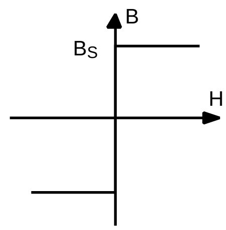
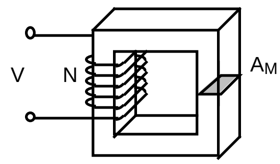
Design Constraints

- **Saturation flux density**
  - Sine-wave excitation
  - Others similar
  - Easily extended to multiple windings and inductors

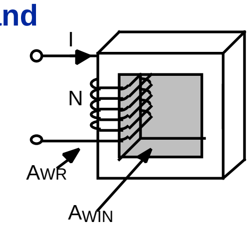
$$N = \frac{\sqrt{2}V}{2\pi f A_M B_S}$$





Design Constraints

- **Winding loss P_W - efficiency and temperature**
  - A_{WR} - wire cross-sectional area
  - $F_W < 1$ - winding factor
  - l_{MT} - mean turn length
  - ρ - resistivity of wire
  - r_{WR} - winding resistance



$$A_{WR} = \frac{A_{WIN}}{NF_W}$$

$$r_{WR} = \rho\frac{Nl_{MT}}{A_{WR}} = \rho\frac{Nl_{MT}}{\frac{A_{WIN}}{NF_W}} = \rho\frac{N^2 l_{MT} F_W}{A_{WIN}}$$

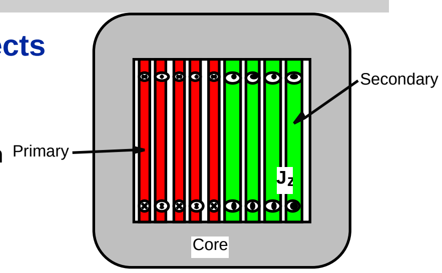
$$P_W = I^2 r_{WR} = I^2\rho\frac{N^2 l_{MT} F_W}{A_{WIN}} = I^2\rho\frac{\left[\frac{\sqrt{2}V}{2\pi f A_M B_S}\right]^2 l_{MT} F_W}{A_{WIN}}$$

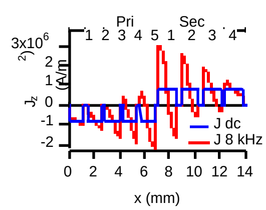
Design Constraints

- **Core size**
  - Core magnetic cross-sectional area A_M
  - Core window cross-sectional area A_{WIN}
- **Material Properties**
  - Resistivity of winding ρ
  - Saturation flux density of core B_S
  - Core loss???
- **Frequency???**

Frequency Limitation

- **Eddy current effects**
  - Lossless magnetic material
  - Non-uniform current distribution
  - Dramatic increase in winding loss
- **Core loss in addition**



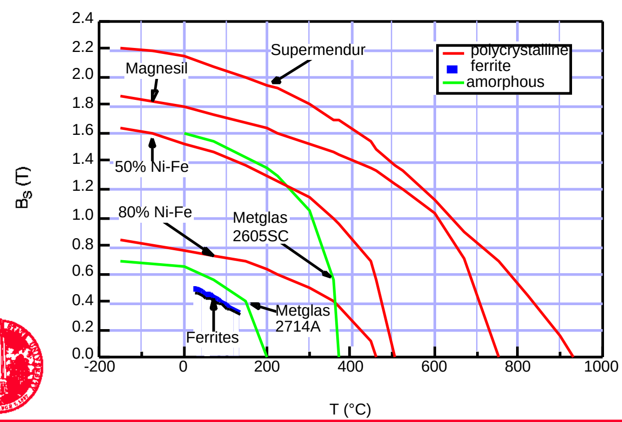


Magnetics Technology Assessment

- **Magnetic materials**
  - **crystalline alloys of Fe, Ni, Co and others**
    - » **laminations**
    - » **powdered**
  - **ferrites**
    - » **Mn-Zn**
    - » **Ni-Zn**
  - **amorphous alloys of Fe, Ni, Co and others**
- **Insulation**
- **Winding technology**

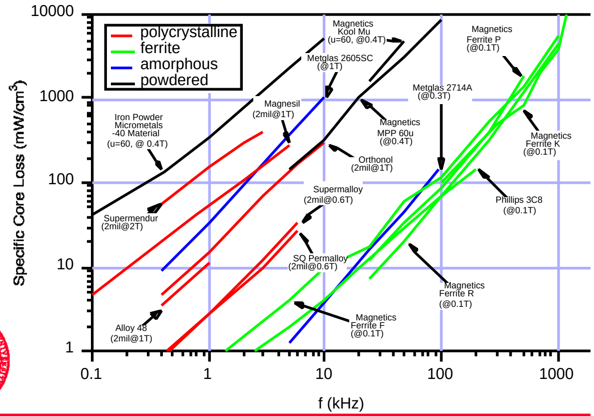
Magnetics Technology

- **Saturation flux density versus temperature**



Magnetics Technology

- **Specific core loss versus frequency**

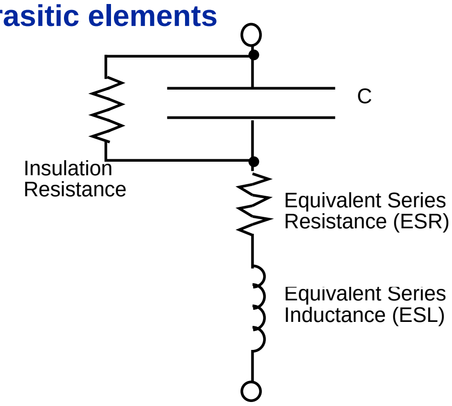


Winding Insulation

- **Requirements**
  - flexible and abrasion resistant
  - thin
  - high temperature
- **Temperature Classes**
  - 105°C
    - » Polyvinyl acetal (Formvar), Polyvinyl formal, Acrylic, Polyurethane, Polyurethane
  - 130°C
    - » Polyurethane nylon
  - 155/180°C
    - » Polyester, Polyester nylon
  - 180/200°C
    - » Polyester poly-amide-imide
  - 220°C and 250°C
    - » Polyimide and High temp. Nylon (Nomex)

Design Constraints

- Minimum volume and weight
- Minimize parasitic elements



Capacitor Technology Assessment

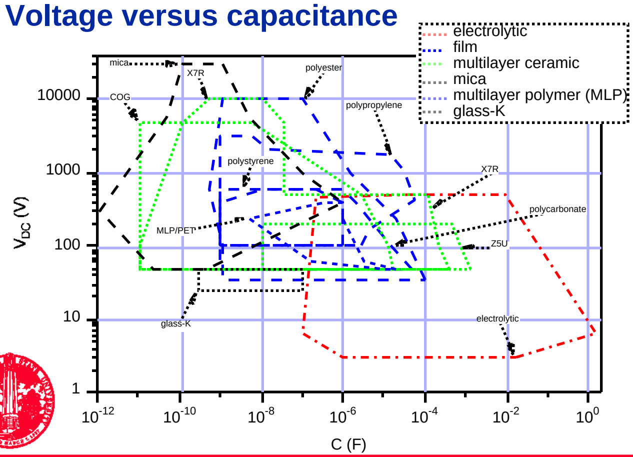
- Major capacitor technologies
  - aluminum electrolytic
  - polymer film
    - "rolled"
    - multilayer (MLP)
  - multilayer ceramic (MLC)
  - mica
  - glass K
- Standards - rare or nonexistent
  - physical
  - electrical

Capacitor Technology Assessment

- **Capacitor performance**
  - voltage versus capacitance
  - volume versus charge
  - capacitance versus temperature
  - dissipation factor versus frequency
  - dissipation factor versus temperature
  - ESR versus frequency
  - insulation resistance versus temperature
- **No ideal capacitor**

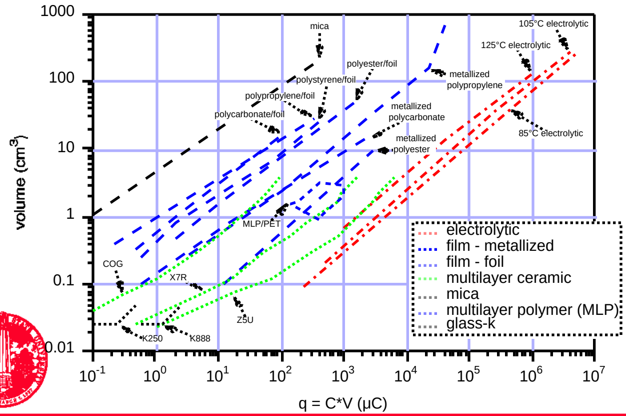
Capacitor Technology

- **Voltage versus capacitance**



Capacitor Technology

- Volume versus charge



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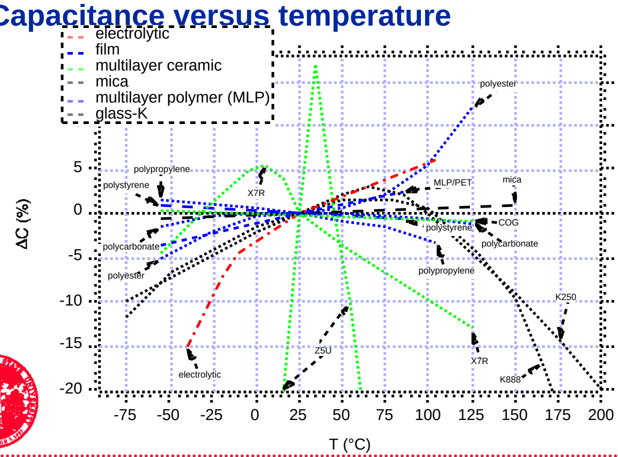
Capacitor Technology

- Capacitance versus temperature



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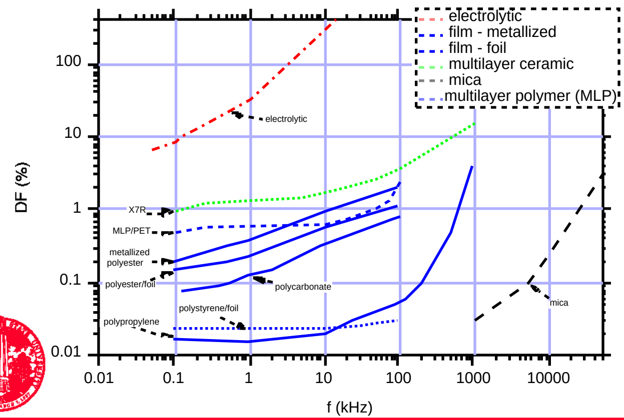
Capacitor Technology

- Dissipation factor versus frequency



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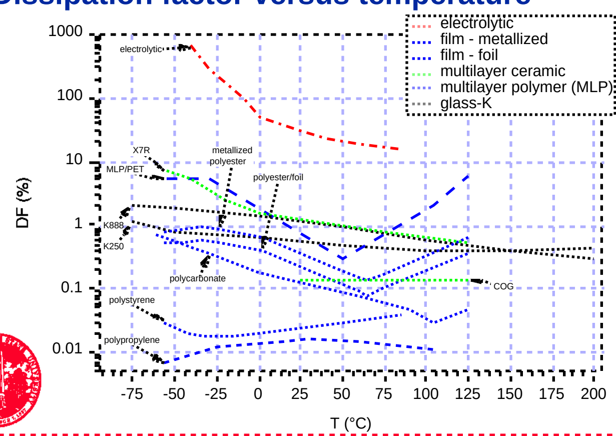
Capacitor Technology

- Dissipation factor versus temperature



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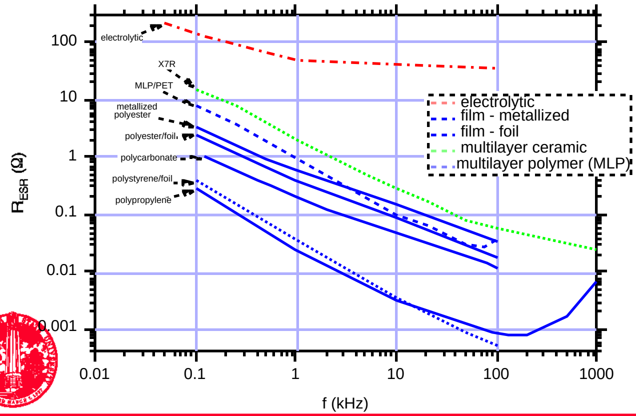
Capacitor Technology

- **ESR versus frequency**



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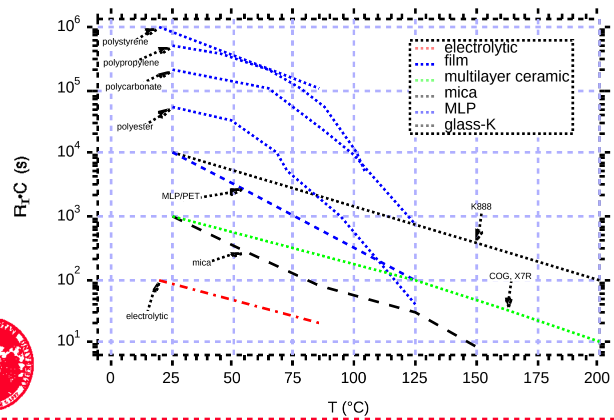
Capacitor Technology

- **Insulation resistance versus temperature**



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Passive Component Challenges

- Vertical integration rare
- Small market can't drive raw materials
- Lacking economic motivation
  - improved materials
  - better manufacturing
- Need high-temperature materials
  - polymers
  - magnetics materials
- Standards – hindered by competition
  - packaging
  - electrical specifications