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CAPACITORS

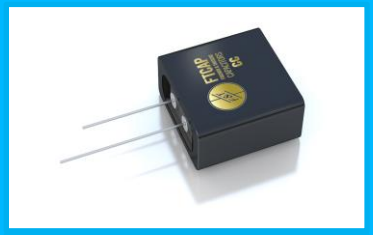
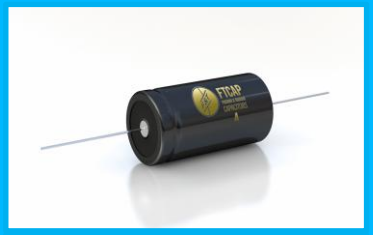
VERMOGENS ELEKTRONICA 2016
14 juni 2016 • Den Bosch

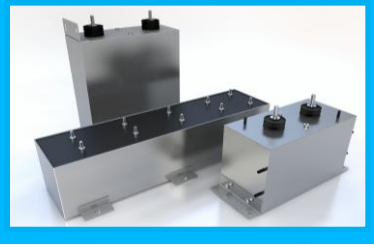
MADE IN GERMANY
– experienced since 1948

# Reduction of parasitic inductances (ESL) in capacitors

Vermogens Elektronica
14 June 2016
Den Bosch



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# Profile

- Fischer & Tausche was founded 1948 in Husum
- Family company
- Production and distribution of electrolytic- and metalized film capacitors
- Focus on individual developments and customized design
- Acquisition of Leclanché Capacitors (Switzerland) in 2004
- 2015 - 16 Mio Euro group sales
- 152 People in Husum + 20 people in Yverdon
- Exclusively manufacturing in Germany and Switzerland

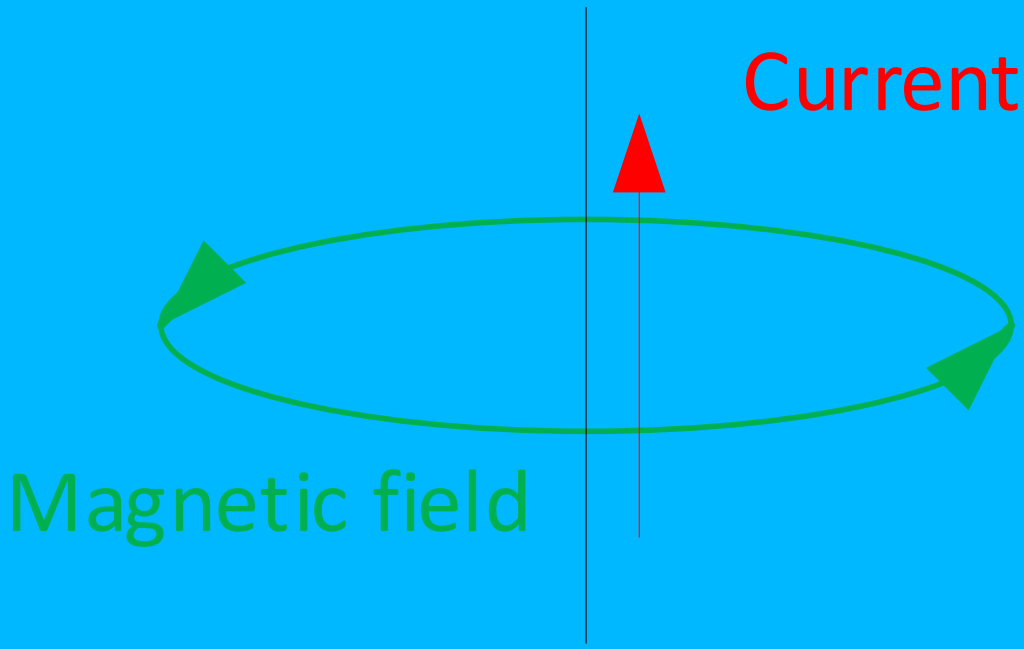
# Point of departure

- great progress in the development of IGBTs (SiC, GaN…)
- used in devices for the conversion and control of electrical energy
  - solar and wind power systems or for the power control of electric motors in e-cars
- trend toward increasingly higher switching frequencies

→ DC link capacitors must have a very low inductive design!

# Inductances

- GENERAL RULE:
  - **Every current in a conductor creates a magnetic field**
  - Current changes over time induce voltages
  - The larger the area surrounded by a current loop, the larger is the magnetic field. This means that all electrical wires must be kept as short as possible.
  - If current carrying back and forth conductors are close together, their magnetic fields will partially cancel each other
  - Parallel-connected inductances reduce the overall inductance.




Magnetic field around a live conductor

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# Self Inductance

## U = L dI/dt

## Relationship between U , L and I(t

# Inductances

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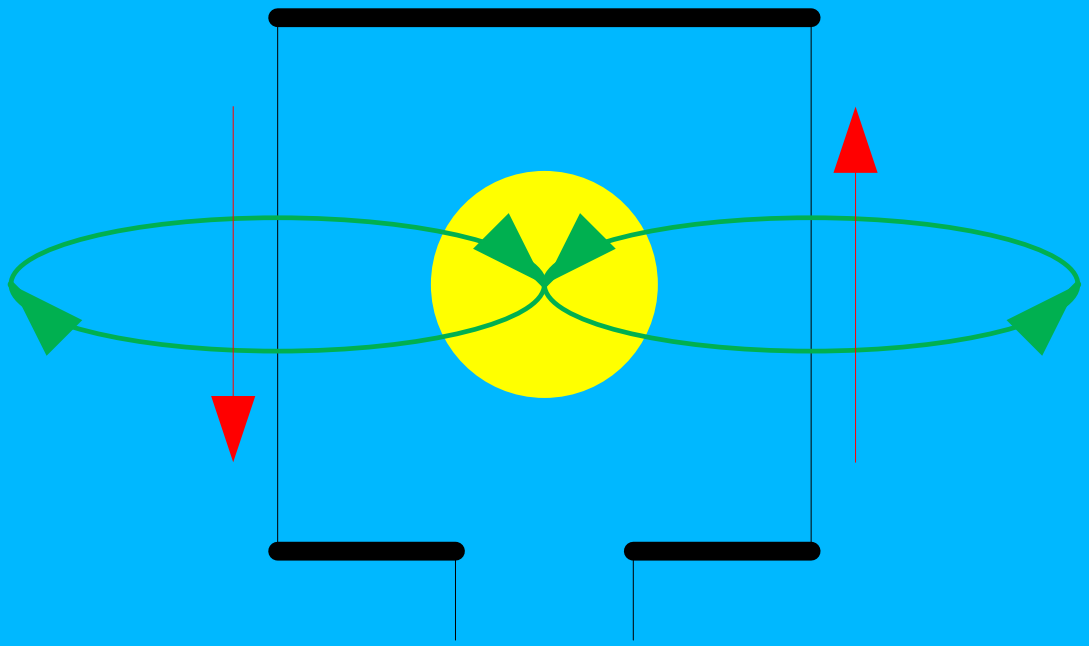

Magnetic fields in the same direction strengthen one another

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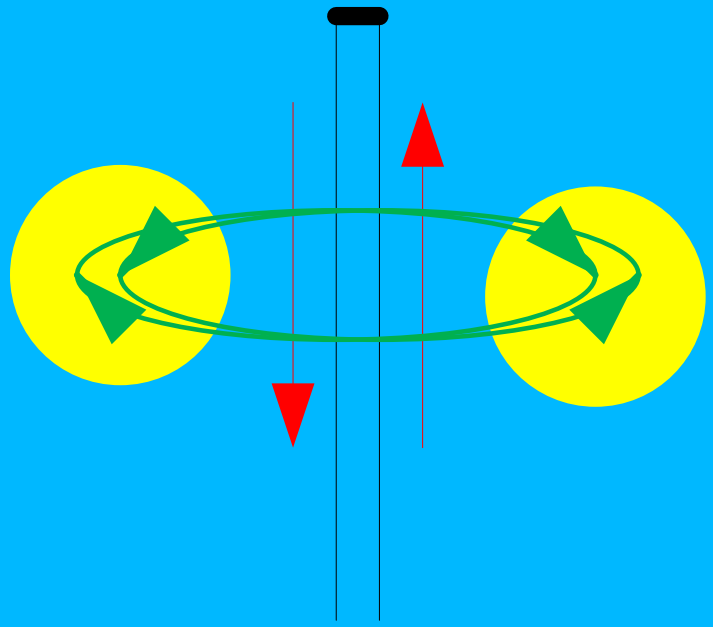

Inversely directed magnetic fields attenuate one another

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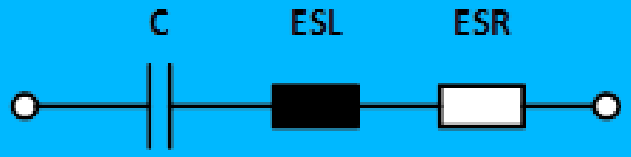
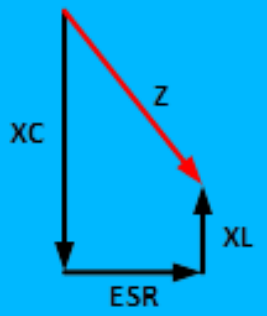
# Effect of parasitic inductances

- Ideal capacitor: the reactance is proportionally inverse to the frequency→ as the frequency increases, the reactance of the capacitor decreases, and with constant AC voltage the current increases accordingly
- real capacitor: only approximately true and applicable only to the lower frequency range
- ideal vs. real capacitor: ohmic losses (ESR) and the parasitic inductance (ESL) of the capacitor must also be considered!

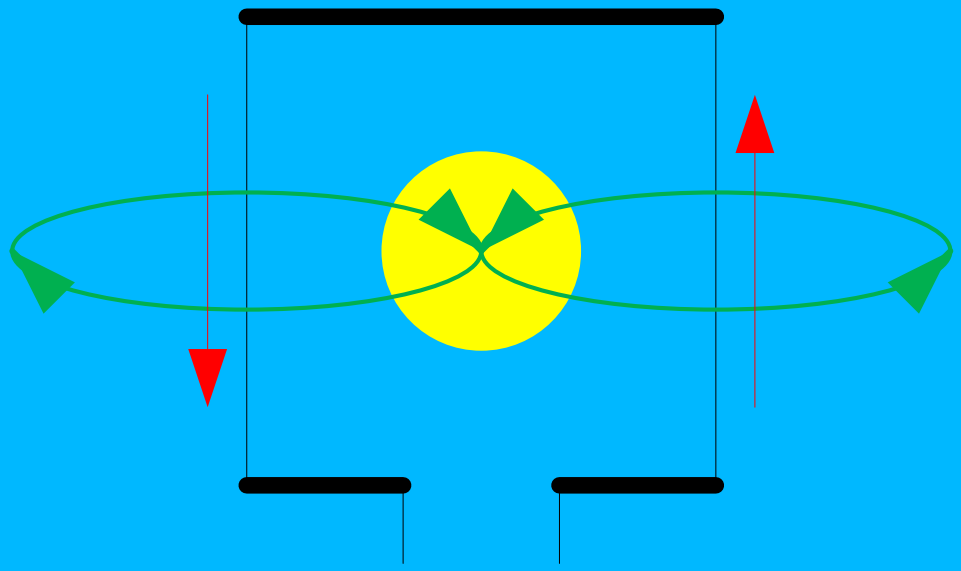


# Effect of parasitic inductances

- ESR
  - Origin of the thermal losses in the capacitor and consists of the sum of the ohmic resistances and the frequency-dependent dielectric losses
- ESL
  - sum of all inductive parts of the capacitor
  - reactance, however with a negative sign and an inverse gradient than the capacitive reactance
  - together with the ESL, the capacitance of the capacitor forms a



# Situation of L related to terminals/connectors of capacitors



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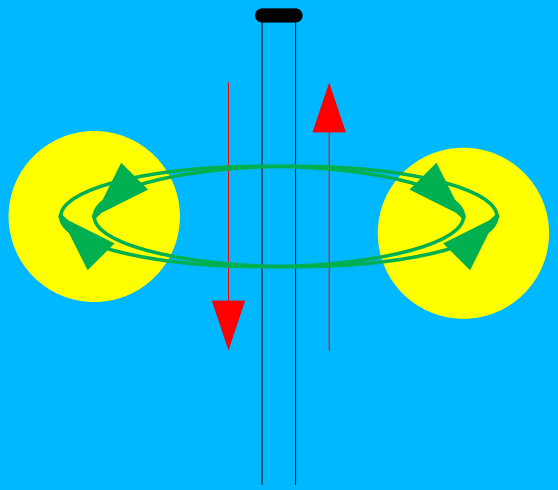
# Situation of L in the capacitor winding



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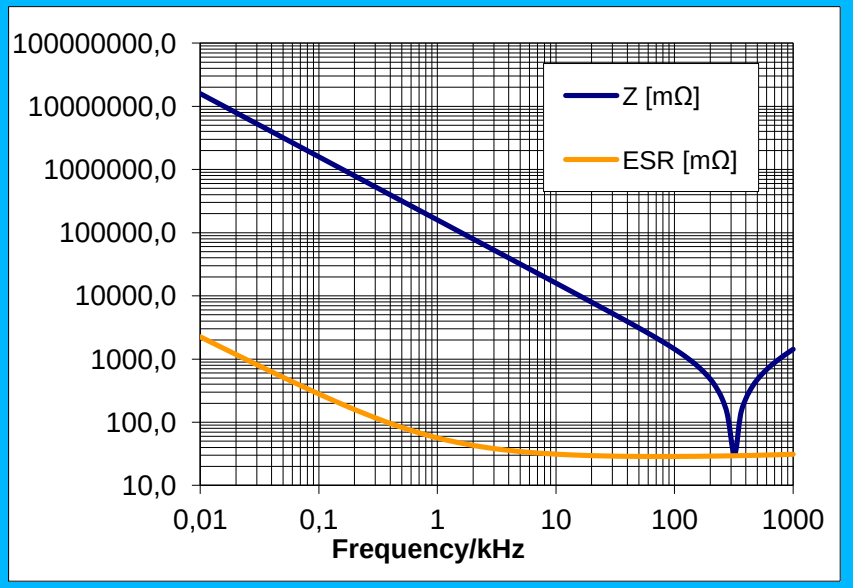
# Effect of parasitic inductances

- through the vectorial addition of the two reactances and the ESR, dependent on the frequency, it is possible to determine the impedance of the capacitor
- Figure: typical V-shaped behaviour, which at its lowest point touches the ESR curve. This is the resonant point where the reactances of the capacitance and the inductance cancel each other out
- above the resonant frequency the impedance of the capacitor is dominated by the inductive components



# Effect of parasitic inductances

Summary:

- In order to use the capacitive properties of the capacitor for a wide range of frequencies, it is necessary to shift the resonant frequency as far as possible! to higher frequency values
- At a given capacitance, this can be achieved only through consistent reduction of the parasitic inductances!

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# FTCAP offers innovative solutions for these problems!

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# Coax Cap

- capacitor winding that is completely enclosed in copper
- milled bottom surface
- extremely low inductance construction (<10nH)
- optimal thermal characteristics
- high current-carrying capacity, with no limitation of the self-healing properties

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# Energy Cap

- designed for frequency converters, DC filters and DC links
- connections between terminals and the far side of the most distant capacitor winding as short as possible → low inductance!
- possible to achieve inductances between 40 nH and 100 nH

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# Copper capacitors

- low inductance alternative to DC link capacitors in combination with fast IGBTs
- solid, enclosed copper construction and the intelligent selection of materials allows inductances below 10 nH
- thermally optimised design ensures a long life
- capacitor is isolated and therefore potential free

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# FischerLink

- low inductance solution from FTCAP
- capacitors are welded directly to the adjacent low inductance copper plates of the internal bus-bar (=without having their own terminals → shortening the connecting wires)
- possible to achieve an ESL of less than 20 nH even in the case of large models

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# Low inductance electrolytic capacitors

- possible to construct single aluminium electrolytic capacitors for DC link applications with extremely low inductance
- FTCAP uses patented short connection bands to achieve the extremely low values
- Many standard types also available as special low inductance versions

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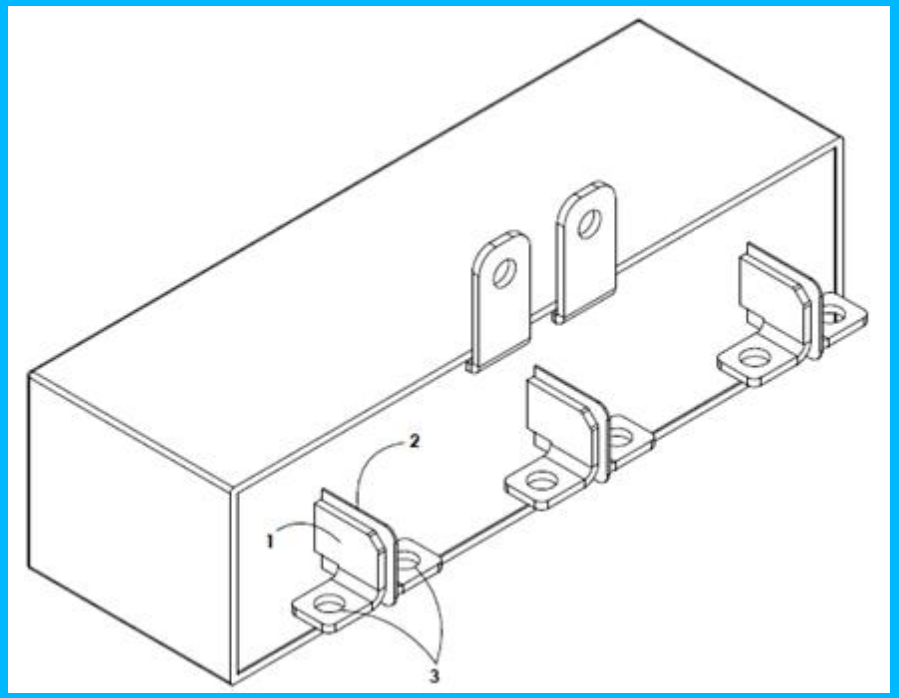
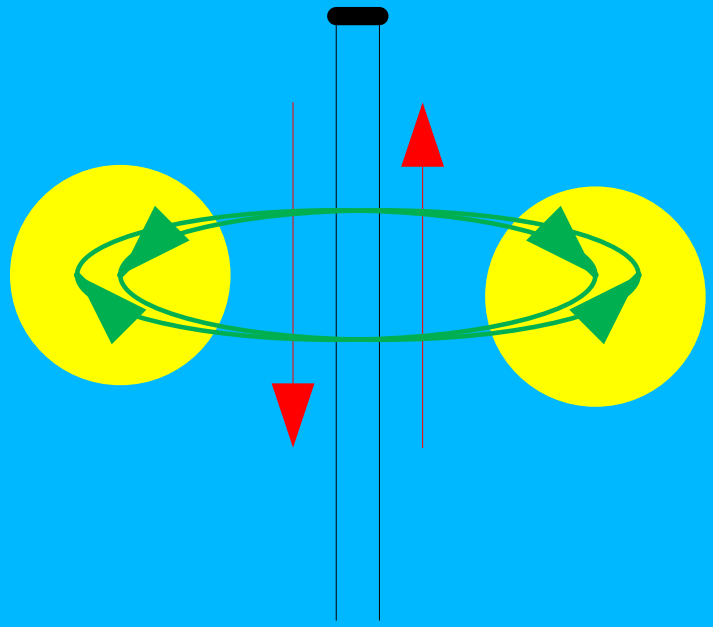
# New IGBT connection terminal

- technical innovation: we can now also offer low inductance IGBT terminals
- new patent-pending connection lugs enable unprecedented low inductance connection of the DC link capacitor to the switching transistors





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# Thank you very much for your attention!

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