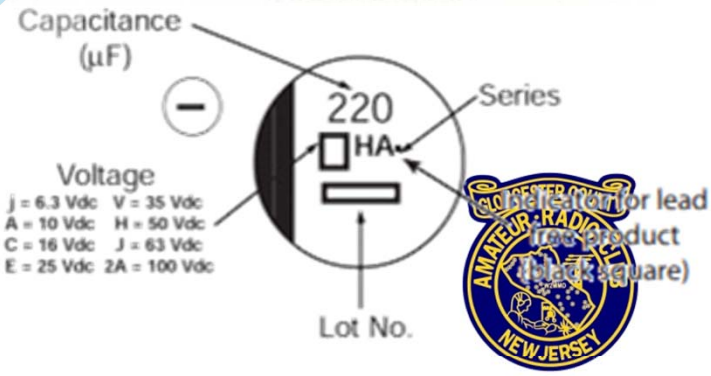
Code	Multiplier
0	x1
1	x10
2	x100
3	x1,000
4	x10,000
5	x100,000
6	x1,000,000
7	x10,000,000
8	x100,000,000
9	x0.1

- The combination of a letter and a number provides for the identification of a large array of capacitor values.
- This scheme does not provide any tolerance information.
- These codes will be on the surface of the capacitor.

Various Capacitor Markings







Questions?