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ISBN 1-580984-67-3

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Introduction

Components

An electronic component is any device that handles electricity. These devices come in many different shapes and sizes. Different components have different electrical functions and are used for a great variety of purposes. For example, some components may be used to slow electricity, and others may be used to store it.

Understanding Electricity

Electricity basically consists of voltage, measured in volts, and current, measured in amperes, or amps. Voltage is the electrical pressure, or force of electricity through a circuit. This is similar to the water pressure in a garden hose. Current is the amount of electricity that goes through the circuit.

Active vs. Passive

Components are active - meaning they can amplify or in[illegible] signals. Active components include diodes, transistors and integrated circuits, also called ICs. Other components are passive - meaning that they cannot change an electrical signal - except to reduce it in size or delay it. Passive components include resistors, capacitors and inductors.

Discrete vs. Integrated

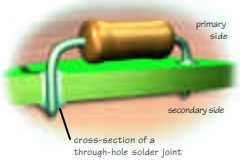
When a component is packaged with only one or two functional elements, it is called a discrete component. An example of a discrete component is a resistor that performs the simple function of limiting the electrical current that flows through it. On the other hand, an integrated circuit is a group of interconnected elements assembled into a single package that performs multiple functions. A well-known example of a complex IC is the microprocessor found in computers.

Electronic Assemblies

When a group of components are placed together on a printed circuit board to perform some function, it's called an electronic assembly. Circuit board assemblies are created by attaching and soldering the components by hand, or by machine.

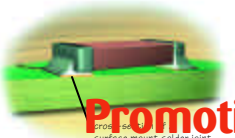
Through-Hole vs. Surface Mount

There are two primary types of components, the difference being how they are attached to the circuit board.



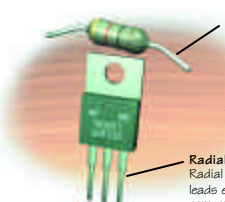
One group is called **through-hole.** Through-hole components have leads that are inserted through mounting holes in the circuit board.

The other type is called **surface mount.** Surface mount components are designed so they are placed directly onto lands that serve as mounting points on the surface of the board.



Through-Hole Leads

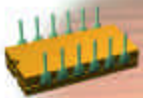
Through-hole leads are rigid metal wires that stick out of the component.



Axial Leads = Arms
Axial leaded components have two leads - with one lead extending from each side of the component, like arms. Axial components need to have their leads bent so they can be inserted through the holes of a circuit board.

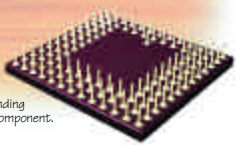
Radial Leads = Legs
Radial leaded components have two or more leads extending from the bottom of the component, like legs.

Single In-line Packages or **SIPs,** are through-hole componente that have a row of leads in a single, straight line.



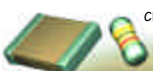
Dual In-line Packages or **DIPs,** are components that have two rows of leads in parallel straight lines.

Pin Grid Arrays or **PGAs,** are ICs that have several rows of round pins extending from the bottom of the component.



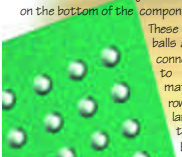
Surface Mount - Leadless

Leadless means there are no metal leads sticking out of the component body. These types of components are attached to a circuit board using some type of metallized termination.



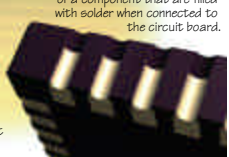
Chips & MELFs use terminations on opposite ends of the component's body.

Ball Grid Arrays, or **BGAs,** consist of rows of tiny balls of solder on the bottom of the component.



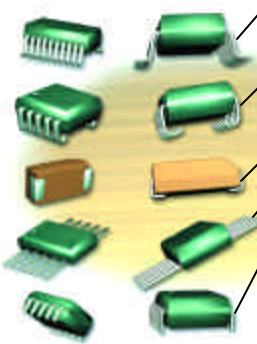
These solder balls are connected to matching rows of lands on the circuit board.

Castellations are half round metallized recesses in the side of a component that are filled with solder when connected to the circuit board.



Surface Mount - Leaded

Leaded surface mount components usually have one of five styles of leads: gull wings, J-leads, L-leads, flat leads or I-leads.



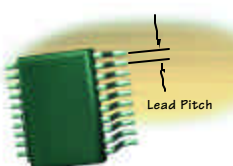
Gull Wing Lead: The gull wing lead is a metal lead that bends down and away - similar to a seagull's wing.

J-Lead: The J-lead is a metal lead that bends down and underneath a component in the shape of the letter J.

L-Lead: The L-lead is inward formed underneath a component.

Flat Lead: The flat lead protrudes directly out from the component.

I-Lead: The I-lead , or butt lead, is actually a through-hole lead that has been cut short for surface mounting. Because the connection is not very strong or stable, the I-lead is not considered suitable for high reliability assemblies.



Lead Pitch
An important characteristic of some leaded surface mount components is lead pitch. Pitch is the distance between the center of one lead to the center of the next. When a component has fine pitch it means the leads are spaced very close together (less than 15 mils).

Component Packaging

Component packaging refers to the way component manufacturers package their product for use by electronics assemblers. See Introduction to Electronics Assembly, IPC-DRM-53, for more about the assembly process. Through-hole and surface mount components are packaged in one of four ways: on tape and reel, in tubes, in waffle trays or in static-safe bags. The packaging method depends on the component type and whether the component will be assembled onto the circuit board by machine or by hand. Most component packages are made to protect the components from electrostatic discharge, or ESD, which could damage them.

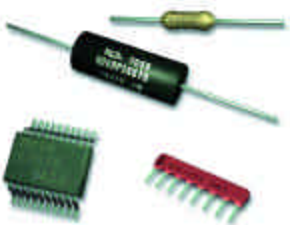
Tape and Reel
Tape reels are used for axial leaded through hole components and the smaller surface mount components. Automatic insertion machines cut through-hole components off tape reels and insert them into the board. Surface mount assembly machines, called pick and place, pick surface mount components from tape reels and place them on the board.

Tubes
Tubes are used to keep components straight and ready to drop into auto-insertion or auto-placement machines.

Waffle Trays
Waffle trays are used for many of the larger surface mount components. They are stackable on pick and place machines. Trays also provide protection for fragile leads during storage and handling.

Static-Safe Bags
Some components are simply packaged loose in static-safe bags. These components are usually simple through-hole axial and radial devices that are too large or unusually shaped to be inserted by machine.

Identifying Components



Every component has a manufacturer's part number. This number is either marked on the component itself, or on the packaging.

The bill of materials

And every assembly to be manufactured comes with an assembly drawing and a parts list, also called the bill of materials, or BOM.

The BOM lists the components by part numbers, quantities and reference designators.

The assembly drawing with diode hi-lighted

The assembly drawing shows the location of each component.

PWB reference designator for a diode

Component Reference Designators

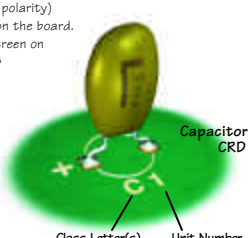
Close-up of a component legend printed on a through-hole PWB

Most of the PWBs made today have a **component legend** silkscreened onto them.

These letters and numbers identify the component to be placed in the holes or onto the lands next to each designation.

Also called the **silkscreen** or **Component Reference Designator (CRD)**, this legend is placed on the **component mounting (primary) side** [illegible] the other side of a through-hole board, like the one shown, is often referred to as the **solder (secondary) side.**

The silkscreen may also indicate the direction (for orientation or polarity) the component is to be placed on the board. SMT boards may have the silkscreen on both sides of the board, if it has components on both sides.



For more definitions of reference designators, see **ANSI Y32.16/ IEEE Std 200.**

For more definitions of component class letters, see **ANSI Y32.2/ IEEE Std 315, section 22.**

Common Class Letters for CRDs

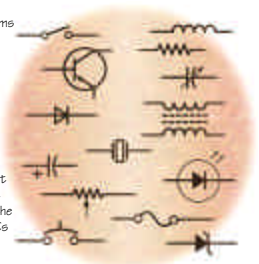
	ANSI/ IEEE	IEC	Other
Amplifier	AR	A	
Capacitor	C		
pack or network	C		CP or U
polarized	C		"+" (by the lead)
variable	C		C VAR, C ADJ
Connector	J or P		
Crystal	Y	B	
Delay Line	DL		D---
Diode	D or CR	V	
Light Emitting Diode	DS (Display)	E	LED, D, DIS, CR
Voltage Rectifier	D or CR	V	VR
Zener Diode	D or VR	V	
Filter	FL	Z	
Fuse	F		
Header	J or P		
Inductor, Choke	L		L
Integrated Circuit	U		IC
Insulated Jumper	W or P		J P
Jumper	W, P or R		JMP, J
Microprocessor	U		IC, MC, CPU
Oscillator	Y (crystal) orG (other)	G	OS
Relay	K		
Resistor	R		
pack or network	R		RN, RP, U
Potentiometer	R		VR, POT
Thermistor	RT		R
variable	R		VR, VAR, VRN, ADJ
Varistor			R, VAR
asymmetrical	D or CR		
symmetrical	RV		
Socket	X, XAR, XU, XQ, etc		TS, S
Switch	S		SW
Test Point or Pin	TP		TST or J
Transistor	Q	V	U
Transformer	T		X, TR
Voltage Regulator	VR		U

Schematic Symbols

Along with the assembly drawing and BOM, schematic diagrams are also used to specify assemblies.

Each discrete component has an associated symbol that is specified in IEEE (Institute of Electrical and Electronics Engineers) Standard 315 and 315A (ANSI Y32.2).

Components with multiple functions, such as an integrated circuit, do not use a specific schematic symbol but are often represented by a block in the schematic diagram. This includes ICs packaged as DIPs, SOICs, QFPs, PLCCs, PGAs or BGAs.

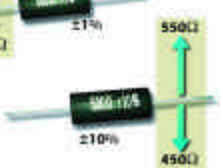


Value and Tolerance

Some components will have a value and tolerance associated with them. The value is a numerical quantity given to the component. This value is usually assigned a tolerance which is the amount of variation allowed from that value.

If a 500 ohm resistor has a **1%** tolerance, its acceptable measurement range would be **495 to 505 ohms.**

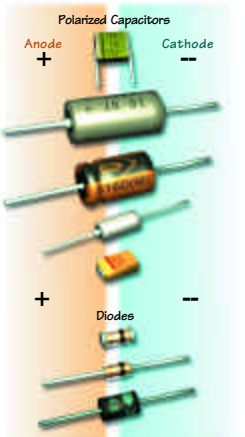
But, if the same 500 ohm resistor has a **10%** tolerance, its acceptable measurement range would be **450 to 550 ohms.**



Reading component values and tolerances is described in detail in the last section of this manual.

Polarity = Positive & Negative

Each component placed on a PWB or "board" has a specific function. Some components have a positive and negative connection to the board and so must be placed on the board in the correct orientation. This means that the correct lead–positive or negative–is in the correct hole, or on the correct land with surface mount components.



Components with this positive and negative connection are said to have **polarity.**

Anode & Cathode

The positive lead is called the **anode**.
The **negative** lead is called the **cathode**.

Polarity can be indicated on parts in a variety of ways.

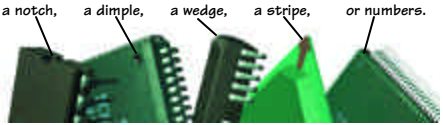
The symbol for a positive lead is the plus sign (**+**), although many components will not have this marking.

The symbol for the negative lead is the minus sign (**–**).

Markings and symbols for either the anode or cathode leads can take many shapes and forms. Markings on the PWB include a square land or pad, a "**+**" symbol, or a diode symbol silkscreened to the board to show the correct orientation.

Orientation = Position

Component **orientation** refers to situations when a component must be installed on the PWB a certain way, whether or not it has polarity. Orientation marks or symbols on a component's body include:



With multi-pin components, such as ICs, these orientation symbols indicate where "Pin One" of that component is located so that pin may be mated with the corresponding pad or land on the PWB. Many ICs have tens to hundreds of I/O (input/output) connection points. These may be pins, leads or terminations.

Also, matching orientation marks may be found on the PWB. These often include silkscreened symbols identical to markings on the component body (notch, dimple, stripe, etc.) or a square pad or land on the board, especially for multi-pin components.

The Square Land / Pad

The square land/pad is a common way to designate polarity or orientation. The square land is most often used by PWB designers to show where the marked lead or Pin One of a multi-pinned component should be placed. Matching Pin One of the component to the correct land or pad on the PWB is critical for the proper function of the component.

For components that have the positive or anode lead marked, like polarized capacitors, the square land typically indicates where the positive lead should be placed. For components which have the negative or cathode lead marked, such as diodes or LEDs, the square land indicates where the marked (negative) lead should be placed.

Square land / pad shows pin 1 orientation

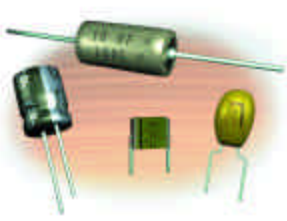
Note: Always verify the polarity against any drawings, schematics, silkscreen markings (or any other documentation from your board and component suppliers) as this may vary.

Capacitor *(Non-Polarized)*

Description: Capacitors store and discharge electricity. They consist of two metal plates, or conducting surfaces, separated by a insulating material called a dielectric. When voltage buildup in one plate, the charge is felt in the opposite plate. There are four basic types of non-polarized capacitors:

- Ceramic disc-radial
- Dipped mica-radial
- Mylar-radial, usually round or oval bodies
- Glass-packed axial, easy to mistake for diode or resistor.

Class letter: **C** (non-polarized)
Prefix: None
Value Code: Measured in microfarads (**µF**), nanofarads (**nF**) or picofarads (**pF**). The value is printed on the capacitor body using some form of abbreviation. Also specified is the operating voltage for the capacitor. These two values determine the physical size of the component.
Tolerance: Printed as percentage (example: ±5%) or as letter scheme.
Orientation: None



Capacitor *(Polarized)*

Description: Polarized capacitors function in the same way as non-polarized capacitors (see page 13).
Class letter: **C**
Other: **F** (by the lead)
Prefix: None
Value Code: Measured in microfarads (**µF**), nanofarads (**nF**) or picofarads (**pF**). The value is printed on the capacitor body using some form of abbreviation. Also specified is the operating voltage for the capacitor. These two values determine the physical size of the component.
Tolerance: Printed as percentage (example: ±5%) or as letter scheme.
Orientation: By polarity. A **Square land** on the PWB may mark where the positive lead (anode) is to be inserted.
Polarity: Polarized capacitors can be both axial or radial and will have one lead marked as postive (+). This positive lead can be marked or formed in several ways:

Symbols:
Plus (+); marks positive lead
Dot (•); marks positive lead
Band; marks positive lead
Line; the line can have pluses (+) leading to the positive leg or minuses (-) leading to the negative leg.
Arrows; arrows down the side lead to the negative end.

Continued. . .

Capacitor *(Polarized)*

. . . Continued:

Colors:
- **Silver square;** marks positive lead
- **Colored end;** marks positive lead

Shapes and forms:
- **Ridge or bevel;** marks positive lead
- **Groove;** marks positive lead
- **Bubble;** marks positive lead
  (if both ends have a bubble, the larger one is positive)
- **Larger lead;** the PWB holes are sized to match the larger lead.

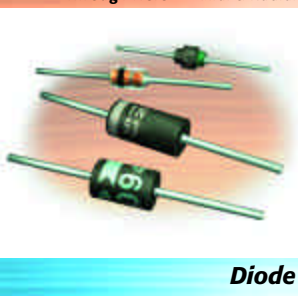
Variable Capacitor

Description: These capacitors can change capacitance by turning a screw that causes the plates to move closer or farther apart. The closer the plates, the higher the capacitance.
Class letter: C
Other: C VAR, C ADJ
Prefix: None
Value Code: Measured as a range, such as 27-200 µF.
Tolerance: None
Orientation: Non-symmetrical lead pattern allows it to be installed only one way.
Polarity: None

Crystal

Description: Crystals usually have metal bodies and produce a consistent electrical pulse. They are typically used as clocks, controlling the timing of events in digital circuits.

Class letter: Y
Other: B
Prefix: None
Value Code: Measured in megahertz (**MHz**), or kilohertz (**kHz**).
Tolerance: None
Orientation: Angled corner or dot
Polarity: None



Diode

Description: Diodes are semiconductors that only allow current to flow in one direction - like a one way street. They can convert alternating current to direct current. A zener diode acts as a voltage limiter for DC voltages. A diode's part number is usually specified by the prefix 1N, followed by two to four digit numbers. Examples include 1N53, 1N751 and 1N4148.

Class letter: D or CR
Other: V
Prefix: 1N
Value Code: None
Orientation: By polarity.
Polarity: Polarity is usually indicated by colored ring or up to three rings near the negative (cathode) end of axial diodes. An arrow may also point to the negative end. The PWB is marked with a stripe, line, or arrow symbol showing where the cathode end of the diode should be placed.

A **Square Land*** may also mark where the cathode end is inserted.

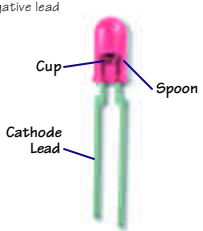
* See page 12, "The Square Land/Pad"

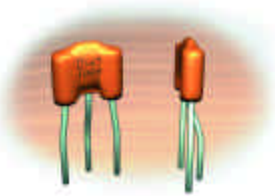
Light-Emitting Diode

Description: Also known as LED's, these components emit light.
Class letter: DS
Other: E, LED, D, DIS, CR
Prefix: None
Value Code: None
Tolerance: None
Orientation: By polarity.
Polarity: LEDs are usually radial leaded and polarity is typically indicated by the location of the cup and spoon inside the lens. The cup is associated with the cathode, or negative lead. The negative lead may also be shorter.

Square Land:
The PWB may also be marked with a square land showing where the cathode end is inserted and/or a silkscreened outline of the component body with a flat edge to indicate polarity.

See page 12, "The Square Land/Pad"





Filter

Description: Filters are used to pass one frequency or frequency band while blocking others. They are often used to filter out electrical noise in a circuit.
Class letter: FL
Other: Z
Prefix: None
Value Code: None
Tolerance: None
Orientation: The installation of filters is usually by lead configuration. The pattern of holes or lands on the PWB means there is only one way to insert the filter.
Polarity: None

Fuse

Description: Fuses consist of a wire with low melting point metal. When current passing through the fuse exceeds a prescribed level, the wire melts and opens the circuit, protecting equipment from damage.

Class letter: F
Prefix: None
Value Code: Measured in amps
Tolerance: None
Orientation: None
Polarity: None

A circuit breaker is a device that when exposed to excess current will "trip" or become electrically open and can be reset.

Class letter: CB

A Circuit Breaker Panel like the one in your home.

Inductor

Description: Inductors consist of a coil of wire that creates a magnetic field when current flows through the coil. Transformers, Coils and Toroids are related to inductors. (See Transformers on page 23). The toroid choke consists of a coil wound on a toroid, or doughnut of magnetic metal. The metal core increases the inductance of the coil.

Class letter: L
Prefix: None
Value Code: Measured in microhenry (**µH**) or millihenry (**mH**). The value is either printed on the inductor body or calculated by decoding 4 of 5 colored bands on the inductor body into numbers.
Tolerance: Printed as last of five-band color band system.
Orientation: None

Choke

Coil

Transformer

Description: Transformers are related to inductors. Transformers basically consist of primary and secondary coils wound on a common core of ferromagnetic material. When alternating current flows through the primary coil, the resulting magnetic field induces an alternating voltage across the secondary coil. The induced voltage can cause current to flow in an external circuit.

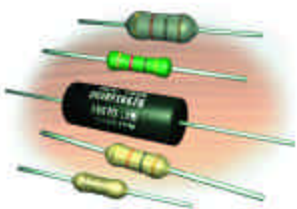
Class letter: T

Prefix: None

Value Code: Measured in microhenry (**µH**) or millihenry (**mH**). The value is printed on the body.

Orientation: Many transformers have non-symmetrical leads which only allow it to be installed one way.

Transformer mounted on a board



Resistor

Description: Resistors limit the flow of electrical current in a circuit. This is like a highway narrowing from six lanes to a single lane road. Fixed resistors are usually made of metal or carbon film. The bigger the metal film resistor, the greater its wattage rating (wattage is a measure of electrical power). Resistors can also be made of hot molded carbon. In addition, there are wire wound power resistors.

Class letter: R

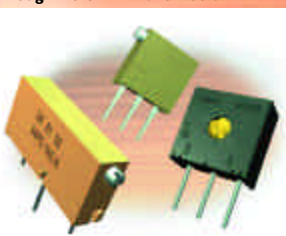
Prefix:
RC = color coded
RN = metal film
RCL = wire wound

Value Code: Measured in ohms (**Ω**). The value is either printed on the resistor body or is calculated by decoding 3 to 5 colored bands on the resistor body into numbers.

Tolerance: Printed on body or as part of color band system.

Orientation: None

Polarity: None



Variable Resistor

Description: Also called a potentiometer, trimpot or trimmer, a variable resistor is a resistor whose value can be changed by turning a shaft, screw or slider.

Class letter: R

Other: VR, VAR, VRN, ADJ

Prefix: None

Value Code: Measured in a range in ohms. Maximum value is usually molded into component body. Example: 20 MΩ.

Tolerance: None

Orientation: Non-symmetrical lead pattern only allows it to be installed one way. Pin One is usually identified. A square land may also mark where pin 1 is inserted.*

Polarity: None

* See page 12, "The Square Land/Pad"

Voltage Regulator

Description: Voltage regulators keep output voltage constant during variations of the output load or the input voltage. Typical uses like a TO220 package. .

Class letter: VR

Other: U

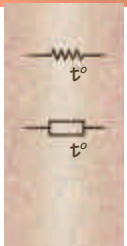
Prefix: None

Value Code: None

Tolerance: None

Orientation: Angle on the body or indented dot.

Polarity: None



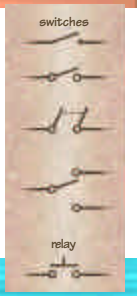
Thermistor

Description: Resists current flow based on temperature. Often looks like a disc capacitor.
Class letter: RT
Other: R
Prefix: None
Value Code: None
Tolerance: None
Orientation: None
Polarity: None

Transistor

Description: Transistors are semiconductors that can amplify, oscillate and provide switching action on electrical signals. Otherwise, transistors do not utilize units of measurement. Instead, their component type is usually specified by the prefix 2N or 3N, followed by two to four digit numbers. Examples include 2N50, 2N701 and 2N2222A.
Class letter: Q
Other: V or U
Prefix: 2N
Orientation: Indicated by one of several methods:

- **Pin Numbers** or pin names which match to the PWB silkscreen.
- **Tab** on the transistor "can". When looking down on the component from the top, pin one is either to the right of, or directly underneath the tab. The pins count counterclockwise from pin one.
- **Matching** component shape with PWB silkscreen outline: Outline on PWB includes the tab—align the tab. Outline on PWB includes the flat side of the transistor—align the flat side. Pattern of through-holes on PWB means there is only one way to insert the transistor.



Switch

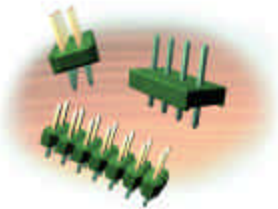
Description: Switches open and close a circuit.
Class letter: S
Other: SW
Prefix: None
Value Code: May have value rating for maximum current in amps. Example: **10 A.** May also have mechanical information such as **DPDT;** "double-pole, double-throw" printed on it.
Tolerance: None
Orientation: Dot or notch
Polarity: None

Relays are switches that open and close when actuated by an applied signal.
Class letter: K

A Relay on a partially assembled PWB

Connector

Description: Connectors are placed on a PWB so that wires, cables and other outside connections can be made to the PWB. They usually have a housing around their pins.
Class letter: P for MALE PLUG connector, or **J** for FEMALE JACK / RECEPTACLE connector.
Orientation: Bevel, notch or pin number molded into the package.
Polarity: None



Header

Description: Headers, like connectors are placed on a PWB so that outside connections can be made. Headers usually do not have a housing around their pins.

Class letter: **J** or **P**

Orientation: Usually none. Often has alignment or locking tabs for the connector which mates with it. Correct orientation of this tab is important.

Polarity: None

Jumper

Description: Also called jumper configuration, jumper wire or head pin configuration. Jumpers connect two pins on the PWB together, providing an electrical path between those points. Jumpers are sometimes used to solve circuitry errors in the PWB itself. Other times they are used to provide a way to change the assembly's configuration for different applications.

Class letter: **W,** or **E** for insulated piece of conductor (wire); or **P**, for a plug.

Other: **JP**

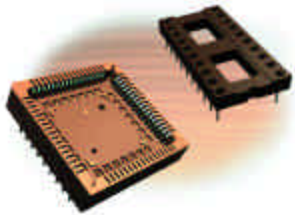
Prefix: None

Value Code: None

Tolerance: None

Orientation: Jumper goes into header socket

Polarity: None



Socket

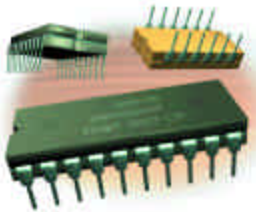
Description: Sockets are soldered onto circuit boards so that an IC can be plugged into the socket and not soldered directly to the board. This makes removing or upgrading components much easier. Sockets are sometimes used for components that cannot be soldered in place because of heat sensitivity.

Class letter: **X, XAR, XU, XQ,** etc..
Other: **TS, S**
Prefix: None
Value Code: None
Tolerance: None
Orientation: Sockets usually have a dot or a notch to indicate orientation to the PWB. Once installed, a socket may cover the PWB orientation mark, so it's important to place the socket correctly.

SIP

Description: **SIP** stands for **S**ingle-**I**n-line-**P**ackage. SIPs are often resistor networks (or packs) or diode arrays.
Class Letter: **RN** for resistor networks, **D** or **CR** for diode array, etc
Other: **RP, RN**
Prefix: None
Value Code: SIP packages sometimes hold banks of passive components. Those values may be marked on the component package. For example, eight 2K resistors would have the value: "8x2K."
Tolerance: None
Orientation: Determined by the location of lead one. A SIP IC's leads are numbered to ensure proper placement of the component on the circuit board or into a PWB-mounted socket. The orientation marking on most SIPs is usually right over lead one. The remaining leads are counted from lead one.

Lead One Markings: The most common markings for orientation on SIPs are numbers, a stripe or a dot.



DIP

Description: **D**ual-**I**n-line-**P**ackage. DIPs are usually made of plastic or ceramic (called CERDIP). They may include hundreds, or thousands of various components.

Class letter: **U**

Other: **IC** or **AR**, **C**, **Q**, **R**, etc.

Prefix: None

Value Code: DIP packages sometimes hold banks of passive components. Those values may be marked on the component package. For example, eight 2K resistors would have the value: "8x2K."

Lead Pitch: 100 mils

Orientation: Determined by the location of lead one. A DIP IC's leads are numbered to ensure proper placement of the component on the circuit board or into a PWB-mounted socket. The orientation marking on most DIPs is usually either right over lead one or on the end at which lead one is found. The remaining leads are counted counterclockwise from lead one.

Lead One Markings: The most common markings for orientation on ICs are:

- notch
- numbers
- stripe
- dimple
- wedge

Square Land: The square land is used to show the location of lead one on the PWB. Aligning lead one of the IC with the square land on the board ensures proper installation of the component.

IC Can

Description: IC Cans are often transistors or voltage regulators.

Class letter: **U** general IC, **Q** for transistor, **AR** amplifier, etc.

Other: [illegible]

Prefix: None

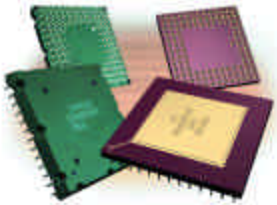
Value Code: None

Tolerance: None

Orientation: Determined by the location of lead one. An IC Can's leads are numbered to ensure proper placement of the component on the circuit board or into a PWB mounted socket.

The orientation marking on most IC Cans is usually a tab in the rim of the can over the highest numbered pin, or between pin 1 and the highest pin.

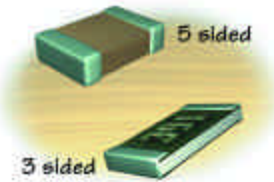
The pins are counted counterclockwise starting from the right of the tab when looking down on the top of the can.



PGA

Description: PGA stands for Pin Grid Array. PGAs have several rows of leads or pins extending from the bottom of the IC. The rows make up a grid of connection points. Shown are plastic packages (left) and ceramic packages (right).

Class letter: U
Other: IC or AR, C, Q, R, etc.
Prefix: None
Value Code: None
Tolerance: None
Orientation: Usually determined by the location of a notch in the package right over pin one. A corresponding mark on the PWB or socket provides proper alignment. Sometimes also by a missing pin on the component, or a missing hole on the board.
Square Land: A square base to one lead among the leads in a PGA is also used to show orientation. Aligning that lead with a matching square land on the board ensures proper installation of the component.



Chip Components

Description: Chip components are usually ceramic-bodied packages with metal connections called terminations at either end. The two most common types of chip components are ceramic resistors and capacitors. Five-sided chip components have a solderable surface on five sides of its terminal contact. The terminal contact is the area where the component is attached to the surface of the PWB. Three-sided components have a solderable surface on three sides of its terminal contact.

Chip Resistors

Class letter: R
Value: Measured in ohms (Ω).
Orientation: None
Polarity: None

Chip Capacitors

Class letter: C
Value: Measured in microfarads (µF) or picofarads (pF).
Orientation: None
Polarity: None Note: See Tantalum Capacitors, page 41

continued . . .

Chip Components

Reading Chip Resistor Value Codes

Sometimes the numeric value (ohms) may be printed on the chip resistor body. More frequently, this value code is printed on the label of the reel in which the chips are packaged. This is because the resistive element is too small, or will not allow for printing on the resistive element.

The code is a three- or four-digit number. With three-digit codes, the first two numbers are value numbers, and the third is the multiplier. For example: **102**, where **1** and **0** are attached to **2** zeroes to equal **1000** Ohms. With four-digit codes, the first three numbers are the value numbers, and the fourth number is the multiplier. For example: **1501**, where **1, 5,** and **0** are attached to **1** zero to equal **1500** Ohms.

For either code, a "**0**" (zero), in the multiplier position means don't add any zeros. Example: **150**, where **1** and **5** are attached to no zeros to equal **150** Ohms. A letter **R** in either code means to "place a decimal point at this spot." Example: **49R9** = **49.9** Ohms.

Tolerance Letter Codes

For some manufacturers, chip resistors with 3-digit codes are assumed to be 5% tolerance, and 4-digit chips are assumed to be 1%.

Tolerance can be decoded from this chart when letter codes are used.

B = ± .1%
C = ± .25%
D = ± .5%
F = ± 1%
G = ± 2%
J = ± 5%
K = ± 10%
M = ± 20%
Z = + 80/-20%

Chip Components

Reading Chip Capacitor Value Codes

Depending on the size of the chip capacitor, the value code may be printed on the body of the component, or on the label of the reel in which the chips are packaged. The code for a chip capacitor is a three-digit number expressing a value usually in picofarads (**pF**).

As with chip resistor three-digit codes, the first two numbers are value numbers, and the third is the multiplier. Example: **221**, where **2** and **2** are attached to **1** zero to equal **220 pF.**

A "**0**" (zero) in the multiplier position for capacitors means no zeros are added to the value. A letter **R** is a decimal point holder. Tolerance comes in many varieties and may be shown with letter codes using the key chart at the bottom of the previous page.

Size Codes

A chip's size, in inches or millimeters, is described by a 4-digit code:

Size Codes (inches)		Size Codes (metric)	
0402	.04" x .02"	**1005**	1.0 x 0.5 mm
0603	.06" x .05"	1508	1.5 x 0.8 mm
0805	.08" x .05"	2012	2.0 x 1.2 mm
1005	.10" x .05"	2512	2.5 x 1.2 mm
1206	.12" x .06"	3225	3.2 x 2.5 mm
1210	.12" x .10"	4532	4.5 x 3.2 mm
1812	.18" x .12"	5664	5.6 x 6.4 mm
2225	.22" x .25"		

It is important to be certain of which measurement system a size code is in.

(inches or **millimeters)**

The first 2 digits are **the length.**

the second 2 digits are **the width.**

Tantalum Capacitors

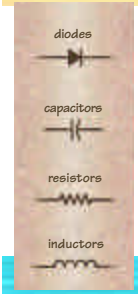
Description: Molded Tantalum Capacitors are polarized chip capacitors with inward formed L-leads. These leads almost touch the body of the component. Inside are metal foils that store and discharge electricity.

Class letter: C
Prefix: None
Value Range: 0.001 µF to 1000 pF, 4 to 100 V dc.
Tolerance: None
Orientation: By polarity.
Polarity: Line, + or A on anode end. Beveled top on anode end.

Size Code: A tantalum capacitor's size is described by one of four letters: **A, B, C,** or **D.** These four size codes stand for metric footprints of length and width.

Tantalum Capacitor Size Codes

A = 3.2 x 1.6 mm
B = 3.5 x 2.8 mm
C = 6.0 x 3.2 mm
D = 7.3 x 4.3 mm



MELF

Description: **M**etal **EL**ectrode **F**ace (**MELF**) leadless components have metallized terminals at both ends of a cylindrical body. Typical MELF components include diodes, resistors, capacitors and inductors. Polarity, value coding and CRDs are the same for these components as for their surface mount chip and through-hole counterparts. The smallest of the MELFs are called "mini-MELFs" and "micro-MELFs."

Class letter: Depends on component type.
Prefix: None
Value Code: Resistors have 4 or 5 bands which convey their value.
Tolerance: Resistors have a tolerance band.
Orientation: By polarity.
Polarity: MELF diodes have a band at the cathode end.

Sizes: MELF resistors are designed to fit same footprints as chip resistors, such as the 0805 (.08 x .05 inches) and the 1206 (.12 x .06 inches).

SOT

Description: **S**mall **O**utline **T**ransistors (**SOTs**) are rectangular transistor or diode packages with two or more gull-wing leads. The most popular size is the SOT23. Other popular sizes include the SOT89, SOT143 and SOT 223. SOTs have 3 or 4 gull wings on two sides of their package.

Class letter: **Q** for transistor packages; **D** or **CR** for diode packages.

Prefix: None

Value Code: By package size.

Tolerance: None

Orientation: Determined by lead pattern, or number one lead.

Polarity: None

DPAK

Description: **DPAKs** are **D**iode **Pack**ages, which accommodate higher powered groups of transistors and diodes. D2PAKs are the largest surface mount transistor made and include a heat sink mounting pad. DPAKs have 3 gull wings on two sides of package.

Class letter: **Q** for transistor packages; **D** or **CR** for diode packages.

Prefix: None

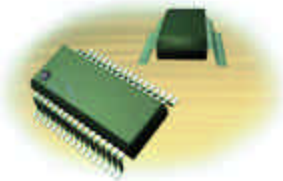
Value Code: Determined by package size.

Tolerance: None

Orientation: Determined by lead pattern.

Polarity: None

Sizes: SOTs and DPAKs are designed to fit the same footprint as their through-hole cousins. For instance, a D2PAK is designed to fit the TO220 through-hole transistor.



SOIC

Description: SOIC stands for Small Outline Integrated Circuit. The SOIC family is made up of nearly a dozen different IC's with a variety of body sizes and lead styles. The number of leads varies also, and is determined by the size of the IC's body. SOICs are usually referred to by their abbreviation, which may or may not include an "IC" at the end. This makes for some confusion as the same package may be called by more than one name. Also, some SOIC names have contradictory words in them. For instance, a SOL and a SOLIC are both names for the same IC—a Small Outline Large IC.

# of Pins: 8-56

Body Width: Various

Lead Type: Gull-wing, J-lead, flat and I-lead

Lead Pitch: From 19.7 to 50 mils

Class letter: U

Other: IC or AR, C, Q, R, etc.

Value: None

Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.

SO

Description: SO stands for Small Outline. The original SOIC.

# of Pins: 8-16

Body Width: [illegible] (3.97 mm)

Lead Type: Gull-wing

Lead Pitch: 50 mil (1.27 mm)

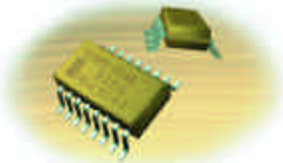
Class letter: U

Other: IC or AR, C, Q, R, etc.

Value: None

Orientation: Indicated by a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.

Polarity: None



SOM

Description: SOM stands for Small Outline, Medium. Commonly used for resistor networks.
# of Pins: 8-16
Body Width: 220 mils (5.6 mm)
Lead Type: Gull-wing
Lead Pitch: 50 mil (1.27 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None

SOL / SOW

Description: SOL stands for Small Outline, Large; SOW stands for Small Outline, Wide. The name SOP, or Small Outline Package is also used for this IC.
# of Pins: 8-32
Body Width: 300-440 mils (6.63 - 12.2 mm)
Lead Type: Gull-wing
Lead Pitch: 50 mil (1.27 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None

SOL-J

Description: SOL-J stands for Small Outline, Large, J-Lead. Also called the SOJ.
# of Pins: 16-40
Body Width: 300-440 mils (6.63 - 12.2 mm)
Lead Type: J-lead
Lead Pitch: 50 mil (1.27 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None

VSOP

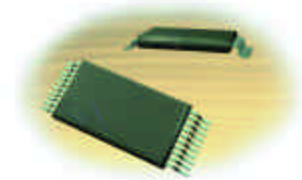
Description: VSOP stands for Very Small Outline Package. Higher density gull-wing leads. Sometimes the name VSOP is used interchangeably with SSOP.
# of Pins: 32-56
Body Width: 300 mils (6.63 mm)
Lead Type: Gull-wing
Lead Pitch: 25 mil (0.65 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None

SSOP

Description: SSOP stands for Shrink Small Outline Package. Same as VSOP but with smaller case.
# of Pins: 8-30
Body Width: 208 mils (5.3 mm)
Lead Type: Gull-wing
Lead Pitch: 25 mil (0.65 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None

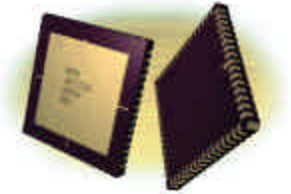
QSOP

Description: QSOP stands for Quarter Small Outline Package. Same as the original SO, but with 25 mil lead pitch instead [illegible]
# of Pins: 16-56
Body Width: 156 mils (3.97 mm)
Lead Type: Gull-wing
Lead Pitch: 25 mil (0.65 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None



TSOP

Description: TSOP stands for Thin Small Outline Package. Low profile package is only 1.0mm in height.
# of Pins: 20-56
Body Width: 208 mils (5.3 mm)
Lead Type: Gull-wing
Lead Pitch: 19.7 mil (0.5 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.
Polarity: None



LCC

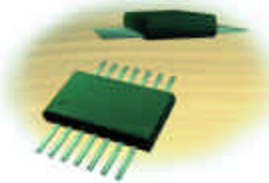
Description: LCC stands for Leadless Chip Carrier. LCCs are most commonly used in aerospace applications. LCCs are rugged and have no leads to bend. They are sometimes called LCCC for Leadless Ceramic Chip Carrier.
# of Pins: 16 - 124
Body Type: Ceramic body, very rugged and able to withstand severe operating conditions, like high temperatures.
Lead Type: Solderable castellations
Lead Pitch: 50 mil (1.27 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one castellation, or an end notch or stripe on the IC.

Castellations are counted counterclockwise from number one. The PWB often has a square silkscreened at the pin number one location.

PLCC

Description: **P**lastic **L**eaded **C**hip **C**arrier. PLCCs fit into IC sockets or may be soldered directly to the PWB. A ceramic version of this IC package is called a LCCC or **C**eramic **L**eaded **C**hip **C**arrier. This name is easily confused with the LCCC which is a leadless component.

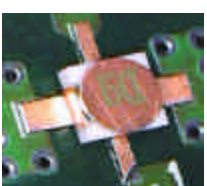
Lead Type: J-lead
# of Pins: 20 - 100
Body Type: Plastic
Lead Pitch: 50 mil (1.27 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead when looking down at the component from the top. The PWB often has a square silkscreened at the pin one location.



Flat Lead Package

Description: Flat lead packages have leads extending from two sides.
# of Pins: 10 - 16
Body Type: Plastic
Lead Pitch: 50 mil (1.27 mm)
Class letter: U
Other: IC or AR, C, Q, R, etc.
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead when looking down at the component from the top. The PWB often has a square silkscreened at the pin one location.

shown here is the Flat Lug Lead, another type of flat lead device.

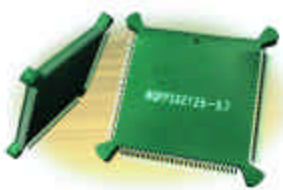


QFP (MQFP)

Description: **QFP** stands for **Q**uad **F**lat **P**ack. Also commonly called the **MQFP,** for **M**etric **QFP**. The QFP family is made up of a variety of different ICs. The "quad" part of the name tells us that leads extend from all four sides of the package. QFPs are high lead count, fine lead pitch devices. QFPs, like most ICs, are usually referred to by their abbreviation, which may or may not include a "QFP" at the end. A metal body version of the QFP is called the MQUAD®, a registered trademark of the Olin Corporation. A ceramic body, internal multilayer version of the QFP is called the CQFP.

# of Pins: 44-132
Body Type: Plastic (Also metal and ceramic)
Lead Type: Gull-wing
Lead Pitch: 11.8 mil (0.3 mm) to 25.6 mil (0.65 mm)
Class letter: U
Other: **IC or AR, C, Q, R,** *etc.*
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.

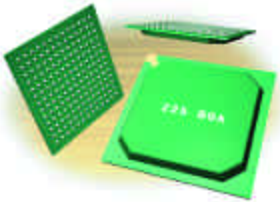
Surface Mount • Large Scale ICs



PQFP

Description: **PQFP** stands for **P**lastic **Q**uad **F**lat **P**ack. The PQFP is essentially the same as a QFP except that each corner has a "bumper." These bumpers protect the leads during handling and assembly. PQFPs are built with true inch measurements of their lead pitch. The 25 mil lead pitch version is .635mm, not the more common .65mm.

# of Pins: 44-132
Body Type: Plastic
Lead Type: Gull-wing
Lead Pitch: 25 mil (0.636 mm)
Class letter: U
Other: **IC or AR, C, Q, R,** *etc.*
Value: None
Orientation: Indicated by a dot or a beveled edge over the number one lead, or an end notch or stripe on the IC. Leads are counted counterclockwise from the number one lead. The PWB often has a square silkscreened at the pin one location.



BGA

Description: BGA stands for Ball Grid Array. Instead of conventional leads they use row upon row of tiny metal balls that are soldered to a matching set of lands on the PWB. The rows make up a grid of connection points.

# of Pins: 25 - 625

Body Type: Plastic, metal or ceramic

Lead Type: Ball grid

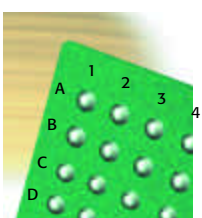
Lead Pitch: 1.5 mm and 50 mil (1.27 mm)

Class letter: U

Other: IC or AR, C, Q, R, etc.

Value: None

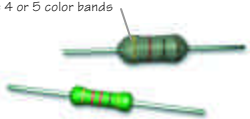
Orientation: Indicated by a dot or a beveled edge over the A1 lead, or an end notch or stripe on the IC. Leads are counted using a grid system, similar to a road map, starting with the A1 lead. The PWB often has a square silkscreened at the A1 location.



Axial Resistor Values

The value of a resistor is expressed in a unit of electrical resistance called ohms (Ω).

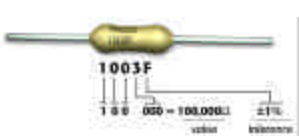
Axial resistors will often have 4 or 5 color bands which are "read" using a **Resistor Band Color Code Chart, page 62.**



Axial resistors will sometimes have their wattage and tolerance values printed on them in number codes.

Numbered Resistors

The example below shows how to read the value and tolerance when a number and letter code system is used. You are provided with the value and multiplier numbers, such as the **1003** example where the **100** is attached to **3** zeros to equal **100,000Ω**



Tolerance Letter Codes

Tolerance is shown with letters using these codes:

F = ±1%
G = ±2%
J = ±5%
K = ±10%
M = ±20%
Z = +80/-20%

4-band Resistors

Value Bands: The first two color bands on 4-band resistors are read as actual numbers.

Multiplier Band: The third band on 4-band resistors is called a "multiplier band" because that color's number on the color chart shows how many zeros to add to the end of the numbers from the first two bands.

Tolerance Band: The last band is the tolerance.

5-band Resistors

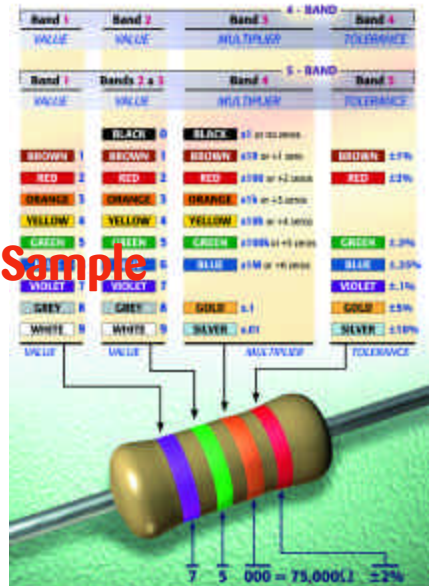
Value Bands: The first three color bands on 5-band resistors are read as actual numbers.

Multiplier Band: The fourth band on 5-band resistors is called a "multiplier band" because that color's number on the color chart shows how many zeros to add to the end of the numbers from the first three bands.

Tolerance Band: The last band is the tolerance.

Military 5-Band: A fifth, white band in a military 5-band resistor means that the resistor has Military Solderable Leads. Ignore the fifth band, and read as a 4-band resistor.

RESISTOR Band Color Codes



Capacitor Values

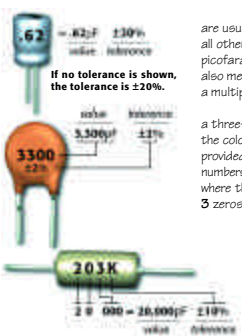
The value of a capacitor is expressed in a unit of electrical capacitance called farade. A capacitor will have the value and tolerance marked on its body. There are three units of measurement for capacitors, using farads:

- picofarads **pF**, The smallest unit of measurement.
- nanofarads **nF**, The middle range unit of measurement.
- microfarad **µF**, The largest unit of measurement.

The values on capacitors are usually printed in picofarads. The chart below will help you convert from picofarads to nanofarads to microfarad:

picofarads - pF		nanofarads - nF		microfarad - µF
100,000,000	=	100,000	=	100
10,000,000	=	10,000	=	10
1,000,000	=	1,000	=	1
100,000	=	100	=	.1
10,000	=	10	=	.01
1,000	=	1	=	.001
100	=	.1	=	.0001
10	=	.01	=	.00001
1	=	.001	=	.000001
.1	=	.0001	=	.0000001

Numbered Capacitors



Values beginning with a decimal are usually measured in microfarads (**µF**), all other values are assumed to be in picofarads (**pF**). Four-digit values are also measured in picofarads, but without a multiplier. (see 3300 cap shown left)

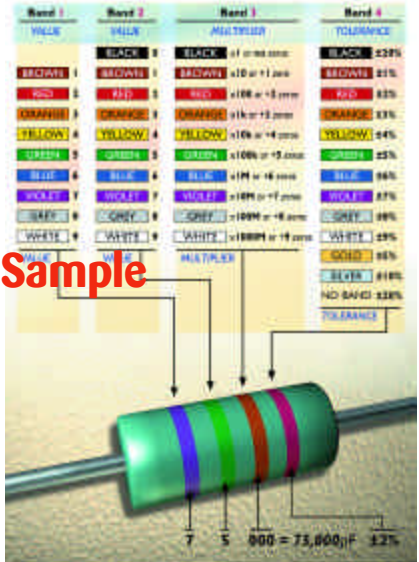
Some capacitors are coded with a three-digit number which is similar to the color-band system, except you are provided with the value and multiplier numbers, such as the **203** example below where the **2** and **0** are attached to **3** zeros to equal **20,000 pF** (or .02 **µF**).

Tolerance Letter Codes

Tolerance is shown with letters using these codes:

F =	±1%
G =	±2%
J =	±5%
K =	**±10%**
M =	±20%
Z =	+80/-20%

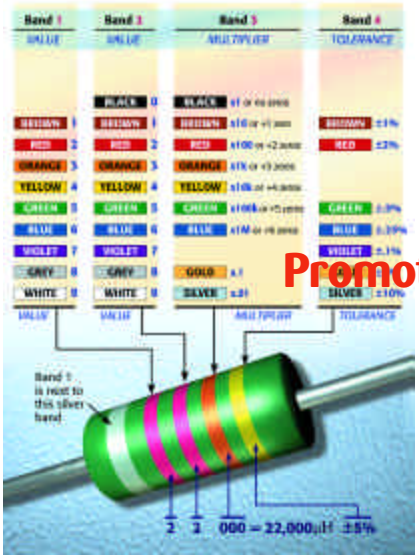
CAPACITOR Band Color Codes



Reading a 4-Band Capacitor

The first two bands' colors tell you numbers. The third bands' color tells you how many zeros to add after the first two numbers. The last band is tolerance. If there is no last band the tolerance is ±20%

INDUCTOR *Band Color Codes*



Inductors are valued in microhenries. The symbol for microhenries is µH. The value for an inductor may be printed on the component body, or it may be printed with color bands, much in the same way as a resistor.

If you have comments or suggestions regarding this Desk Reference Manual,

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DRM-18
original - 9/95 -1m
revision A - 4/96 -5m
revision B - 2/97 -5m
revision C - 7/98 -5m
revision D - 7/99 -5m
revision E - 8/00 -5m
revision F - 8/01 -5m