BE1M13VES

Manufacturing of Electrical Components

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Prague, 2017

Overview

TOPIC

Capacitors

Parameters:

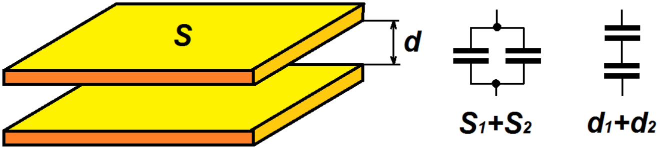
- C... capacitance
- δ... tolearance
- U... nominal voltage
- D... dissipation factor
- ESR... equivalent series resistance
- TCC... temperature coeficient of capacitance
- VCC... voltage coeficient of capacitance
- frequency dependence

Capacitance of Capacitors

Capacitance:

$$C = \epsilon_0 \cdot \epsilon_r \cdot \frac{S}{d}$$

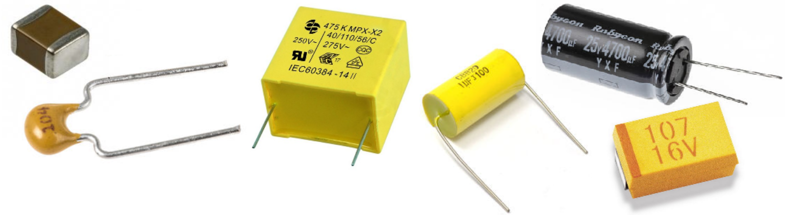
- ϵ_0 ... is the electric constant ($\epsilon_0 \approx 8.854 \cdot 10^{-12}$ F/m),
- ϵ_r ... is the relative static permittivity,
- S ... is the area of overlap of the two plates,
- d ... is the separation between the plates.



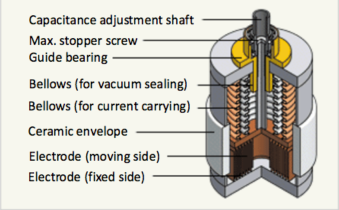
Technology Overview

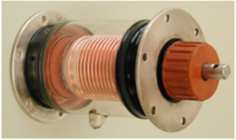
Technologies are derived from dielectric material:

- Air, vacuum capacitors
- Ceramic capacitors (NP0, X5R,...)
- Film (foil) capacitors (paper, PP,...)
- Electrolytic capacitors (Al_2O_3,...)



Vacuum Capacitor



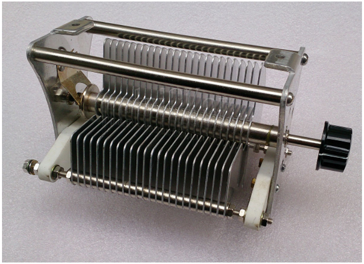


Source: renosubsystems.com/plasma-etching-deposition-technologies/rf-matching-networks/

- Electrodes (stator and rotor) are very similar to air capacitors.
- Advantageous is higher insulation capability. Maximum applied voltage is given just by auto-emission of electrons between stator and rotor parts.
- Most widespread design is vacuum tube similar to electron tubes. Most critical is hermetic sealing (glass tubes).
- Low power dissipation.

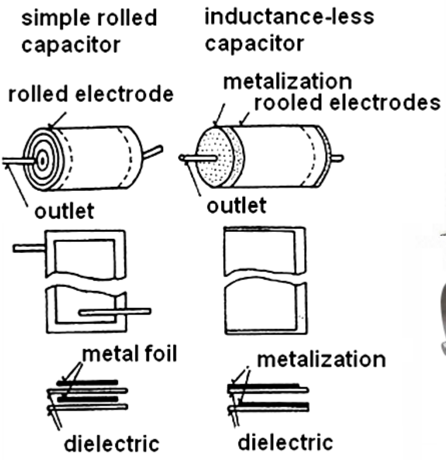
Air Capacitor

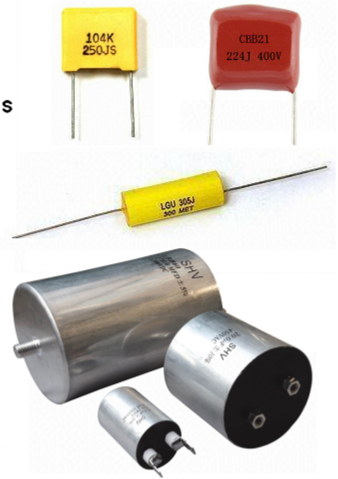
- They are created with a set of metal plates separated with an air dielectric.
- Power losses are negligible.



- They are used as tuning and variable capacitors.
- Maximum applied voltage is given just with the air-isolation capability.

Foil Capacitors



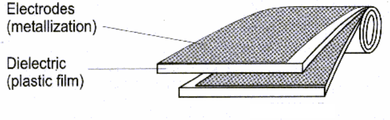


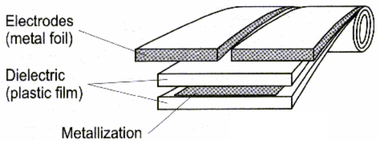
Foil Capacitors

dielectric dry paper for capacitors (natron-celluloze) from 6 to 20 μm thickness, typically 2 layers. Plastic foils: polystyrene, polyethylentherepthalath (PETP), polycarbonate, polyimide, polypropylene,

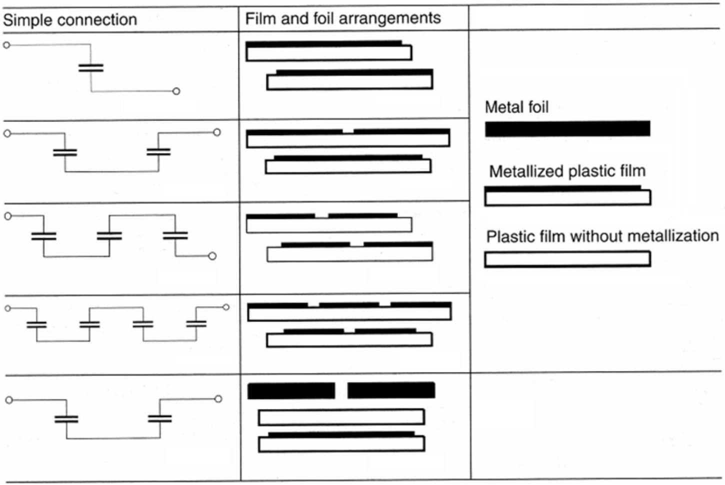
electrodes aluminum foil, thickness - units of μm,

leads copper pads bonded directly on electrodes, copper wires rolled into bulk of capacitor.





Arrangement for high voltage



Ceramic Capacitors

Ceramic material with relative permittivity from range 1 (linear) up to 10^4 (ferroelectric) is used for dielectric layer. Conductive surface of electrodes is made from silver. Silver is deposited by evaporation.

- **the oldest ceramics (1930):** were based on oxides of titan and manganum (ϵ_r $10 - 100$, TCC from -750 to $100 \cdot 10^{-6}$ $^\circ C^{-1}$).
- **titan based ceramics:** ($BaTiO_3$, $CaTiO_3$, $SrTiO_3$, $MgTiO_3$) have ϵ_r in range 1000 - 20000 but they are ferroelectric - exhibit Curie's temperature, dielectric hysteresis and they are voltage dependent.

Ceramic Capacitors - Types

capacitor called „class 1“:

- stable and linear ϵ_r,
- low power loss: D factor at maximum $2 \cdot 10^{-3}$,
- TCC from -680 to $200 \cdot 10^{-6}$ °C^{-1},
- voltage independent.

Commercial names:
STEALIT (similar to porcelain), STABILIT, TEMPA, RUTILIT, KONDENSA, NEGALIT.
Typically contain TiO_2, MgO, ZrO_2. Such capacitors are good for high frequency and high voltage applications.

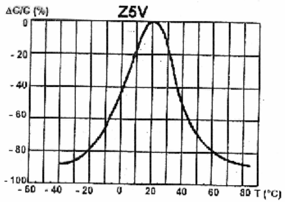
Ceramic Capacitors - Types

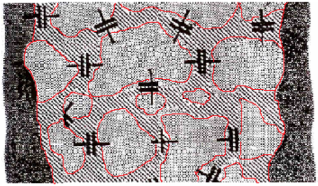
capacitor called „class 2“:

- dielectric with high ϵ_r,
- ferroelectric features (voltage dependent),
- very temperature sensitive. Peak of maximum ϵ_r can be shifted by additional oxides ($SrTiO_3$, $PbTiO_3$, $BaSnO_3$, $CaSnO_3$) or flatten ($CaTiO_3$, Bi_2SnO_3).

Commercial names:

PERMITIT ($BaTiO3$, D max. $3 \cdot 10^{-2}$, tolerance $\pm 50\%$). Suitable for coupling and filtering capacitors.





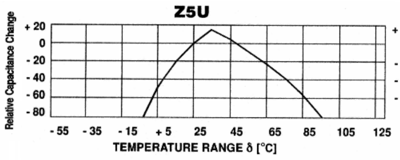
Ceramic Capacitors - Types

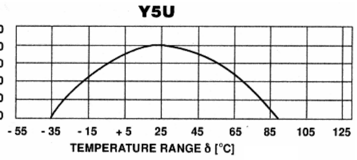
capacitor called „class 3“:

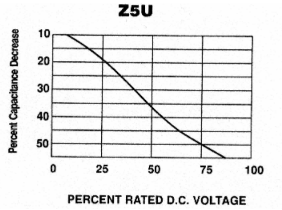
- dielectric with high ϵ_r,
- similar ceramic as for „class 2“ but different burning process (re-oxide ceramic),
- large power loss, due to high electrical strength in ferroelectric, ceramic exhibit some „semiconductor“ behavior,
- Material has a domain structure - ferroelectric properties again.

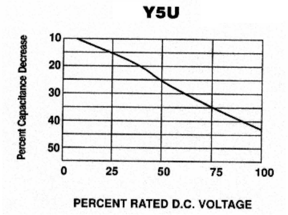
Commercial names:
SUPERMIT, SIBATIT (ϵ_r approximately $5 \cdot 10^4$).
These capacitors are not high-quality devices, ideal for low-cost application.

Temperature Dependency

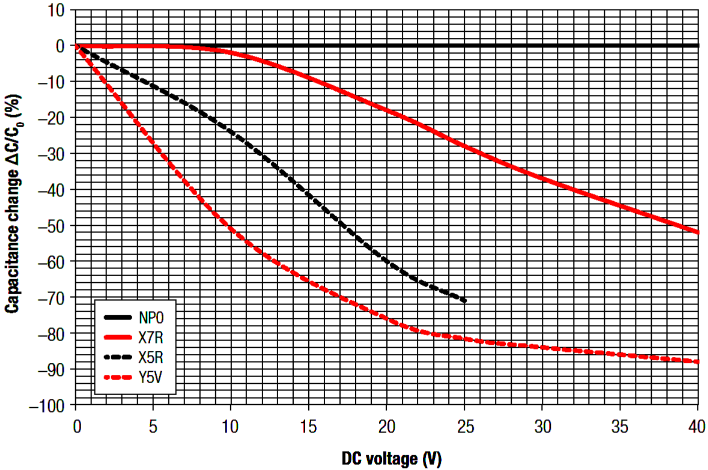




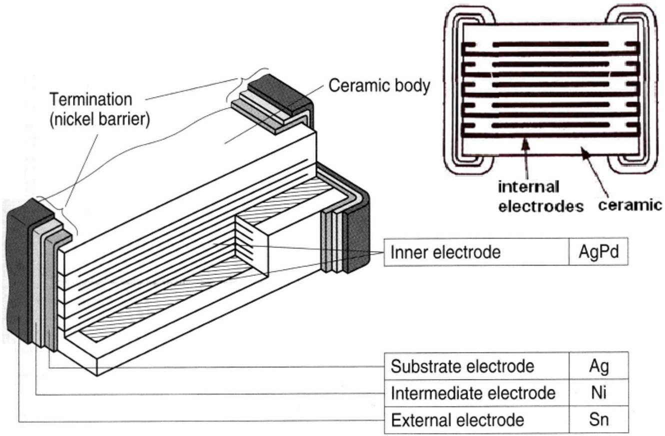




Voltage Dependency



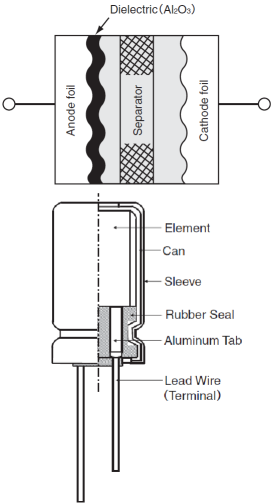
Mechanical Design - SMD



Electrolytic Capacitor

Dielectric: created by a very thin oxide layer placed on one side of electrode. Thickness allows to achieve large capacity in a small volume. Disadvantageous is a polarization of oxide layer.

Design: aluminum electrolytic capacitors are similar to rolled capacitors. Rolled electrodes are made of aluminum strip. Surface is enlarged by brushing and finally is etched. Dielectric layer is formed by anodic oxidation process. Rolled strips are impregnated by electrolyte.



Parameters

- High capacity due to very small insulation thickness and large surface,
- only one polarity,
- relatively small maximum nominal voltage:
  - Aluminium (Al_2O_3) up to 500 V
  - Tantalum (Ta_2O_5) up to approximately 50 V (100 V)