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AME

Coils and Caps Test Coupon

Single Elements

J.A.M.E.S engineering

AME-Elements Workflow with optimization

- from Simulation to full optimized & functional electronics
    - Without tuning manually

Design, Simulation, Optimization

Process Knowhow

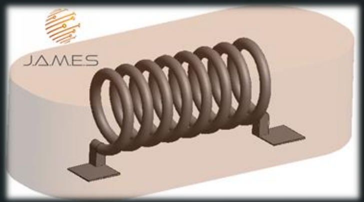
Material Parameters

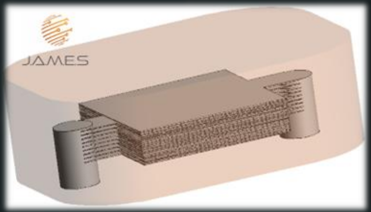
→ Slicing → PrintJob preperation, optimization → AME-Realisation →

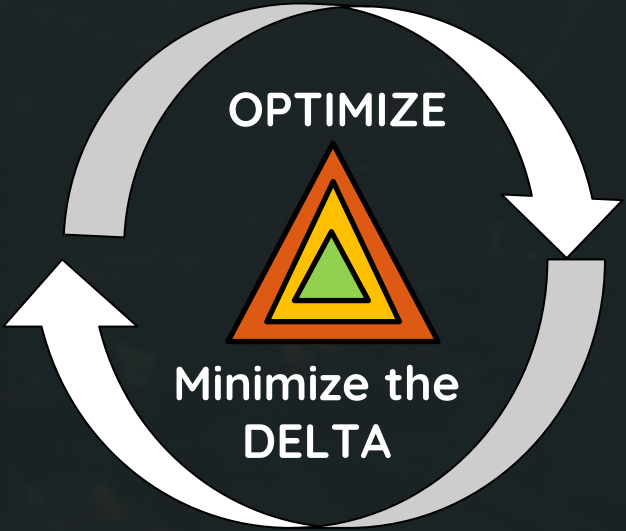
Verification & Test

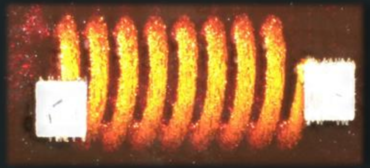
Tolerances

Electronic performance (RF)

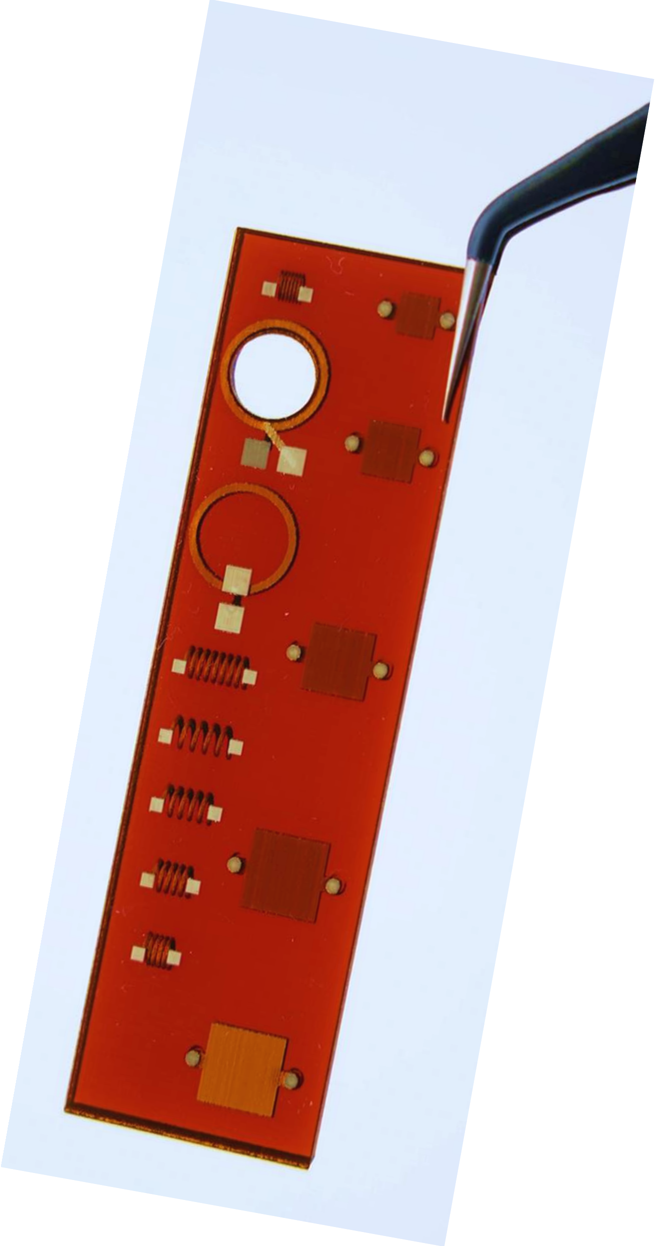








Inside the Coils and Caps coupon-Design



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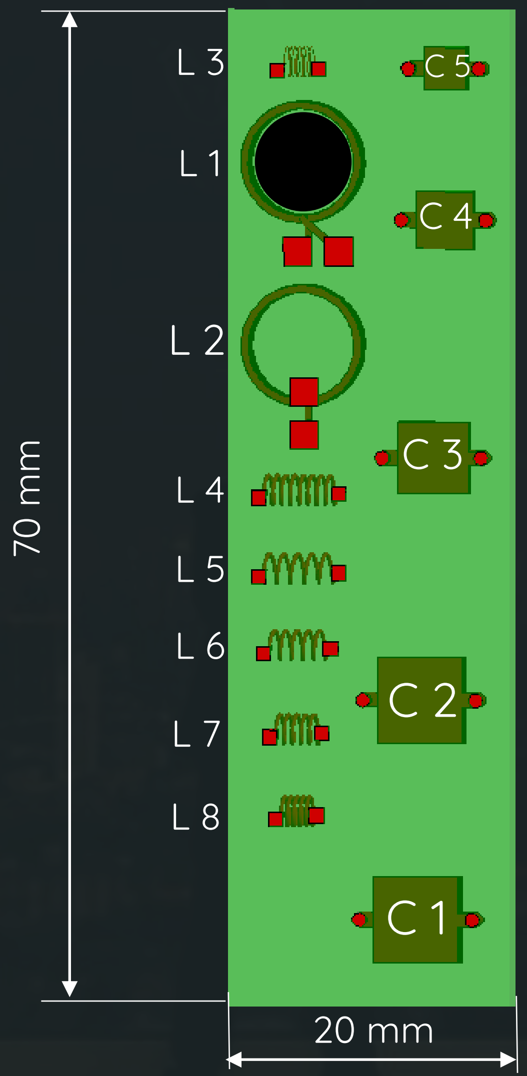
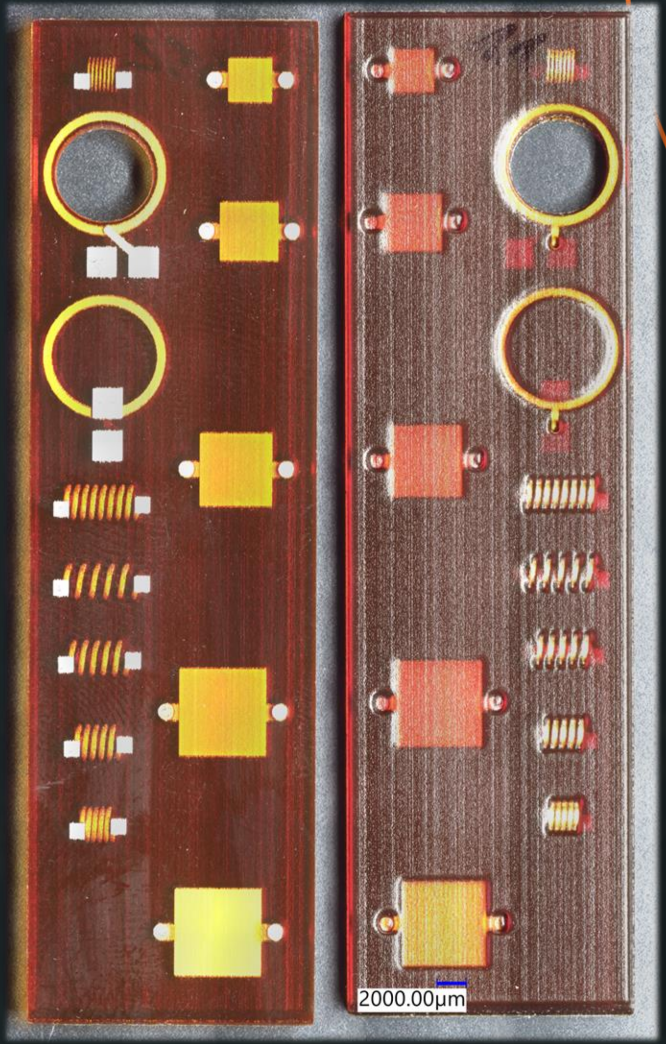
Coils and Caps Coupon

- Design Insights of all single elements in the coupon sample





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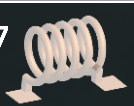
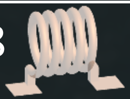
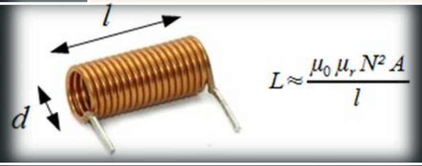
Coils and Caps Coupon

- Examples for 3D-Coil-Design variations

AME-Coil	comments
L1 	Air filled
L2 	DI filled
L3 	d = 2.2mm, l = 2.1 mm N = 7; wires 0.1 mm
L4 	d = 3mm, l = 5.2 mm N = 8; wires 0.3 mm

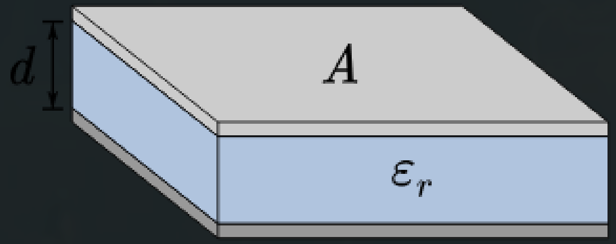
AME-Coil	comments
L5 	d = 2.2mm, l = 5.4 mm N = 8; wires 0.3 mm
L6 	d= 2.2mm, l = 4.2 mm N = 5; wires 0.3 mm
L7 	d = 2.2mm, l = 3.4 mm N = 5; wires 0.3 mm
L8 	d = 3mm, l = 2.5 mm N = 5; wires 0.3 mm
	

Coils and Caps Coupon

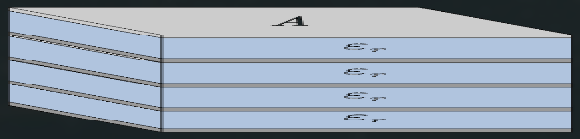
- Examples for 3D-Capacitor-Design variations

AME-Cap	comments
C5 	6x6 mm 36 plates, 1 mm thick
C4 	6x6 mm 18 plates 2 mm thick
C3 	5x5 mm 18 plates 1 mm thick
C2 	4x4 mm 18 plates 1 mm thick
C1 	3x3 mm 18 plates 2 mm thick

$$C = \varepsilon_0 \, \varepsilon_r \, \frac{A}{d}$$



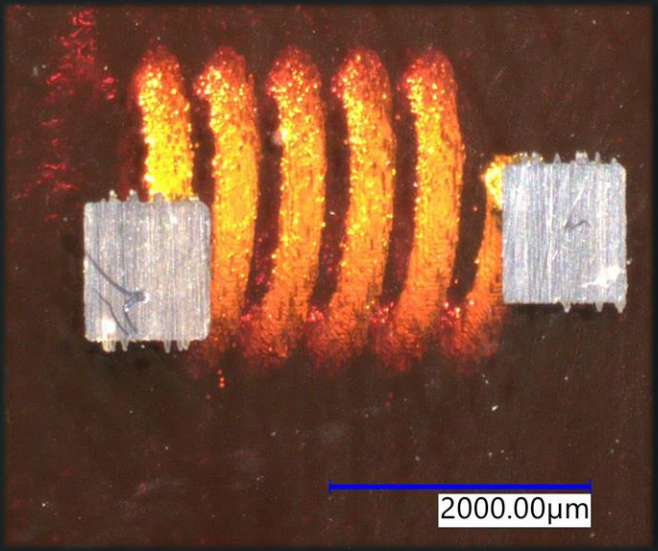
$$C = \varepsilon_0 \, \varepsilon_r (N-1) \frac{A}{d}$$

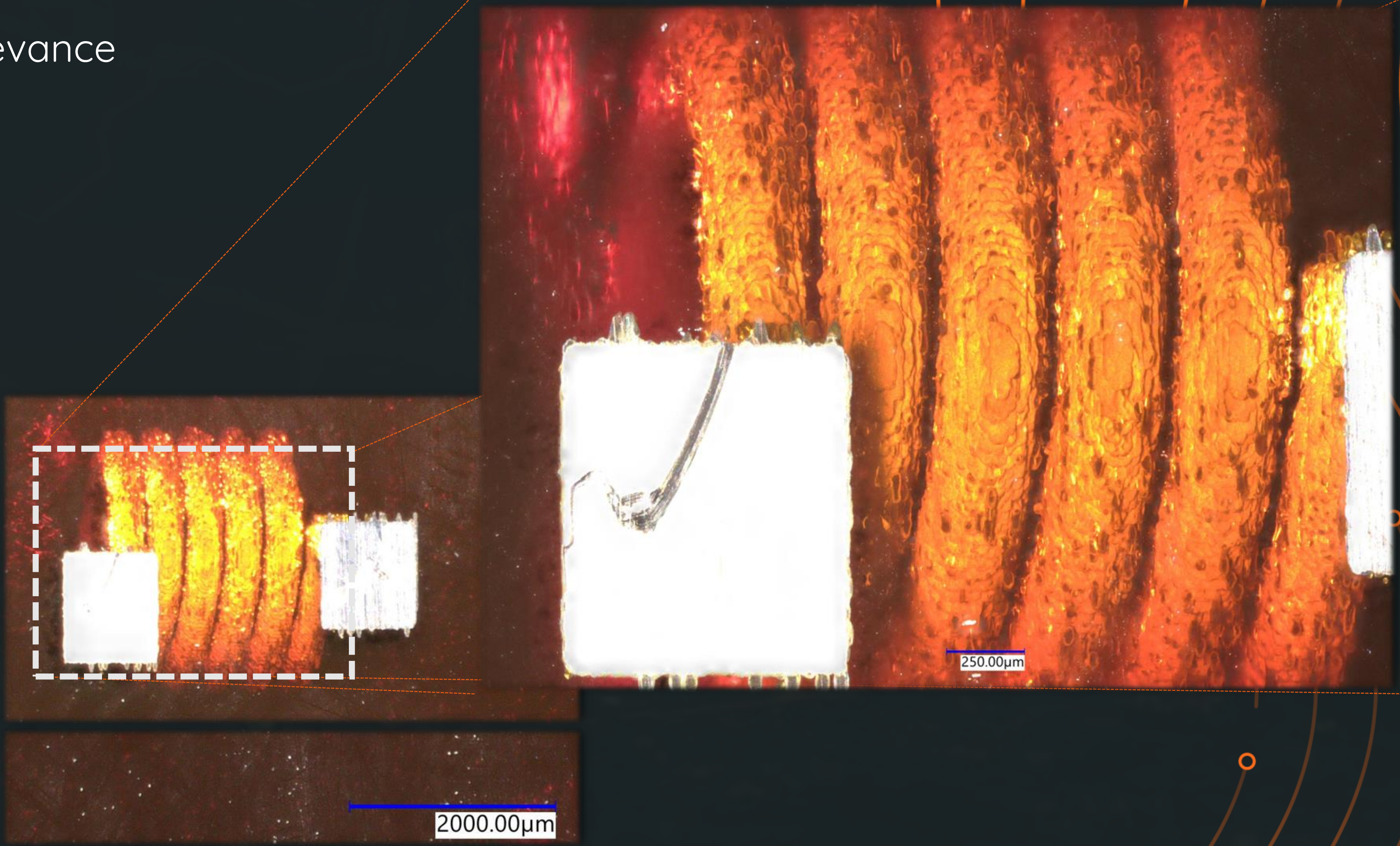


N

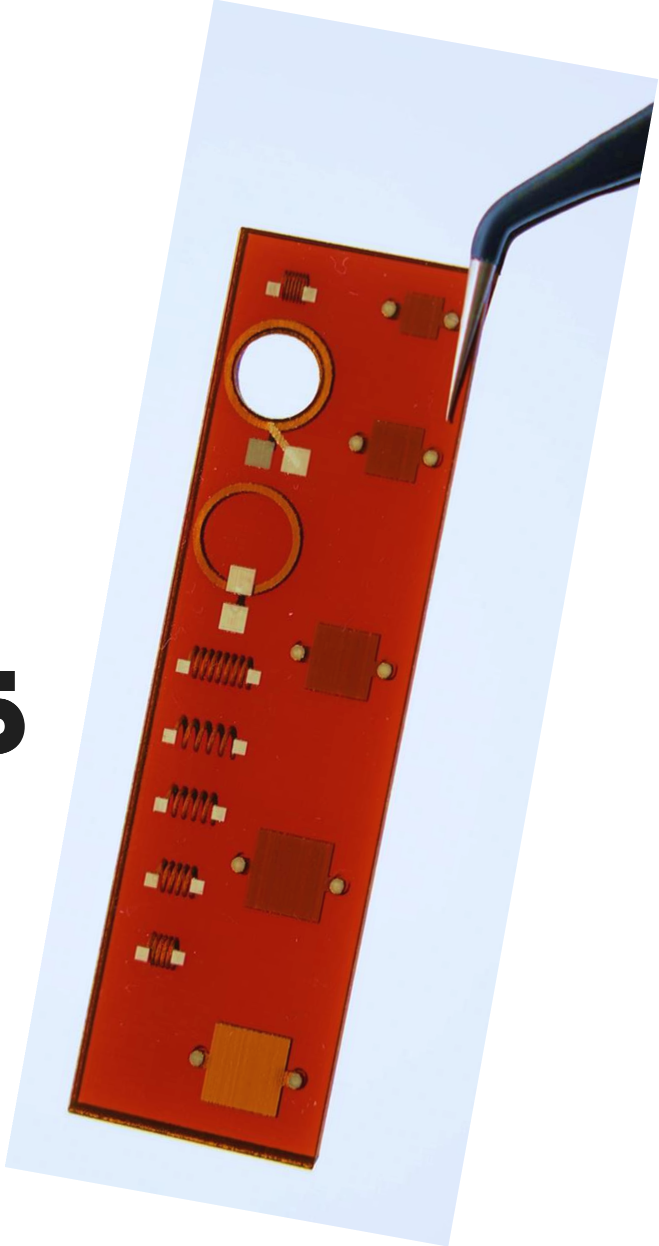
Coils and Caps Coupon

- Deep insights
- High z-axis conductivity relevance





Measuring results For Coils and Caps coupon-Design



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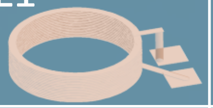
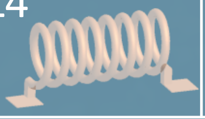
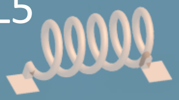
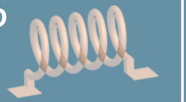
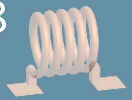
Coils and Caps Coupon - **measured**

Measurement results (with LCR Bridge)

- Verification method different by usecase and frequency

AME-Coil	**Measurement [µH] @100 kHz**
L1 	3,4 µH
L2 	3,4 µH
L3 	not verified
L4 	8 µH
Verification ongoing as KPI for printing process	

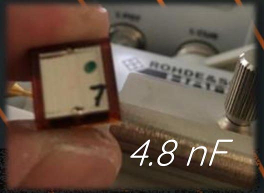
AME-Coil	**Measurement [µH] @ 100 kHz**
L5 	8 µH
L6 	7 µH
L7 	7 µH
L8 	7 µH
Verification ongoing as KPI for printing process	

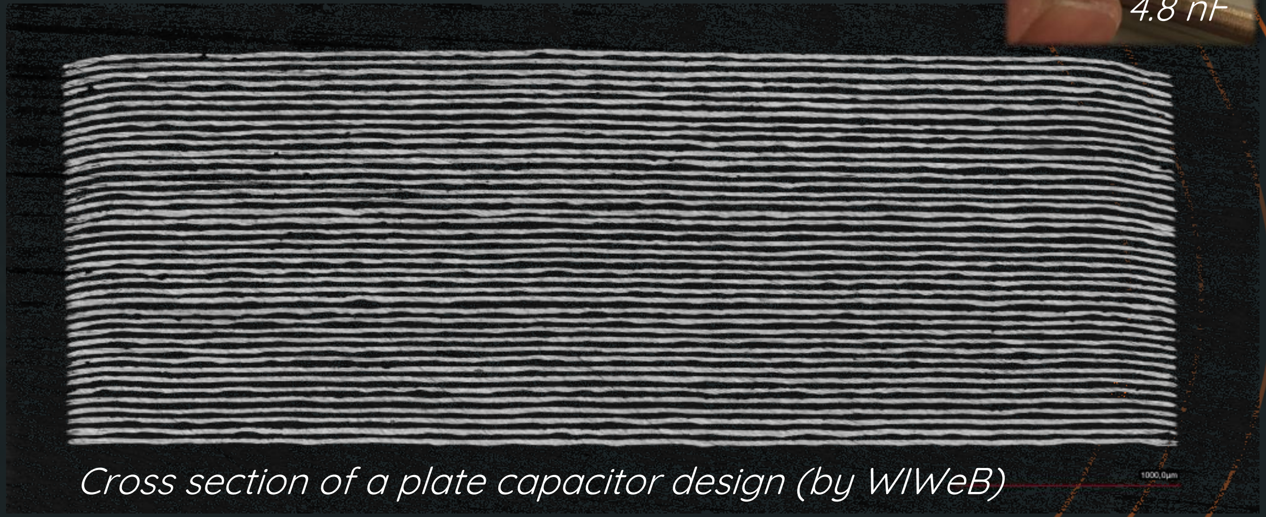
Coils and Caps Coupon - **measured**

- Measurement for 3D-Coil-Design variations
- Verification method different by usecase and frequency

AME-Cap	Measurement [pF] @100 kHz
C5	185 pF
C4	325 pF
C3	510 pF
C2	730 pF
C1	1420 pF

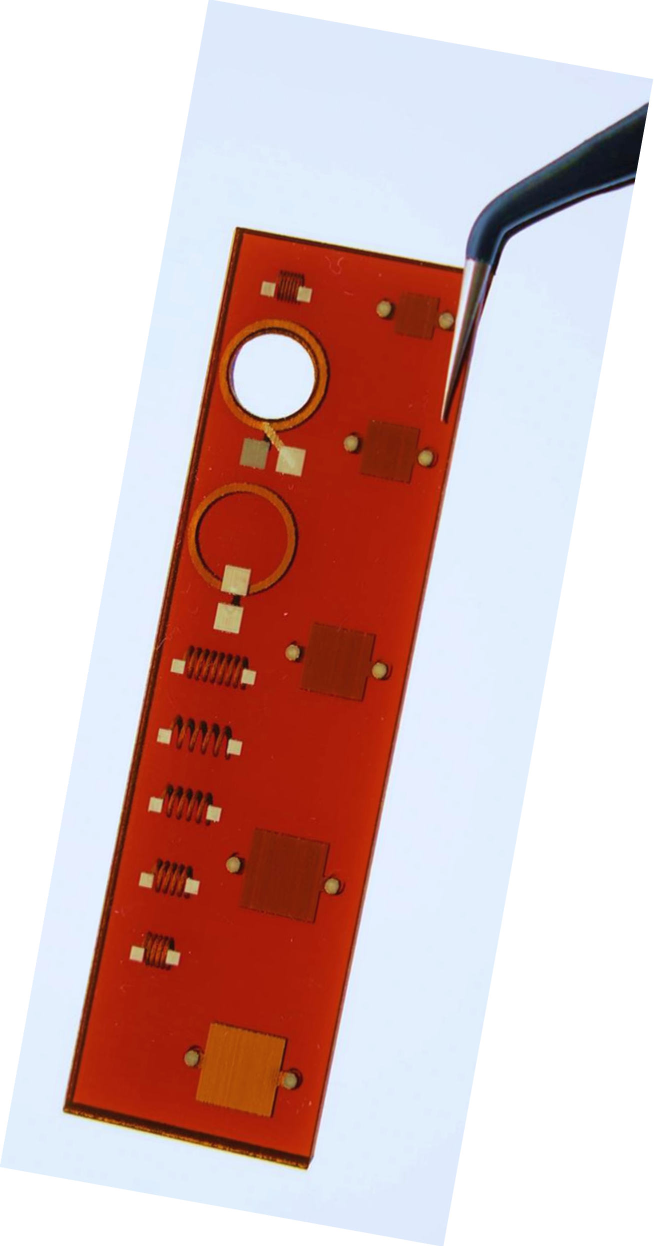
Measurement with LCR Bridge





Cross section of a plate capacitor design (by WIWeB)

Single Coils and Caps Samples From Coupon-Design



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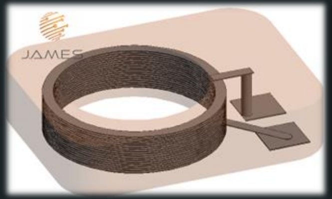
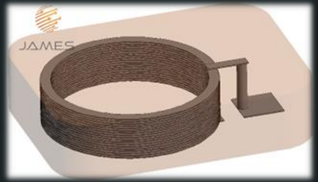
Coils and Caps single Coupon samples

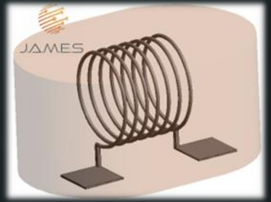
- Digital designs to implement in your design (simulated with epsilon r = 2,79)



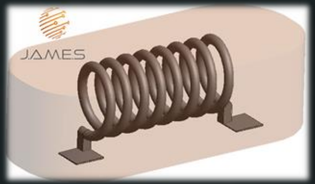
L1
3.15µH



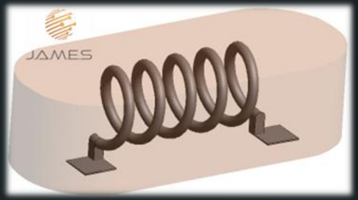
L2
3.13µH



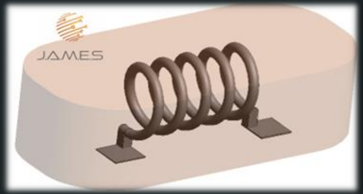
L3
76nH



L4
42nH

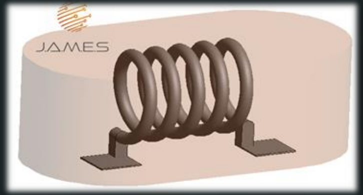


L5
23nH

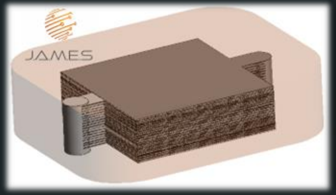


L6
23nH

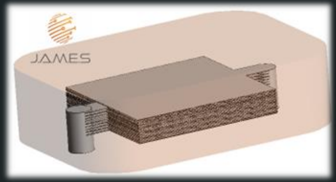
L7
25nH



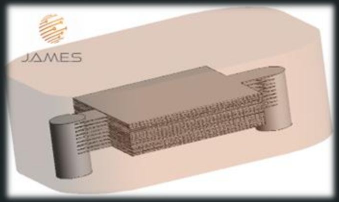
L8
27nH



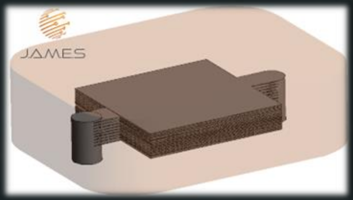
C1
171 pF



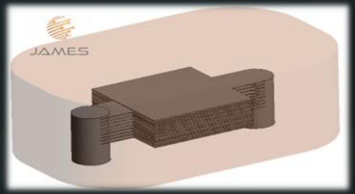
C2
462 pF



C3
299pF

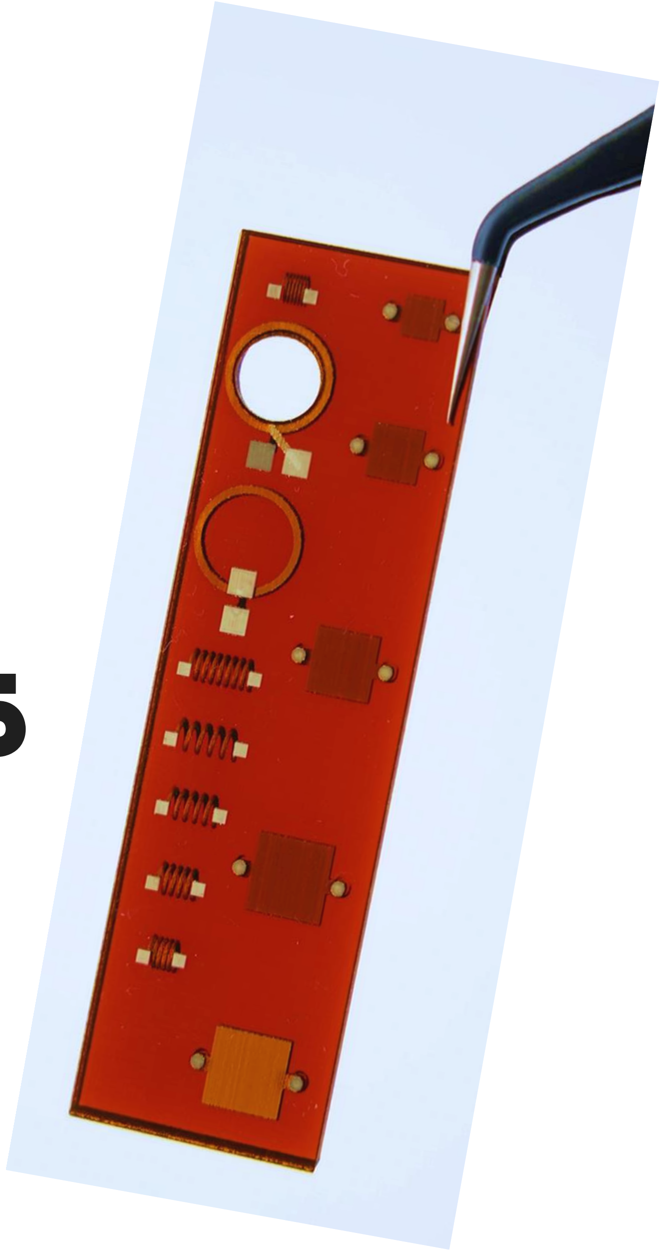


C4
661 pF



C5
1.35 nF

Simulation results For Coils and Caps coupon-Design



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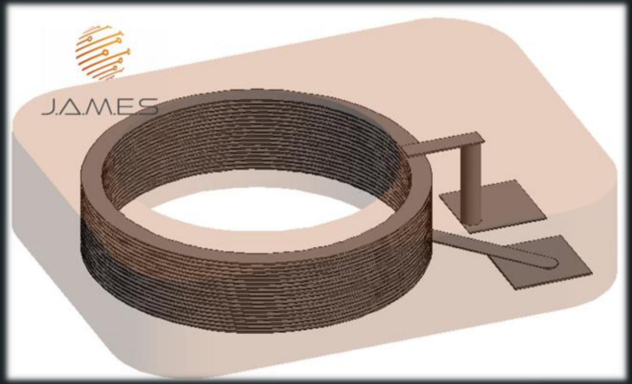
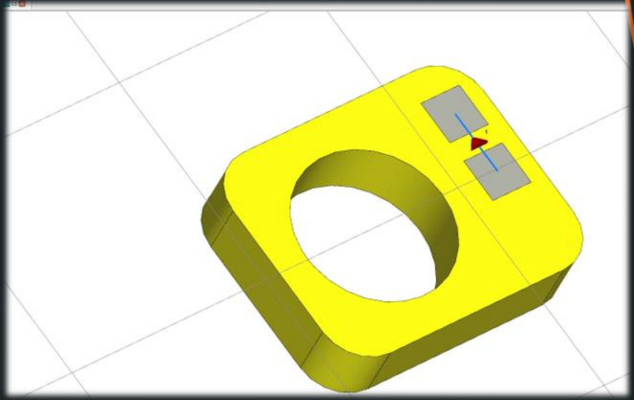
Coils and Caps single Coupon samples

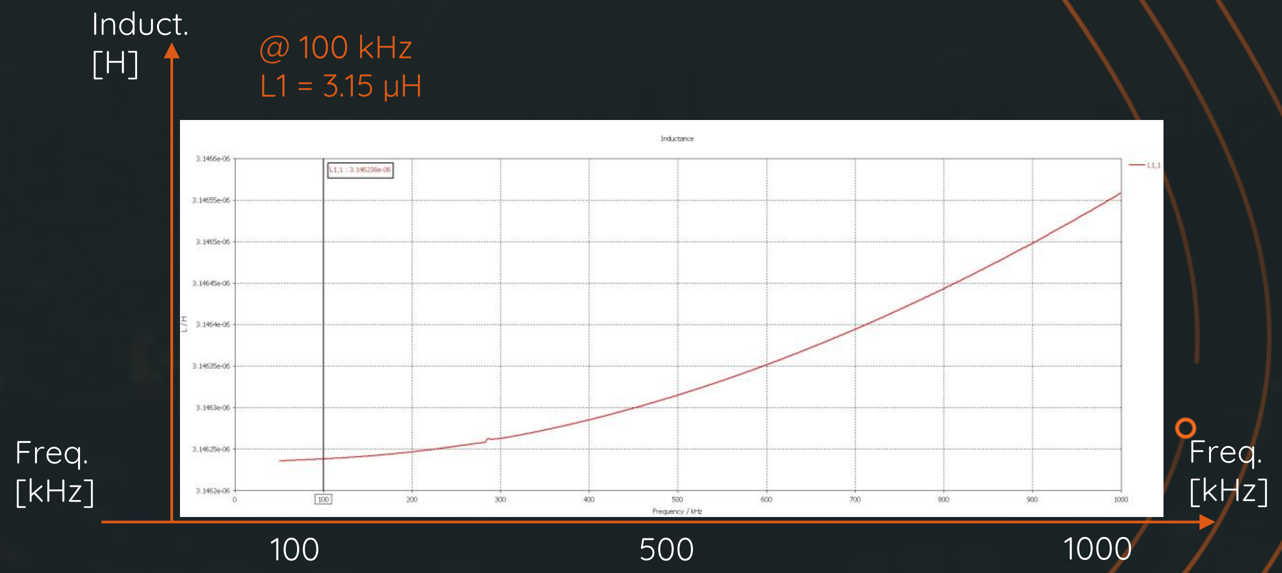
- Expample for one AME-Coil L1



L1 = 3.15 μH
Measured 3.5 μH

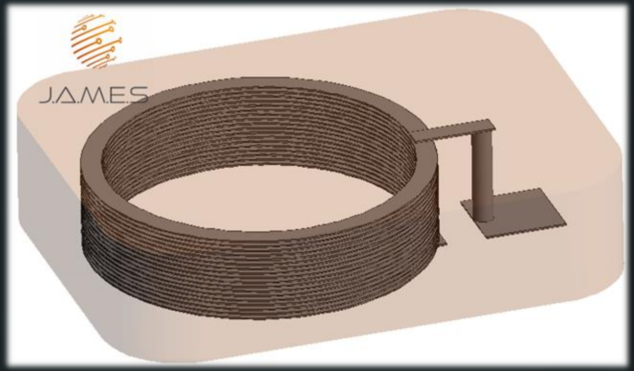
- CST-Model for Simulation





Coils and Caps single Coupon samples

- Expample for one AME-Coil L2

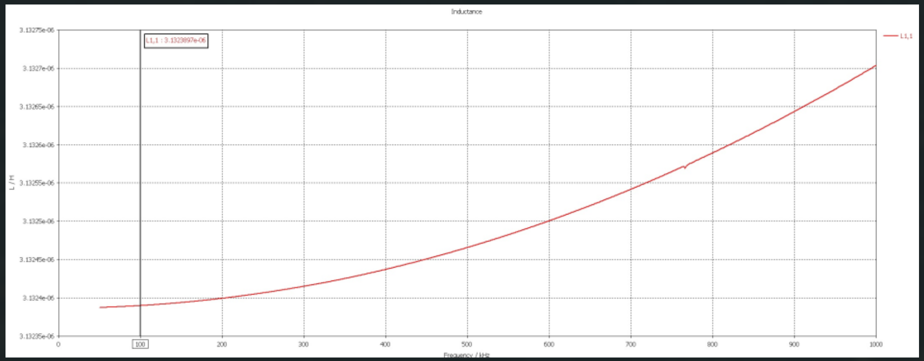


L2 = 3.13 µH

Measured 3.6 µH

Induct. [H]

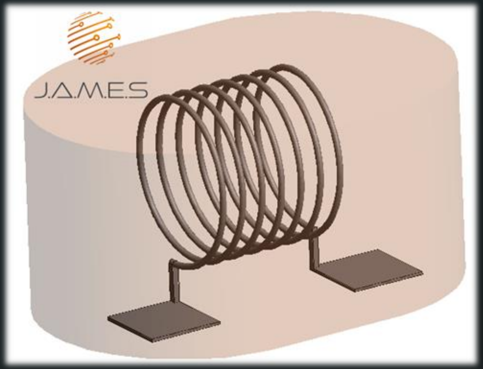
@ 100 kHz
L2 = 3.13 µH



Freq. [kHz]

100 500 1000

- Expample for one AME-Coil L3

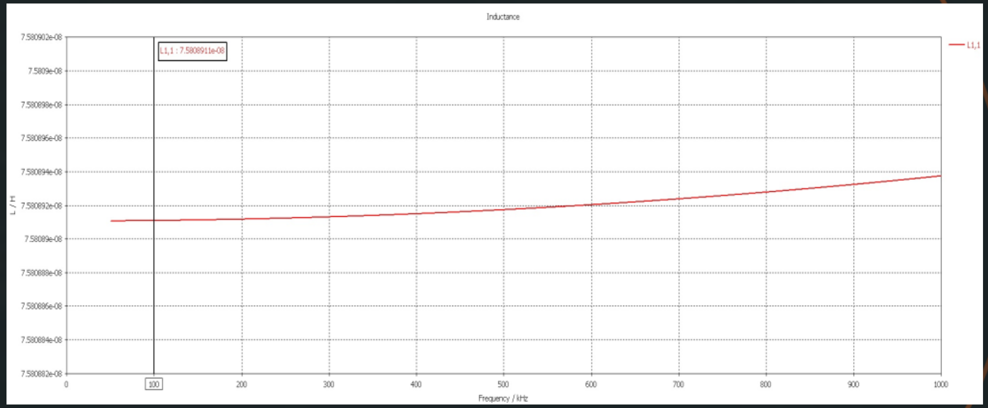


L3 = 76 nH

Not verified

Induct. [H]

@ 100 kHz
L3 =76 nH

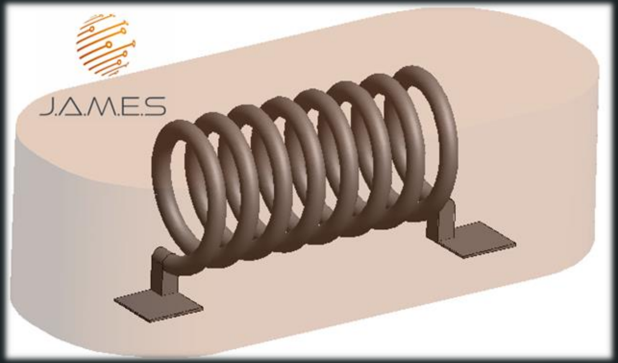


Freq. [kHz]

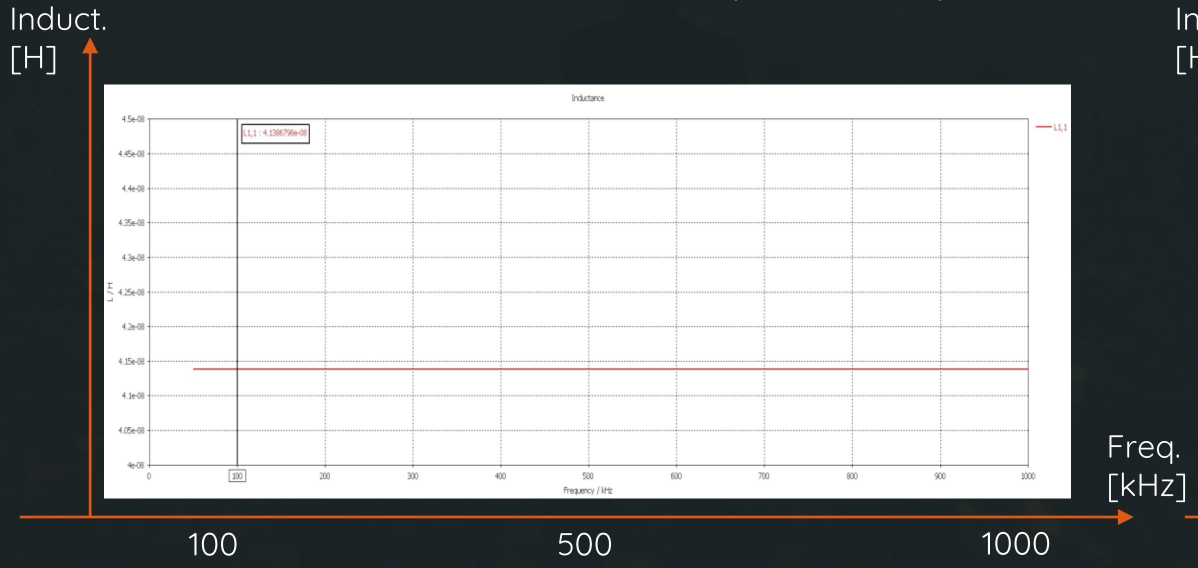
100 500 1000

Coils and Caps single Coupon samples

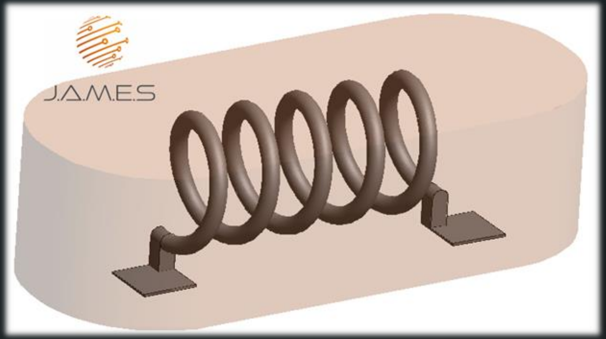
- Expample for one AME-Coil L4



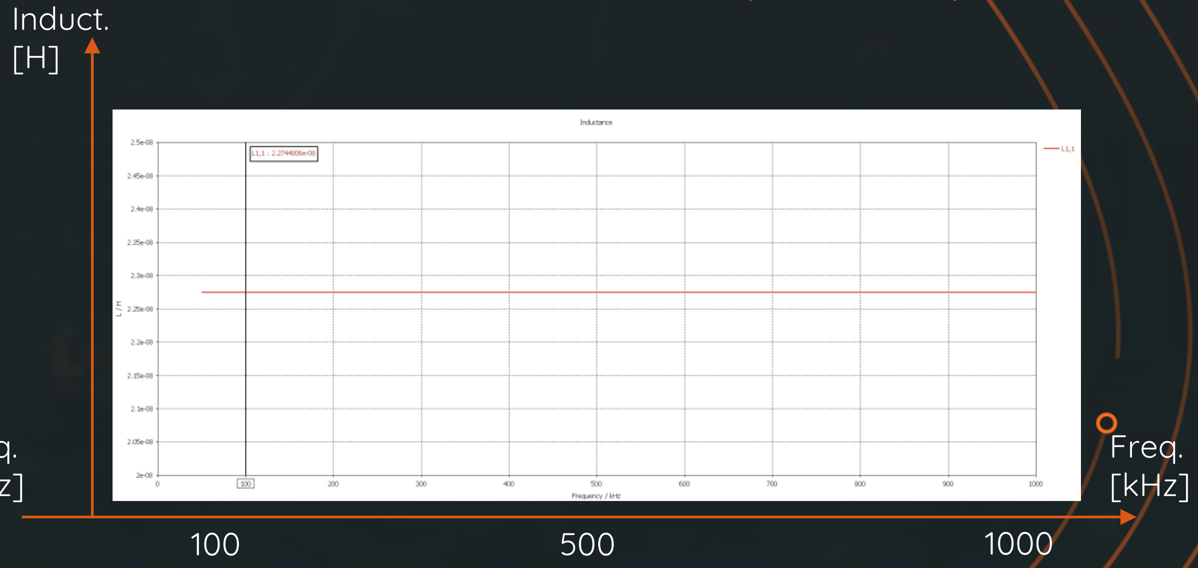
L4 = 42 nH
Measured 8 µH
(to be checked)



- Expample for one AME-Coil L5

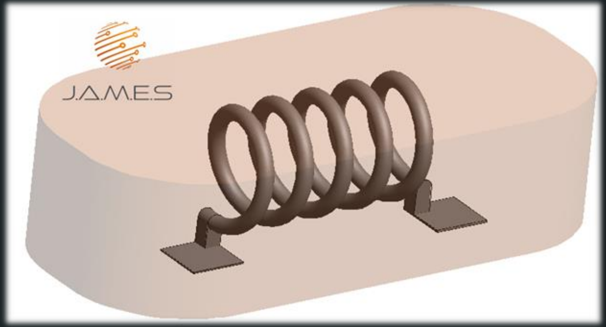


L5 = 23 nH
Measured 8 µH
(to be checked)

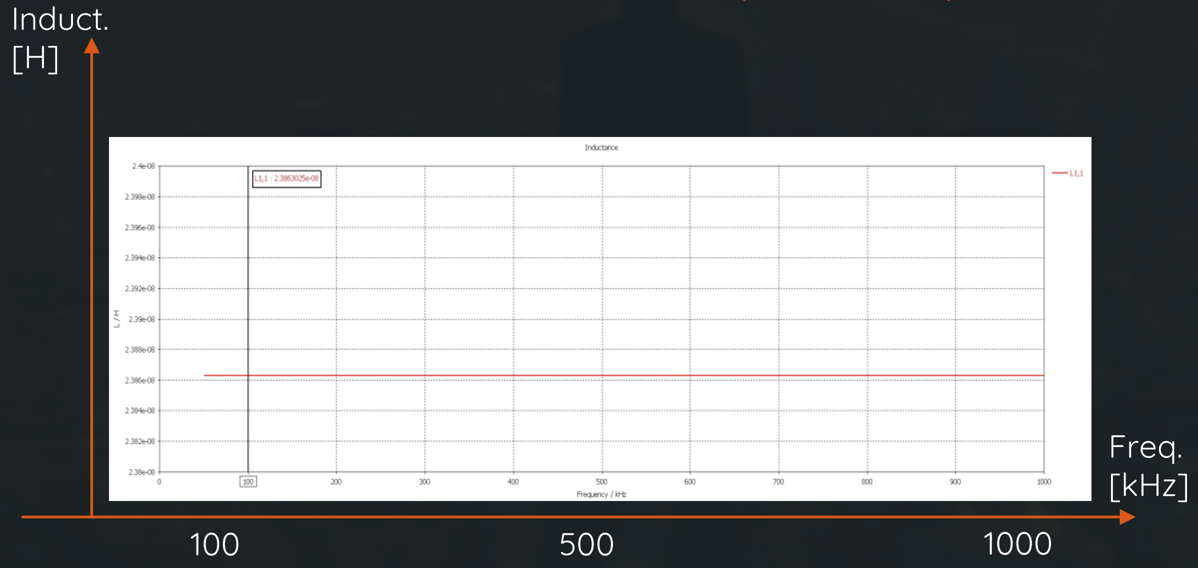


Coils and Caps single Coupon samples

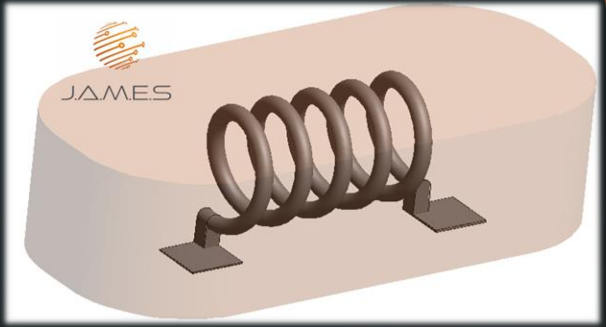
- Expample for one AME-Coil L6



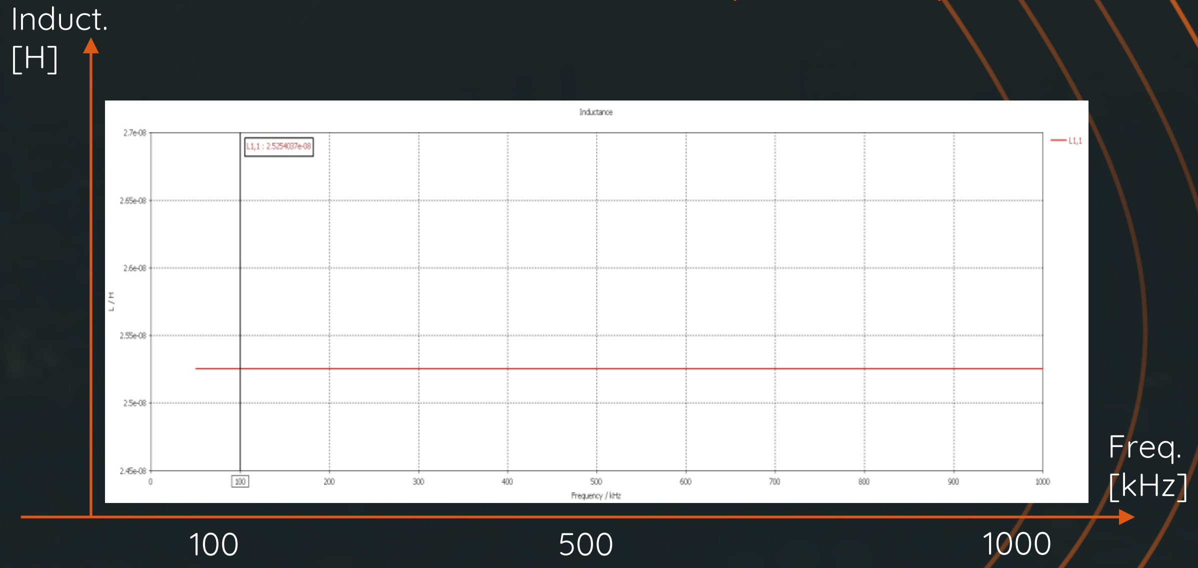
L6 = 23.9 nH
Measured 7 µH
(to be checked)



- Expample for one AME-Coil L7

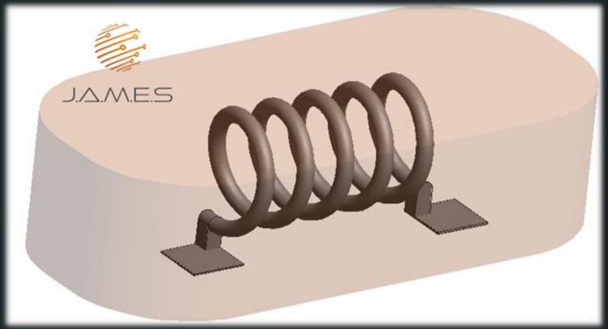


L7 = 25 nH
Measured 7 µH
(to be checked)



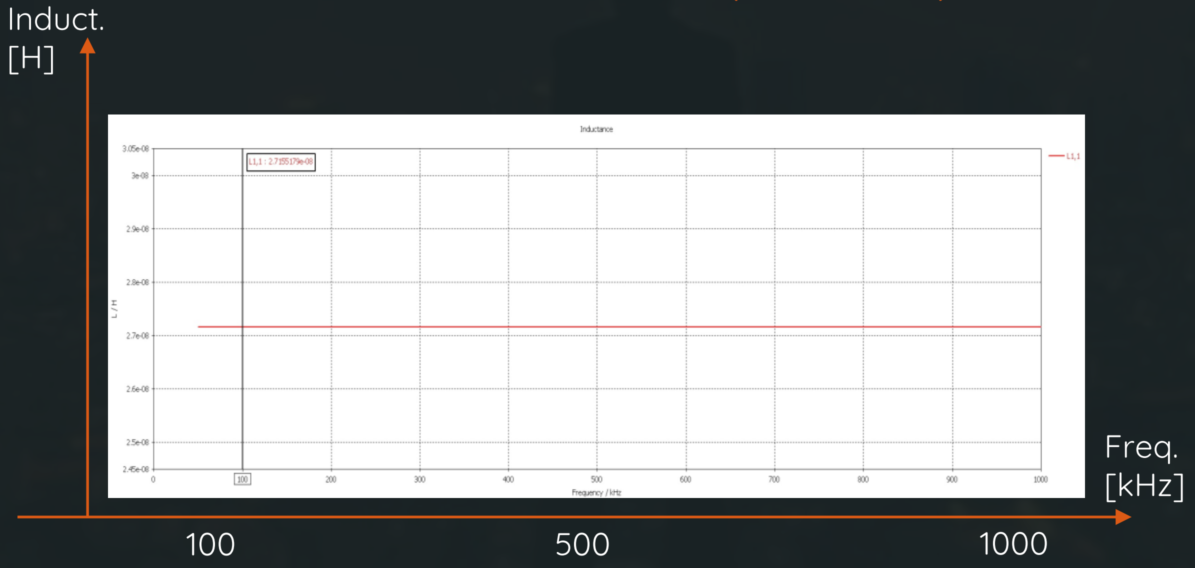
Coils and Caps single Coupon samples

- Expample for one AME-Coil L8



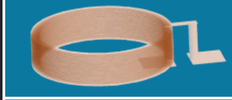
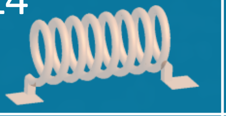
L7 = 27 nH

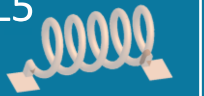
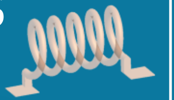
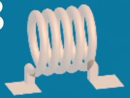
Measured 7µH
(to be checked)



Coils and Caps Coupon - **Simulation**

- Simulate 3D-Coil & Caps Design variations

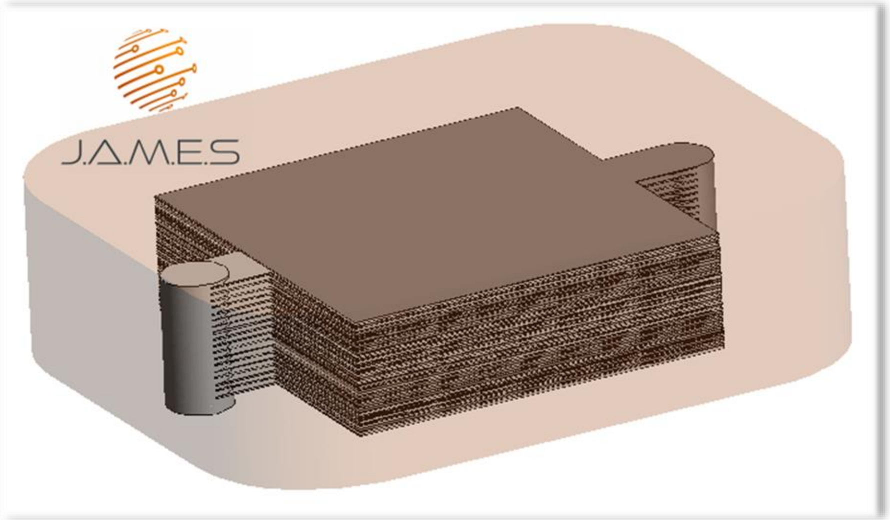
AME-Coil	Simulation @100 kHz
L1 	3.15 µF
L2 	3.13 µF
L3 	76 nH
L4 	42 nH

AME-Coil	Simulation
L5 	25 nH
L6 	23 nH
L7 	25 nH
L8 	27 nH

AME-Cap	DC-Simulation
C5 	171 pF
C4 	462 pF
C3 	299 pF
C2 	661 pF
C1 	1.35 nF

- **Ongoing and additional investigations**
  - **Potential contribution activities by**
    - **Academia**
      (e.g. Bachelor- / Master-Thesis)
    - **Industry experts with AME-strategy**

Comparison to Conventional COTS Elements



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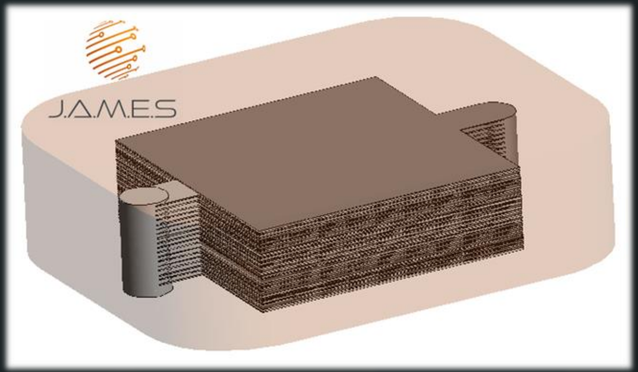
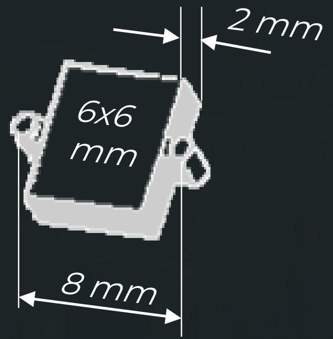
AME Capacitor and conventional COTS

- By example AME Design C1 and custom of the shelf **1400 pF Multilayer Ceramic Capacitor MLCC by KEMET**
- Typical applications
  - Frequency converters, industrial and high-end power supplies, solar inverters
- What to take into account?

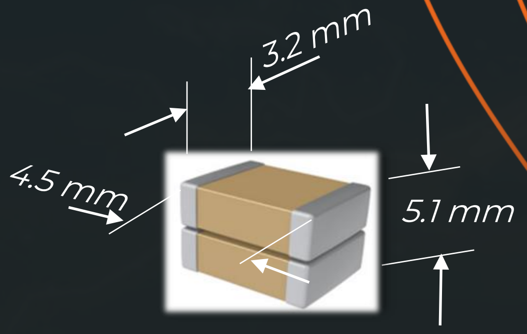




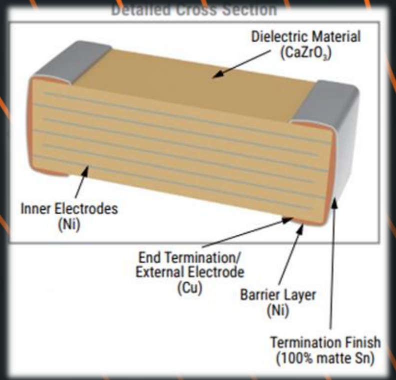
C1 ~ 1.42 nF @ 100 kHz

No further characterization available

SIMULATION characterization essential



SMD 1812



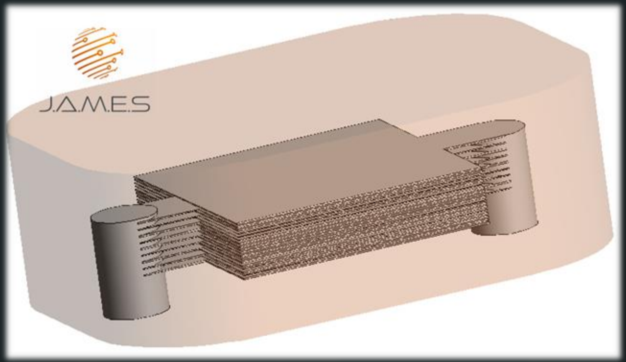
Full characterization available

Table 1A - 1812 Product Ordering Codes, Ratings, and Package Quantities

KEMET Part Number[1]	Capacitance	Cap Code	Voltage	Number of Chips	Thickness mm (inch)	Typical Average Piece Weight (g)	Tape & Reel Quantity 7" Tape & Reel	Tape & Reel Quantity 13" Tape & Reel
C1812(a)142(b)ZGLC(c)	1.4 nF	142	2,500 V		5.1 (0.200) ±0.4 (0.016)	0.30	200	850

AME Capacitor and conventional COTS

- By example AME Design C5 and custom of the shelf **AC rated ceramic condensator 470 pF SMD** by Murata
- Typical applications
  - Switching power supplies, noise suppression filters etc.
- What to take into account?



C3 ~ 510 pF @ 100 kHz

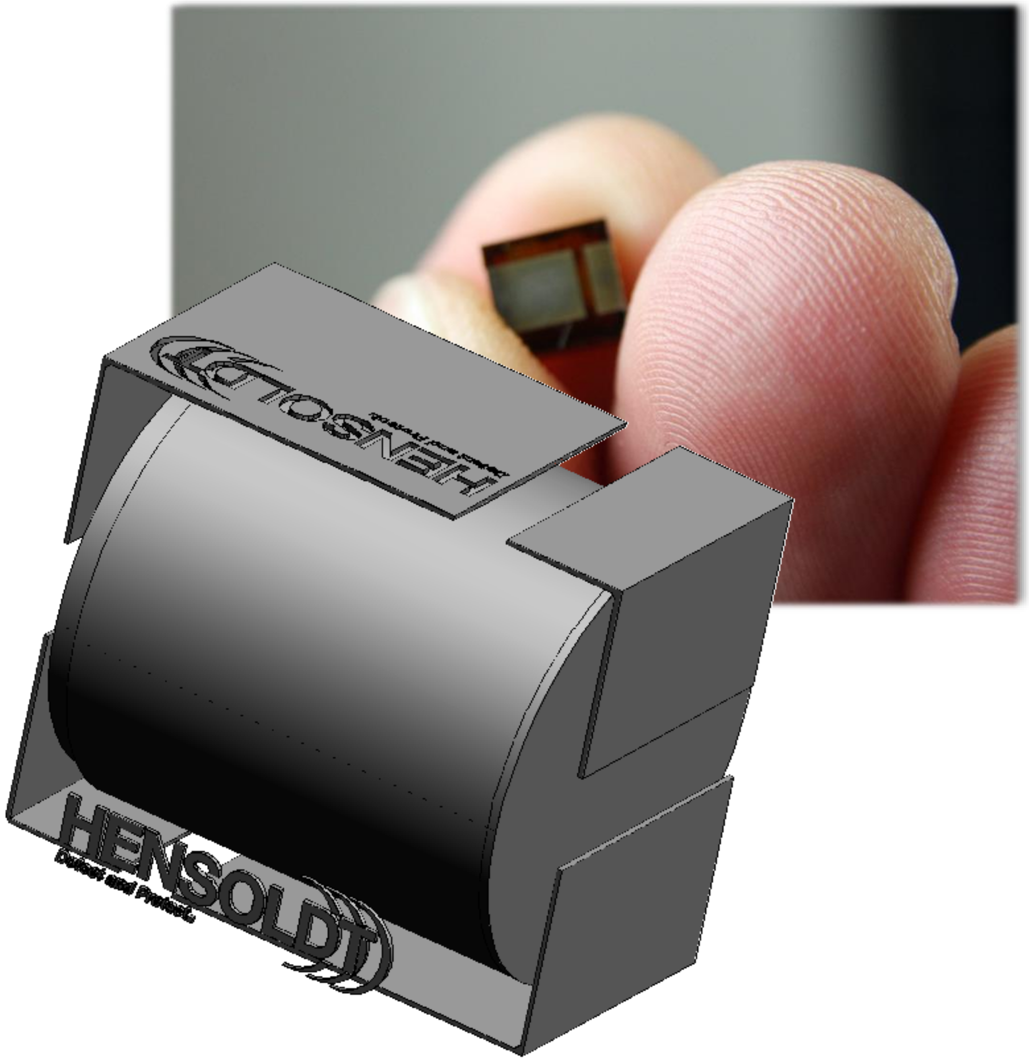
No further characterization available

Full characterization available

Minimum quantity procurement 2000

SIMULATION characterization essential

Outlook



Outlook

- Further Designs for 3D AME-printed lumped elements will appear (e.g. for Filter building blocks)

- The ability to create freshaped passive lumed elements for
  - Individual formfactors
  - Miniaturised applications
  - Avoiding assembly
  - Technical reasons from DC to RF

  Show an upcoming trend and usecase for additively manufacturing electronics

- Sustainability reasons could play some relevant role
  - Needs-based Production of components in individual amounts can help to avoid production for waste

- Increase Effords to reach out a product level use case for 3D AME-printed elements
  - More characteristics data have to be provided
  - Simulation of AME-elements will play a major role for the future
  - The existing performance gap between simulation and realization results has to be bridged
    - In accordance to the overall AME long term stability issues

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