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Syfer Capacitor Basics

What is a Capacitor

A capacitor is a charge storing device consisting of two or more conducting plates separated from one another by an insulator. These two constituent parts are called the electrode and the dielectric.

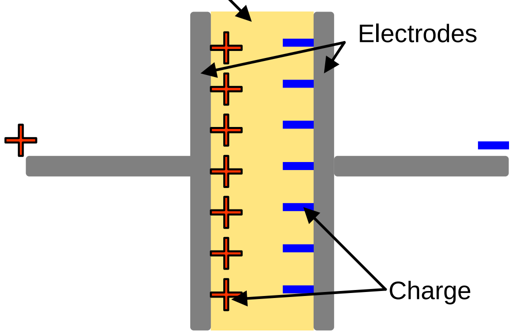

Fig. 1

Electrode

The electrode must be a good conductor of electricity, materials widely used in capacitor manufacture are:

Aluminium
Copper
Nickel
Palladium
Platinum
Silver
Tantalum

Depending on the manufacturing process used the electrode may also be required to be unreactive and have a high melting point. This is the case for oxidising atmosphere fired ceramic capacitors which are manufactured at Syfer. The sintering temperature of the ceramic dielectric material is around 1100°C; in order to stop the electrode from melting during firing a combination of Silver and Palladium is used. This method of manufacture is referred to as the PME or Precious Metal Electrode system.

Dielectric

The dielectric must be a good insulator, materials widely used in capacitor manufacture are:

Ceramic	ε_r 15-10000
Porcelain	ε_r 6
Metal Oxide	ε_r 12
Mica	ε_r 5.4
Plastic Film	ε_r 3

Dielectrics have other important characteristics other than their ability to insulate. Dielectric constant or relative permittivity, ε_r, is one of the most important. This is the dominant characteristic in determining the capacitance value attainable at a given size and voltage, the value relates to the permittivity of a vacuum which has a ε_r of 1. The ceramics used by Syfer are split into two main types, C0G/NP0 which have ε_r values of between 20 and 100 and X7R which have ε_r values of between 2000 and 3000.

Construction

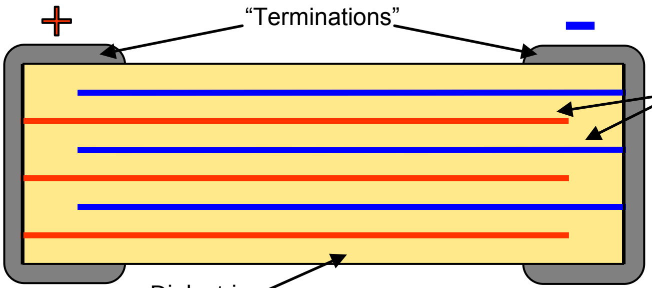

Fig. 2

The most basic type of capacitor is a single layer which is shown in Fig. 1 and consists of a layer of dielectric material sandwiched between a positive and a negative electrode. The MLC capacitor, which Syfer produce, takes this concept and multiplies the number of layers to increase the available capacitance hence multilayer ceramic capacitor, see Fig.2. Layers of ceramic are built up using a screen printing process, these are interleaved with electrodes of alternating polarity. The like polarity electrodes are then joined together using a termination material. The termination can then be attached to wires or legs to form a radial leaded MLCC or electroplated to form a surface mount MLCC.

MLCC Uses

A MLCC has many different applications in electronic circuits. However, the three main uses are:

Blocking:

A capacitor has dc voltage applied combined with a much smaller ac signal voltage. An important application of capacitors is to stop direct current (dc) but allow alternating current (ac) from one part of an electronic circuit to another. A dc voltage is blocked when the capacitor is charged but if a varying (alternating positive and negative) voltage is applied then a current will flow first in one direction, then in the other as the capacitor charges and discharges. You will find capacitors used in this way in T.V. Radio and Audio Amplifiers.

Frequency Selection:

Capacitors are used to help detect Radio Frequency and they are part of the tuning circuit. Again, they are used in T.V. and Radio circuits.

They can also be used to 'filter out' frequencies, which could interfere with the equipment.

Storage of Electrical Energy/Smoothing:

The ability of capacitors to store charge is used to stabilise the voltage to sensitive devices. This application accounts for a large proportion of all MLCCs used. The capacitors are utilised close to the memory chips in computers and ensures that the chip operating voltage stays constant in spite of the electrical activity going on all around. The same property is used to smooth the outputs from power supplies and voltage converters.

Limitations and Factors for Consideration

Capacitance (*C*) is:

Directly proportional to electrode overlap area (*A*) $C \alpha A$

Directly proportional to dielectric constant (ε_r) $C \alpha \varepsilon_r$

Inversely proportional to dielectric layer thickness (*T*) $C \alpha \frac{1}{T}$

Voltage rating is related to a non linear positive function of dielectric thickness. $V_w = f.T$

These relationships have knock-on effects on the amount of capacitance available at set sizes and voltages. Smaller footprint and restricted thickness limit the available capacitance value. Higher voltage capacitors need greater dielectric thickness which means less capacitance, this is not a linear function, especially for high voltage capacitors. For example, to increase the voltage from 1000V to 2000V requires a typical doubling of dielectric thickness; this in turn means that only half the number of electrodes can fit into a set thickness. Due to the fact that capacitance is directly proportional to overlap area and inversely proportional to dielectric thickness; the overall capacitance available in a given size at 2000V is roughly 25% of that at 1000V.

Dielectric Types

There are many types of dielectric material each of which have their own characteristics and therefore uses. Syfer use predominantly Barium Titanate and Neodymium Titanate based dielectric materials which, in different formulations and designs make X5R, X7R, X8R, 2C1(BZ) and 2X1(BX) and C0G materials, Syfer also have a High Q material. There is a trade off between ε_r and stability and loss. Generally speaking dielectrics with a higher ε_r value, are less stable with temperature, time and voltage than those with a lower ε_r value. The main stability characteristics are defined as:

> *T_{CC}* – Temperature Coefficient of Capacitance, how much capacitance changes with temperature
>
> *V_{CC}* – Voltage Coefficient of Capacitance, how much capacitance changes with applied voltage
>
> *Ageing* – How much capacitance changes over time
>
> *DF and Q* – Dissipation Factor and Quality factor, reciprocals of each other and measure the losses with the capacitor

The different material codes help define the performance of the dielectric material

EIA Class 2 Classification					
Minimum Temperature		Maximum Temperature		Capacitance Change Permitted	
X	**-55°C**	4	+65°C	A	±1.0%
Y	-30°C	**5**	**+85°C**	B	±1.5%
Z	-10°C	6	+105°C	C	±2.2%
		7	**+125°C**	D	±3.3%
		8	**+150°C**	E	±4.7%
		9	+200°C	F	±7.5%
				P	±10%
				R	**±15%**
				S	±22%
				T	+22% / -33%
				U	+22% / -56%
				V	+22% / -82%

X7R

X7R is an EIA Class II dielectric; Syfer dielectric code 'X'

The 'X' and '7' define the lower and upper operational temperature range, i.e., -55°C and +125°C respectively and 'R' defines the stability within the temperature range, in this case ±15%.

Dissipation factor is a maximum of 2.5%

V_{CC} is unspecified for standard X7R material.

The ageing rate for X7R is typically 1% to 2% per time decade which means that, at 1% ageing, 2% of the capacitance value will be lost between hour 10 and hour 1000. Syfer supply X7R capacitors to their 1000 Hour capacitance value.

X7R has a high ε_r value of around 3000 and is used for capacitance values in the nF to µF range. X7R capacitors are generally used in energy storage, smoothing and filtering applications.

X5R

X5R is an EIA class 2 dielectric Syfer dielectric code ‘P’.

X5R is generally similar to X7R except that the top operational temperature limit denoted by the ‘5’ is +85°C.

X5R capacitors are used in similar applications to X7R but where the environmental conditions are more stable.

X8R

X8R is an EIA class 2 dielectric Syfer dielectric code ‘N’.

X8R is generally similar to X7R except that the top operational temperature limit denoted by the ‘8’ is +150°C.

X8R capacitors are used in similar applications to X7R but where the environmental conditions require stability at higher temperatures. Automotive under hood, industrial and down hole applications are some examples.

2C1 (BZ) and 2X1 (BX)

Syfer dielectric codes ‘R’ and ‘B’.

These dielectric classifications are based on X7R dielectrics but include a V_{CC} specification and a different T_{CC} requirement.

2C1 has T_{CC} of ±20% and a V_{CC} of +20%-30% with rated voltage applied.

2X1 has T_{CC} of ±15% and a V_{CC} of +15%-25% with rated voltage applied.

These dielectric classifications are useful where a more defined and stable capacitance value is required.

C0G

C0G is an EIA Class I dielectric, it is also known as NP0, the Syfer dielectric code is ‘C’. C0G is much more stable than the EIA Class 2 dielectrics.

T_{CC}, C0G is defined as having an allowable capacitance change of ±30ppm/°C over the -55°C to +125°C operational temperature range.

V_{CC}, C0G is stable with voltage.

C0G has negligible ageing.

C0G has a lower DF, or higher Q than X7R, defined as a maximum of 0.15%. This means that when operating at higher frequencies the power lost in the capacitor is reduced and it is less inclined to overheat.

C0G dielectrics have ε_r values of between 20 to 100 and are used to make stable lower capacitance parts in the pF to nF region. These are typically used for filtering, balancing and timing circuits.

High Q

High Q is a C0G dielectric, the Syfer dielectric code is ‘Q’.

Generally similar to standard C0G except that the DF is lower/ Q is higher.

High Q material has a low ε_r value and is used to make parts typically in the pF range, these are used generally in high frequency applications which require low losses.

Useful Formulae and Calculations

$Q = \frac{1}{DF}$ Q is Quality Factor, DF is Dissipation Factor

$X_C = \frac{1}{2\pi fC}$ X_c is Capacitive Reactance in Ohms, f is frequency in Hertz and C is capacitance in Farads

$R_S = DF.X_C$ R_s is Equivalent Series Resistance in Ohms, DF is Dissipation Factor and X_c is Capacitive Reactance in Ohms

$P = I^2R$ P is Power dissipated in capacitor in Watts, I is rms current in Amps and R is R_s in Ohms

Recognising a Syfer Part Number

A standard Syfer part number is 15 characters long, e.g., 1206J5000682KXT. This breaks down into:

Case Size	Termination	Voltage	Capacitance	Tolerance	Dielectric	Packaging
1206	J	500	0682	K	X	T

Case Size

1206	J	500	0682	K	X	T

The four case size characters represent the X and Y dimensions in thousandths of an inch. Syfer's range goes from 0402 (40 thou by 20 thou) to 8060 (800 thou by 600 thou).

Termination

1206	**J**	500	0682	K	X	T

Code 'J' is the industry standard glass frit type termination. Glass material loaded with silver is applied to the ends of the capacitor. Sintered on at high temperature it ensures contact with the ends of the internal electrodes. The termination is then electroplated with Nickel and Tin.

'Y' termination, trade name FlexiCap™, is the termination material which introduced the world to flexible terminations. Pioneered by Syfer it protects the body of the capacitor from mechanical stress. Polymer material loaded with Silver is cured onto the ends of the capacitor to make an excellent bond with the internal electrodes. The termination is electroplated with Nickel and Tin.

'A' and 'H' terminations are similar to 'J' & 'Y' respectively but are electroplated with a minimum Lead content of 10%. (Used primarily in military and space applications to combat the potential problem of tin whisker growth in certain environments.)

Termination codes '2', '3', '4' and '5' are the equivalent of 'J', 'Y', 'A' and 'H' terminations but with a Copper barrier layer rather than Nickel. They provide a non-magnetic termination finish with excellent solder leach resistance.

Code 'F' is an un-plated Silver Palladium loaded glass frit termination for non-magnetic and epoxy bonding applications.

Voltage

1206	J	**500**	0682	K	X	T

010 – 999 are straightforward 10V to 999V, 1kV and above are in kV with the K as a decimal point so 1K5 is 1.5kV up to 12K for 12kV.

Capacitance

1206	J	500	**0682**	K	X	T

The first three digits are significant figures and the fourth digit is a base 10 multiplier with the final value being in picofarads (pF). For example 0682 = 068 × 10^2 = 6800pF

A 'P' or 'N' is used to specify fractions to denote the decimal point, so 4P70 would be 4.7pF and 12N4 would be 12.4nF

Tolerance

1206	J	500	0682	**K**	X	T

C0G <10pF	C0G ≥10pF	X7R
H ± 0.05pF	F ± 1%	J ± 5%
B ± 0.1pF	G ± 2%	K ± 10%
C ± 0.25pF	J ± 5%	M ± 20%
D ± 0.5pF	K ± 10%	
F ± 1.0pF		

Dielectric Code

1206	J	500	0682	K	**X**	T

Class I	Class II
A – C0G to AEC-Q200	B – 2X1 (BX)
C – C0G	D – X7R to IECQ-CECC
F – C0G to IECQ-CECC	E – X7R to AEC-Q200
Q – High Q	N – X8R
	P – X5R
	R – 2C1 (BZ)
	X – X7R

Packaging

1206	J	500	0682	K	X	**T**

'T' is taped and reeled on 178mm (7") reels

'R' is taped and reeled on 330mm (13") reels

'B' is bulk packed in tubs

For further information or technical assistance please contact our Sales Department on:

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