

# The Handyman's Guide to CAPACITORS

Capacitors comprise the largest variety of electronic components. There are many types of capacitors, great variations in their performance, many methods of packaging and marking. and dozens of major manufacturers not to mention new types constantly being introduced with specific applications and performances As result, capacitors open cause lots of problems for homebrewers. Hopefully this article will take some of the mystery out of the myriad of capacitors available, plus present some of the classic "do's and don'ts"

## PRINCIPAL CAPACITOR TYPES

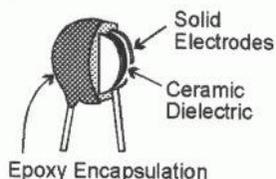
There are many capacitor types, which usually refers to the material used for the electrodes, dielectric, and the packaging or sealing method. Here are some of the major capacitor types used by QRPers:

### DISK CERAMIC CAPACITORS



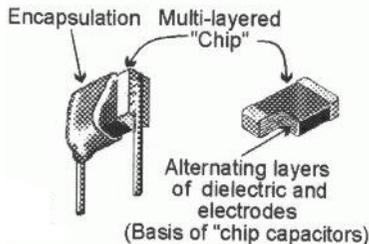
Disk Ceramics consist of two metallic plates separated by a ceramic dielectric whose area and spacing determines the capacitance. These caps are low cost and suitable for many applications Their main

disadvantage is high capacitance changes with temperature (high temperature coefficient), except for the "NPO" varieties that are temperature stable. These caps are the most commonly used for general purpose circuits, but the non- NPO types should be avoided in frequency determining circuits



### MONOLITHIC CERAMIC CAPACITORS

Alternating layers of electrodes and ceramic dielectric allow higher capacitances in physically smaller packages. Their characteristics are very similar to disk ceramics. They are encapsulated in epoxy to withstand insertion, soldering and solvent cleaning by the automatic PCB



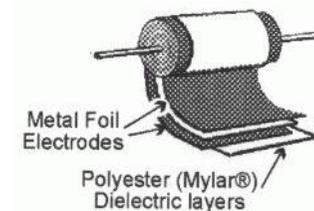
assembly machines. Introduced for mass

production, they are inexpensive and available from surplus dealers



### POLYESTER FILM CAPACITORS

Polyester Films use layers of metal and polyester (Mylar®) dielectric to make a wide range of capacitances in a relatively small package at low voltages. These have become the standard caps for DC applications The "rolled" film layers cause



vs. temperature problems and should be used carefully in high frequency or high current applications

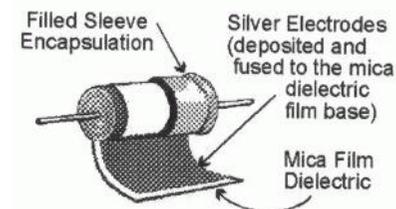
### POLYPROPYLENE FILM CAPACITORS

Polypropylene Films use layers of metal and polypropylene dielectric films virtually identical to Polyester Film caps. The polypropylene however, is a dielectric offering a higher breakdown voltage than polyester, and thus more suitable for high voltage applications. such as switching power supplies. They also have low loss factors and good capacitance stability making them a good choice for high frequency applications, including oscillators and other frequency sensitive circuits. The main disadvantages are slightly higher cost, and larger physical sizes over other film dielectric capacitors.



### SILVER MICA CAPACITORS.

This is a type of capacitor known as *metalized film* capacitor, in that the electrodes are a metal deposited by a sputtering process onto the dielectric Film. Silver Mica's use a mica film dielectric with a thin layer of deposited silver forming the electrodes. These are very stable capacitors for high frequency circuits and the preferred choice for VFO and oscillator circuits. The main disadvantage are their higher cost. low operating voltages, and sometimes hard to find from hobby vendors.



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## POLYCARBONATE FILM CAPACITORS

These capacitors have become the standard for high stability MIL-SPEC film dielectrics. Their very low dissipation and extreme temperature stability make them almost the ideal capacitor -- *at a price!* They are very expensive capacitors and not available from the hobby vendors. but listed herein the event you have the opportunity to appropriate some!

## ELECTROLYTIC CAPACITORS

Aluminum Electrolytics are the most common, inexpensive electrolytic available from all hobby vendors They are made similar to the polyester films using aluminum foil electrodes and a dielectric material rolled into layers to increase the effective plate area to form high capacitances in small packages. The aluminum foil is "wetted" with a chemical agent to assist in conduction and increases the dielectric properties when a DC voltage is applied. This wetting agent can dry out after long periods of no use, or exceeding the rated voltage, causing a breakdown of the dielectric and component failure (usually a short circuit between the terminals).



This is why electrolytics are often found shorted in older equipment that has not been powered for years. This is seldom a problem with equipment that is periodically powered up. These inexpensive aluminum electrolytic caps are suitable in all QRP applications.

## TANTALUM CAPACITORS

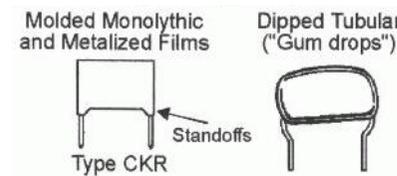
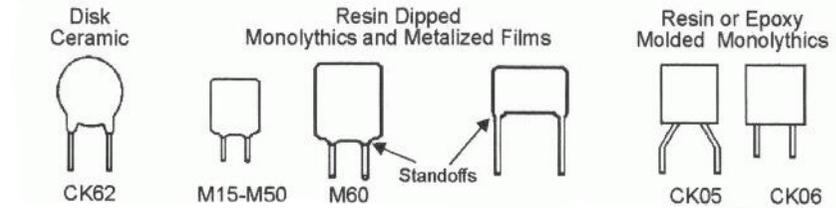
Tantalum's are a most unusual process that yields a high reliable electrolytic with along life. Tantalum pentoxide powder is mixed with a manganese dioxide electrolyte and formed into a "pellet" forming *both* the dielectric and the positive electrode plate. Graphite or silver plating forms the negative plate. This "pellet" forms a *very large effective plate area*, and thus very high capacitances to very small packages. Both wet and dry electrolytes are used, and called *wet* or *dry* tantalums. There are few QRP applications where tantalum's would be *a must*, but if you have them -- use them! The chief disadvantages are higher cost due to the complicated manufacturing process, and ensuring you never reverse the polarity. A small positive voltage on the negative terminal can fuse the "pellet"



## PRINCIPAL PACKAGING STYLES

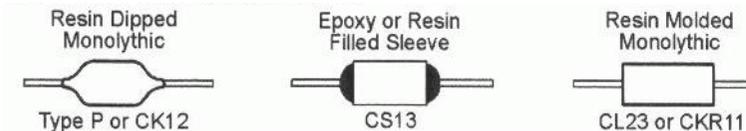
In addition to the capacitor types, (ceramic, metalized films etc.), the packaging *style* is also important and often required when ordering. The major capacitor packaging styles are shown below, which can also be used as an aid in identifying unknown capacitors.

## CAPACITORS WITH RADIAL LEADS



Conformal Coating is stated on modern data sheets, rather than specifying the actual encapsulation material. This means an epoxy or resin agent is used suitable for automatic insertion, wave soldering and industrial cleaners. Conformal coatings are more durable than coatings used on older type capacitors.

## CAPACITORS WITH AXIAL LEADS



## ORDERING/SPECIFYING CAPACITORS

When ordering capacitors, obviously the first concern is the capacitance, voltage rating and capacitor type needed. However, the *temperature coefficient* (TC) should be considered in frequency sensitive circuits (oscillators, VFO's, etc.) and the *dissipation factor* (DF) or Q when efficient energy transfer is needed (interstage coupling, active filters etc) or high peak to peak voltages (transmitter output filter caps).

## TEMPERATURE COEFFICIENT

The temperature coefficient (TC) is the change in capacitance vs. a change in temperature. The ideal capacitor should have very little capacitor change with temperature, but as the charts show below, some capacitor types are far from ideal!

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The most common ceramic/monolithic ceramics are **X7R**, **Z5U** and **Y5V**. The **Z5U** and **Y5V** have a large temperature coefficient (and large dissipation factor -- see below) and should not be used in frequency critical circuits or for coupling between stages. They are suitable for other general purpose applications and for DC and bypassing caps.

**X7R's** are the next best with moderate capacitance change vs. temperature and suitable as a general purpose capacitor and can be used in oscillator circuits where moderate drift is acceptable.

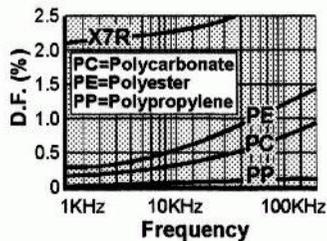
**NPO (or COG)** are those ceramics made with a temperature stable dielectric which exhibits very little capacitance change with temperature. NPO's (N-P-zero) are recommended for oscillators and frequency sensitive circuits.

**FILM CAPACITORS**, such as the polyester and polypropylene, have much better capacitance stability VS. temperature than the general purpose ceramics, as also shown in the charts. Polyester caps are quite stable until about 120F.

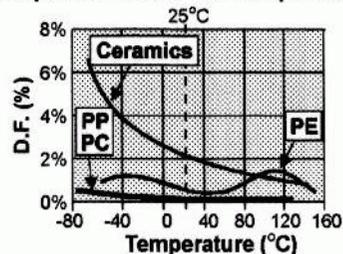
**DISSIPATION FACTOR (DF)**

The Dissipation Factor (DF) is the ratio of the energy dissipated (lost) to the energy stored in the capacitor. The DF is frequency sensitive and specified at a certain frequency, such as 1KHz (for ceramics). **The Quality Factor (Q)** is the ratio of the energy stored vs. the energy dissipated-or the opposite of the dissipation factor. Film capacitors are usually specified by their "Q" factor.

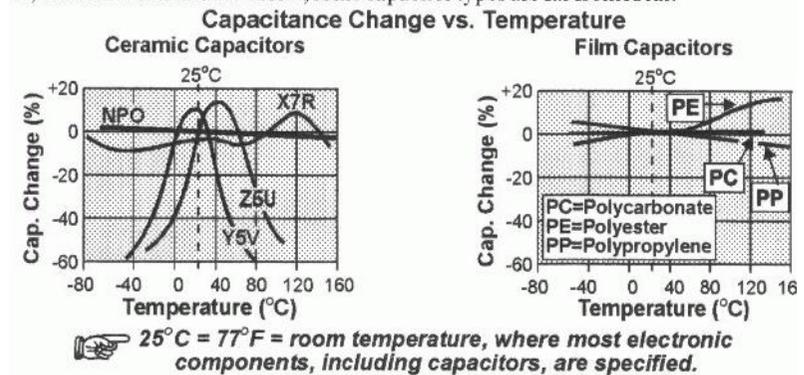
**Dissipation Factor vs. Frequency**



**Dissipation Factor vs. Temperature**



Capacitors used for coupling small signals between stages, in active filters, the shunt caps on crystal filters, or in the transmitter output filter, should use low DF caps. Most all polyfilm, caps and some monolithic ceramics meet this requirement. Old ceramic caps in your transmitter output filter should be replaced with a low DF capacitor type, as a high DF cap here can absorb a surprising amount of your output power, and us QRPers need to get as much of that power to the antenna as we can.



**THE BOTTOM LINE**

Ceramics that are not NPO make good general purpose capacitors for bypass caps, etc. but should not be used for interstage coupling or in oscillators. When ordering new caps, I would recommend purchasing the monolithic ceramics for their lower cost.

**NPO Ceramics** (especially the monos) are a good choice for oscillator circuits.

**Film Dielectrics** are a good choice for a general purpose capacitor with low dissipation factors and good temperature characteristics. With their reasonably low cost, and about the same as ceramics, they would be today's preferred choice when purchasing new capacitors due to the low cost and about the same performance characteristic.

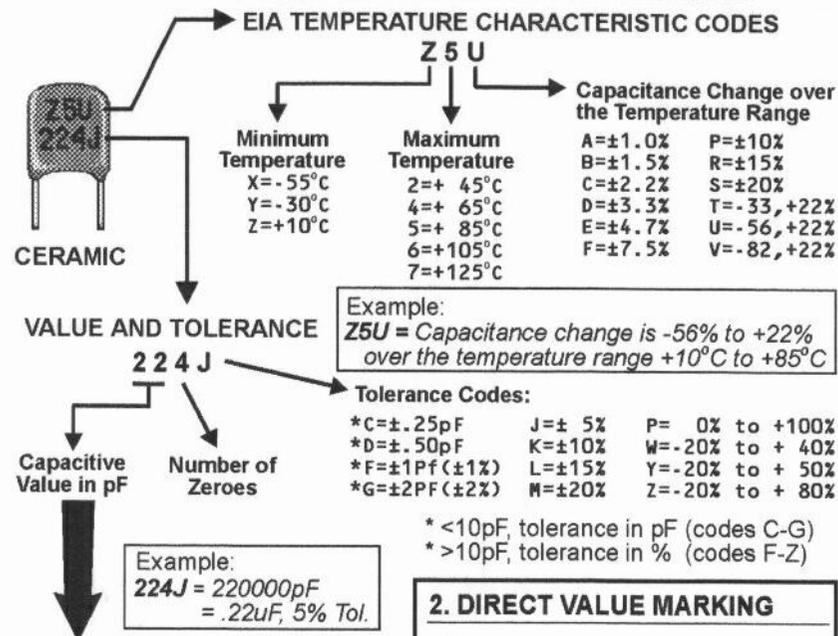
When ordering caps, look at the specifications carefully for TC and DF, along with the information and charts in this article. to make the best choice, performance vs. cost.

**REFERENCE INFORMATION**

The information on the following pages is meant to be a general reference guide to assist in identifying capacitors, specifications and standard values.

<p>Title: The Handyman's guide to Capacitors.          Author: Paul Harden, NA5N (NA5N@Rt66 com)          With grateful thanks to George Heron N2APB - editor of QRP Homebrewer where this article first appeared.          Page 3 of 4</p>	 <p><b>GQR Club          Datasheet</b></p>
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### 1. EIA IDENTIFICATION MARKINGS FOR CERAMICS



**EIA DECADE VALUES:**

1R0 = 1pF	103 = .01uF
100 = 10pF	104 = .1uF
101 = 100pF	105 = 1uF
102 = .001uF	106 = 10uF

Ex.: 203=.02uF, 473=.47uF, 503=.05uF, 5R1=5pF, 220=22pF, 221=220pF, etc.

### 2. DIRECT VALUE MARKING

Some manufacturer's mark the capacitance value directly on the case, along with other information. Ceramics will use the EIA codes (Z5U, X7R, etc.) while non-ceramics will use the industry codes (NPO, N150, etc.) for the temperature coefficient.

### 3. INDUSTRY MARKINGS FOR MONOLYTHIC & FILM CAPACITORS

Non-ceramic capacitors use the EIA markings for the capacitance value and tolerance. However these dielectrics, such as polyester or polypropylene, have a linear change in capacitance per °C and thus the temperature coefficients are expressed in parts-per-million (ppm)/°C or in %/°C. A few of the common industry (non ceramic) and EIA (ceramic) markings are shown in the table.

Temperature Coefficients (TC) Ceramics (EIA) & Films Dielectrics		
EIA#	INDUSTRY	T.C. (ppm/°C)
COG	NPO	0ppm/°C
S1G	N033	-33ppm
U1G	N075	-75ppm
P2G	N150	-150ppm
S2H	N330	-330ppm
U2J	N750	-750ppm
P3K	N1500	-1500ppm

### 4. COLOR CODING SCHEMES

Capacitor color coding schemes have all but disappeared except on some foreign made ceramics and dipped tantalums. The prevalent schemes are shown below.

#### CURRENT COLOR SCHEMES (STILL IN USE)

##### DIPPED TANTALUM CAPACITOR

**Use Table 1**

1st Digit  
2nd Digit

Multiplier  
-01 Gray  
-1 White  
1 Black  
10 Brown

Voltage Rating

3v White	20v Blue
6.3 Yellow	25v Gray
10v Black	35v Pink
16v Green	

#### MONOLYTHIC CAPACITOR

**Use Table 1**

1st Digit  
2nd Digit  
Multiplier  
Tolerance

Voltage

Brown	100v
Red	200v
Yellow	400v

Black ±20%  
White ±10%  
Green ±5%

#### CAPACITOR COLOR CODES

Color	1st-2nd Digit	Multiplier	% Tol.	T.C. ppm/°C
Black	0	1	±20%	-0
Brown	1	10	±1%	-30
Red	2	100	±2%	-80
Orange	3	1K		-150
Yellow	4	10K		-220
Green	5	100K	±5%	-330
Blue	6	1M		-470
Violet	7	--		-750
Gray	8	.01		+30
White	9	.1	±10%	+500

**TABLE 1**  
Capacitance Values for all capacitor types  
Temp. Coefficient and Tolerance for Ceramic/Monolithic types only

These are the **EIA standard capacitor values**. These are the values available from most vendors Non-polarized run from 1pF to 1uF, while electrolytics are available from 0.1uF and higher (not all electrolytic values listed here)

1.0pF	10pF	100pF	.001uF	.01uF	.1uF	1.0uF	10uF
1.2pF	12pF	120pF	.0012uF	.012uF	.12uF	1.2uF	12uF
1.5pF	15pF	150pF	.0015uF	.015uF	.15uF	1.5uF	15uF
1.8pF	18pF	180pF	.0018uF	.018uF	.18uF	1.8uF	18uF
2.2pF	22pF	220pF	.0022uF	.022uF	.22uF	2.2uF	22uF
2.7pF	27pF	270pF	.0027uF	.027uF	.27uF	2.7uF	27uF
3.3pF	33pF	330pF	.0033uF	.033uF	.33uF	3.3uF	33uF
3.9pF	39pF	390pF	.0039uF	.039uF	.39uF	3.9uF	39uF
4.7pF	47pF	470pF	.0047uF	.047uF	.47uF	4.7uF	47uF
5.6pF	56pF	560pF	.0056uF	.056uF	.56uF	5.6uF	56uF
6.8pF	68pF	680pF	.0068uF	.068uF	.68uF	6.8uF	68uF

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