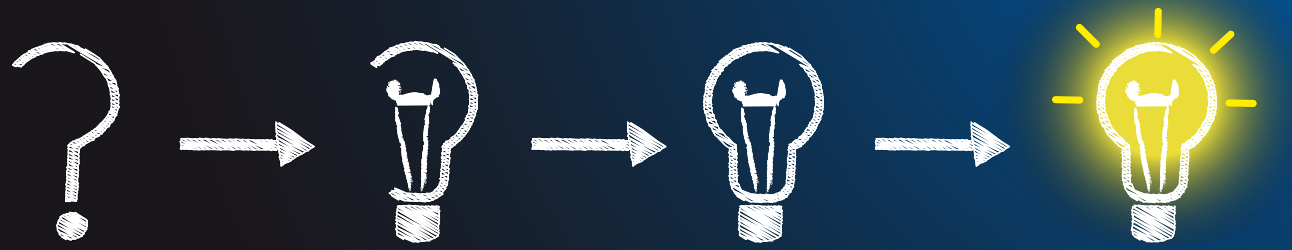


# 10th Power Analysis & Design Symposium

March 10th, 2021 - Worldwide (Virtual)

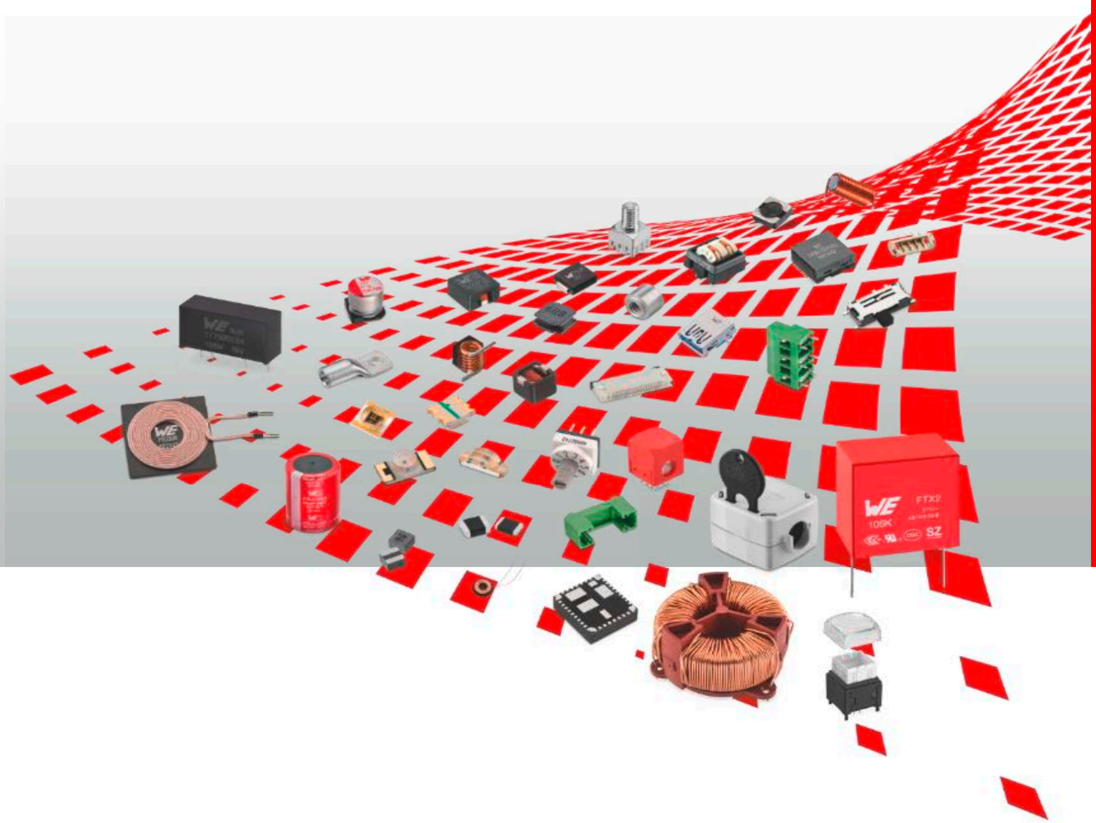
**The Search for the Best DC-Bias Components**

by Melanie Klenner (K&K Prime Engineering) & Joanne Wu (Würth Elektronik)

OMICRON LAB

WÜRTH ELEKTRONIK

# The search for the best DC-Bias components



more than you expect

Joanne Wu
WE eiSos
&
Melanie Klenner
K&K Prime

# Agenda

- Introduction
- Low Current
- High Current
- DC-Block
- Measurement to Simulation
- Final Summary

# Introduction
## *Use-Case – Narrowband*

WÜRTH ELEKTRONIK

- **Applications combining RF & DC**

- GPS
- Satellite communication
  - Low Noise Block (LNB)
- Wireless LAN (WiFi)


© Garmin

© Summitsource.com

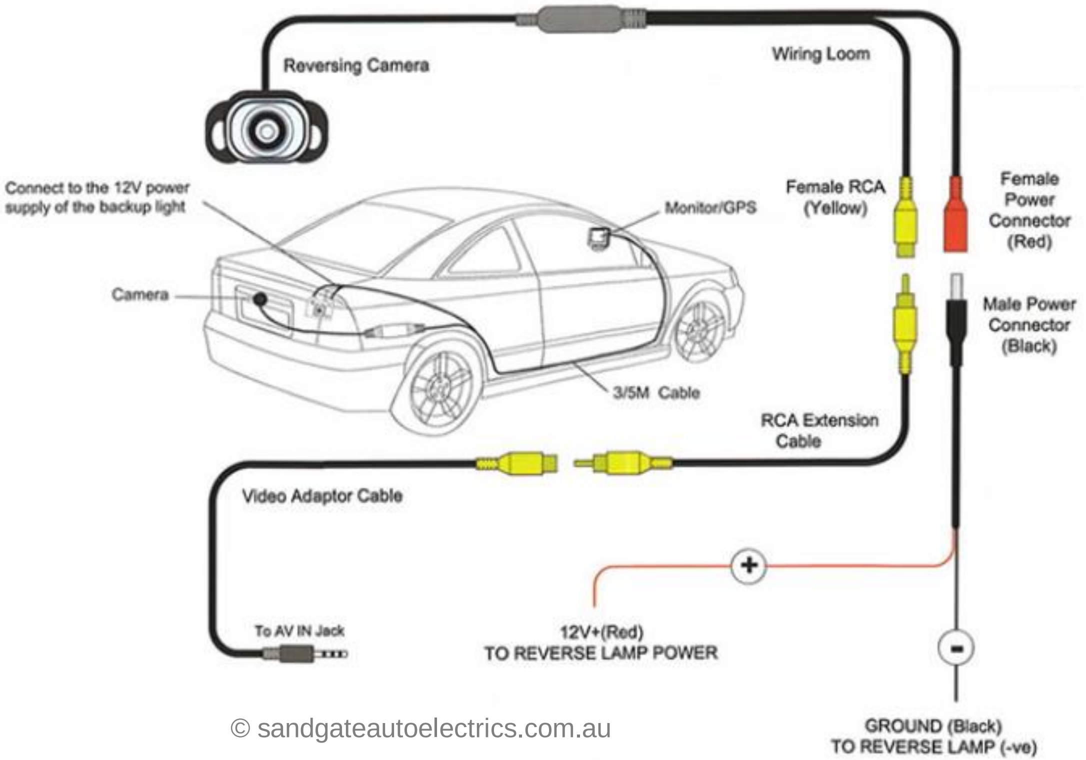

© pngimage.net

# Introduction

## *Use-Case – Narrowband*

- **Applications combining RF & DC**
  - Camera system in vehicles

© Komando.com




© sandgateautoelectrics.com.au

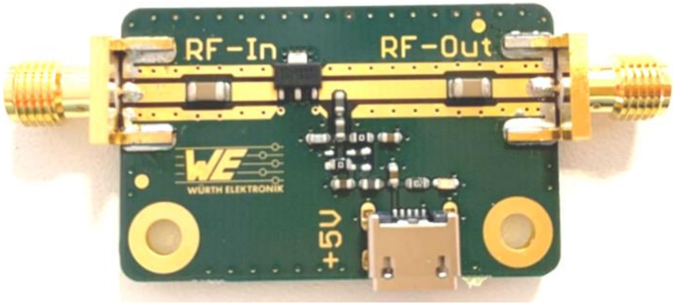
# Introduction

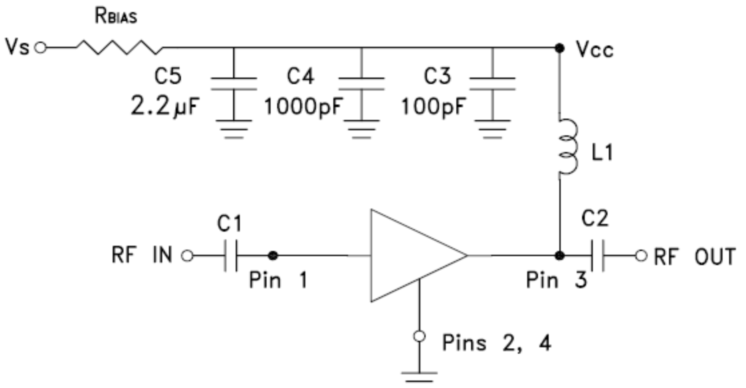
## *Use-Case – Broadband*

- **Gain amplifier:**
  - Broadband amplifiers needed for signal generators
  - Bias network within RF circuit design is crucial for overall performance
  - Limited or only narrowband literature

- **Question:**

  **How to achieve good RF throughput for broadband applications?**




***Recommended Component Values***

| Component | Frequency (MHz) | | | | |
|---|---|---|---|---|---|
| | 50 | 900 | 1900 | 2200 | 2400 |
| L1 | 270 nH | 56 nH | 18 nH | 18 nH | 15 nH |
| C1, C2 | 0.01 µF | 100 pF | 100 pF | 100 pF | 100 pF |

© Analog Devices, HMC311ST89

# Introduction

## *Summary*

### General Information

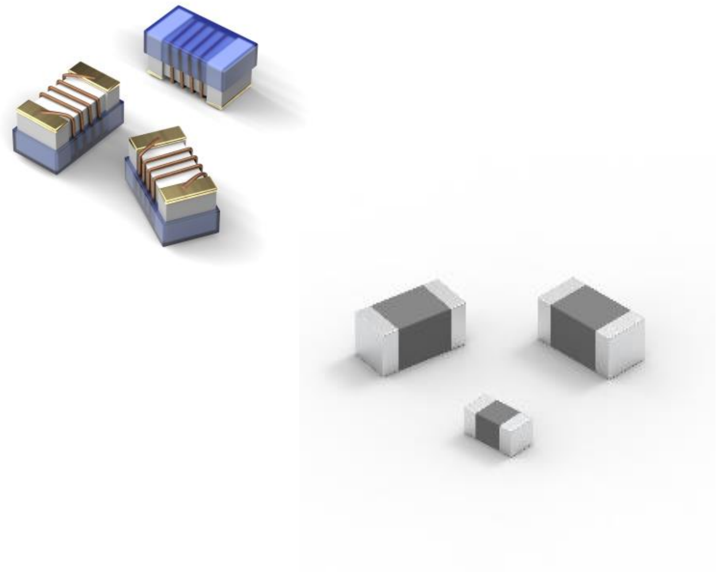
- Wrong DC-biasing:
  - RF signal loss
  - RF signal within power line
- Limited literature about broadband DC-Biasing

### Main categories

- Low current
  - Up to 1A
- High current
  - More than 1A
- DC Block

# Low Current

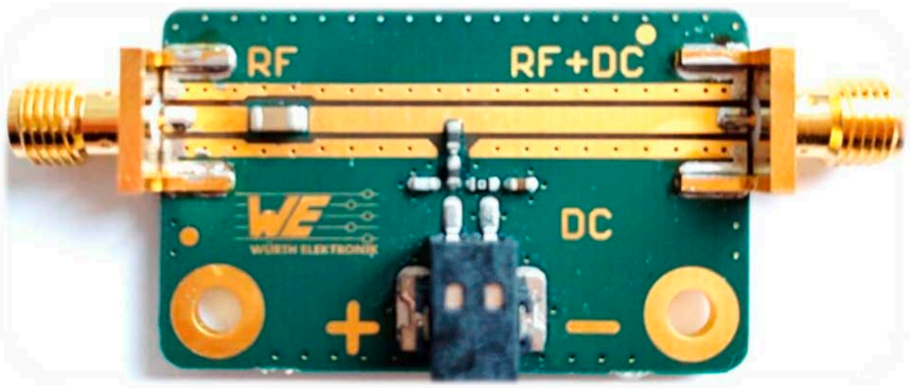
- *Combining RF+DC*
- *Standard Approach*
- *Unconventional Approach*
- *Selecting the best fit*

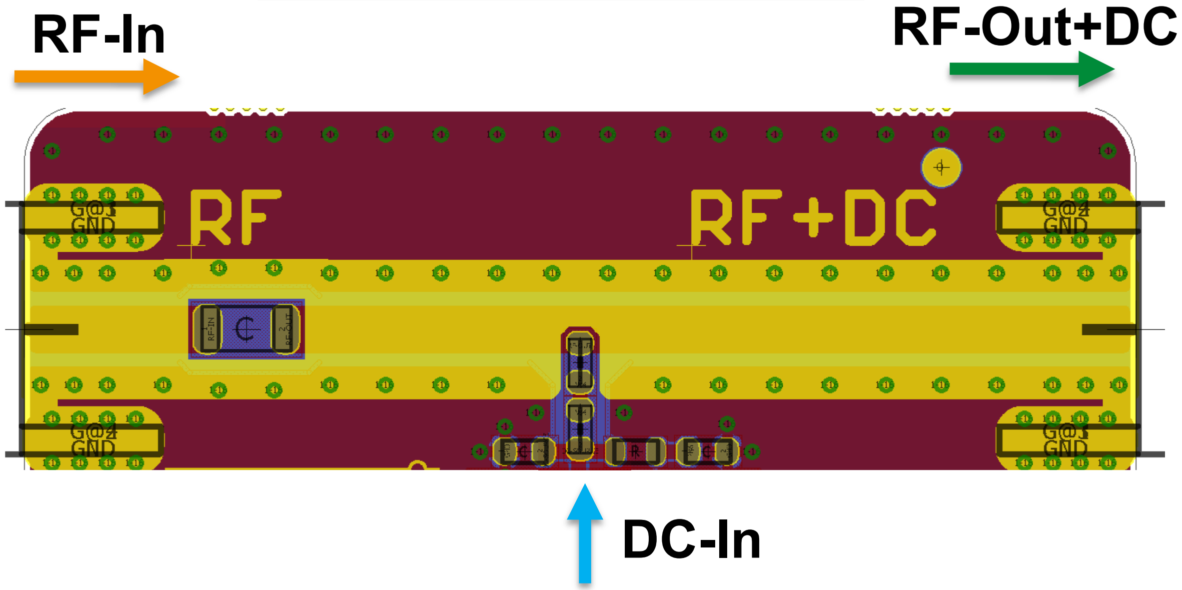


# Low Current

## *Combining RF+DC*

- **RF Trace:**
  - Check line impedance
  - Avoid solder mask & Use via fence
- **Components:**
  - Minimize stray parasitics
  - Good GND for SMA connectors
- **S-Parameters:**
  - S11: Reflection at RF-In
  - S21: Throughput from RF-In to RF-Out

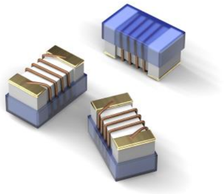


# Low Current

## *Standard approach – Wire wound ceramic*

- **WE-KI:**
  - 744761156A - 56nH



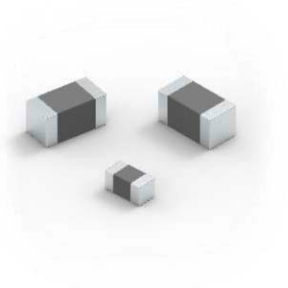
- **Pros & Cons:**
  - + Broadband
    - 400 MHz to 6 GHz
  - – Resonate with filter capacitors
  - – Self resonation with high Q
  - – Not for low frequency <400 MHz


Inductor WE-KI

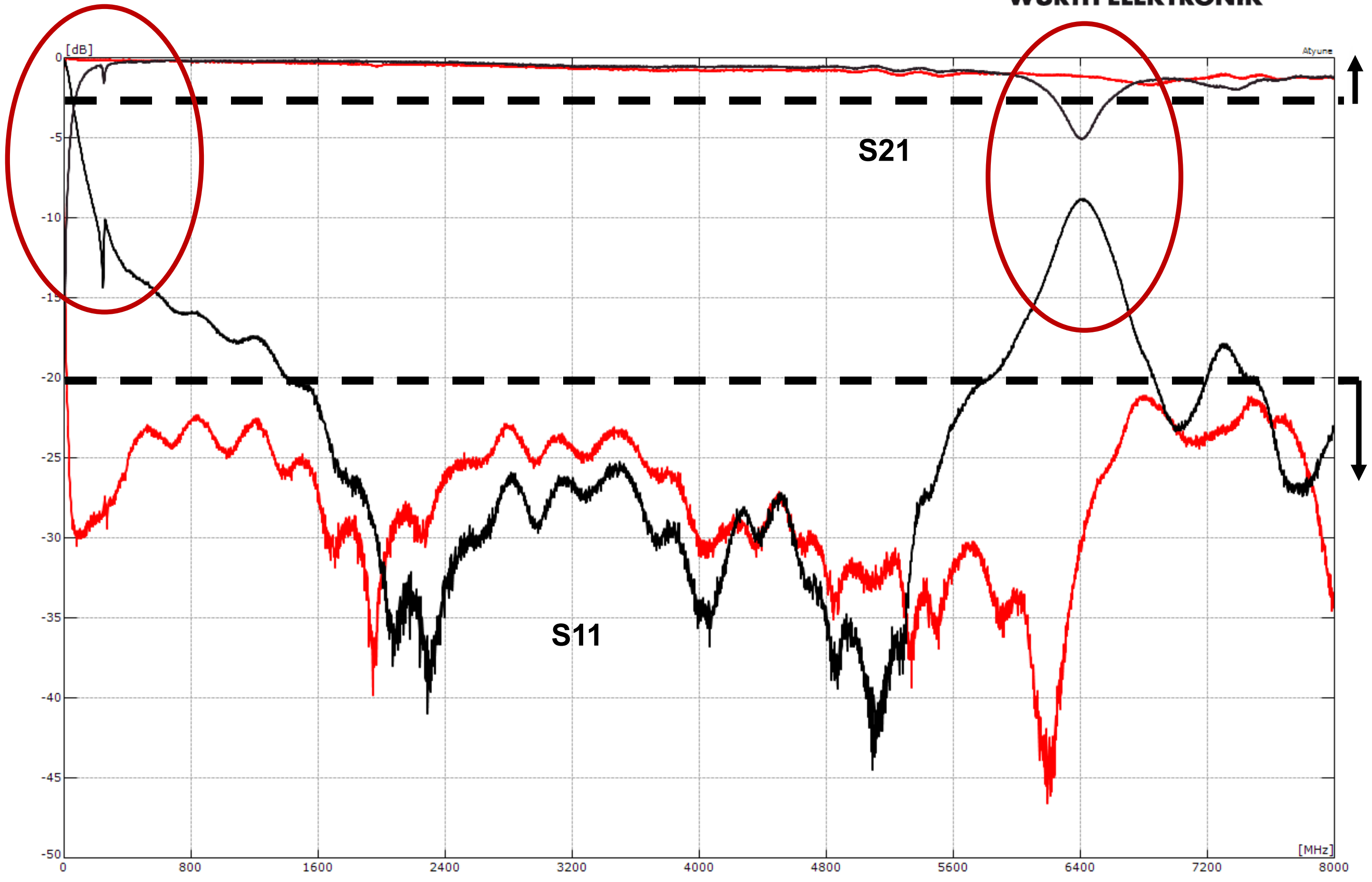
# Low Current

## *Unconventional approach – Ferrite beads*

- **WE-CBF HF:**
  - 742863160 - 600Ω



- **Pros & Cons:**
  - \+ Very broadband
    - 30 MHz to 7 GHz
  - \+ Low frequencies
  - – Low current rating
  - – Bead saturation



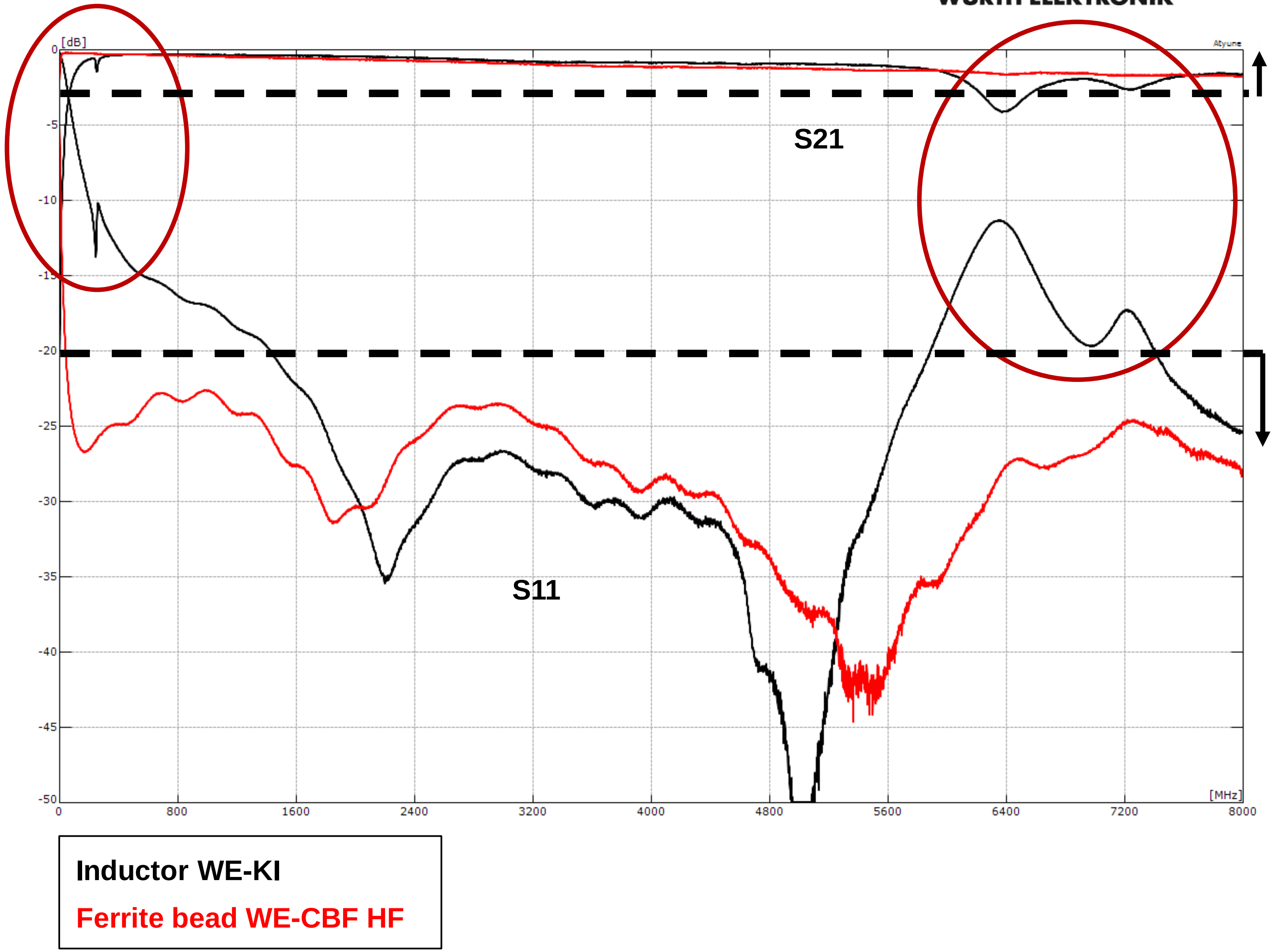

**Inductor WE-KI**

**Ferrite bead WE-CBF HF**

# Low Current

## *Unconventional approach – Ferrite beads 0.1A*

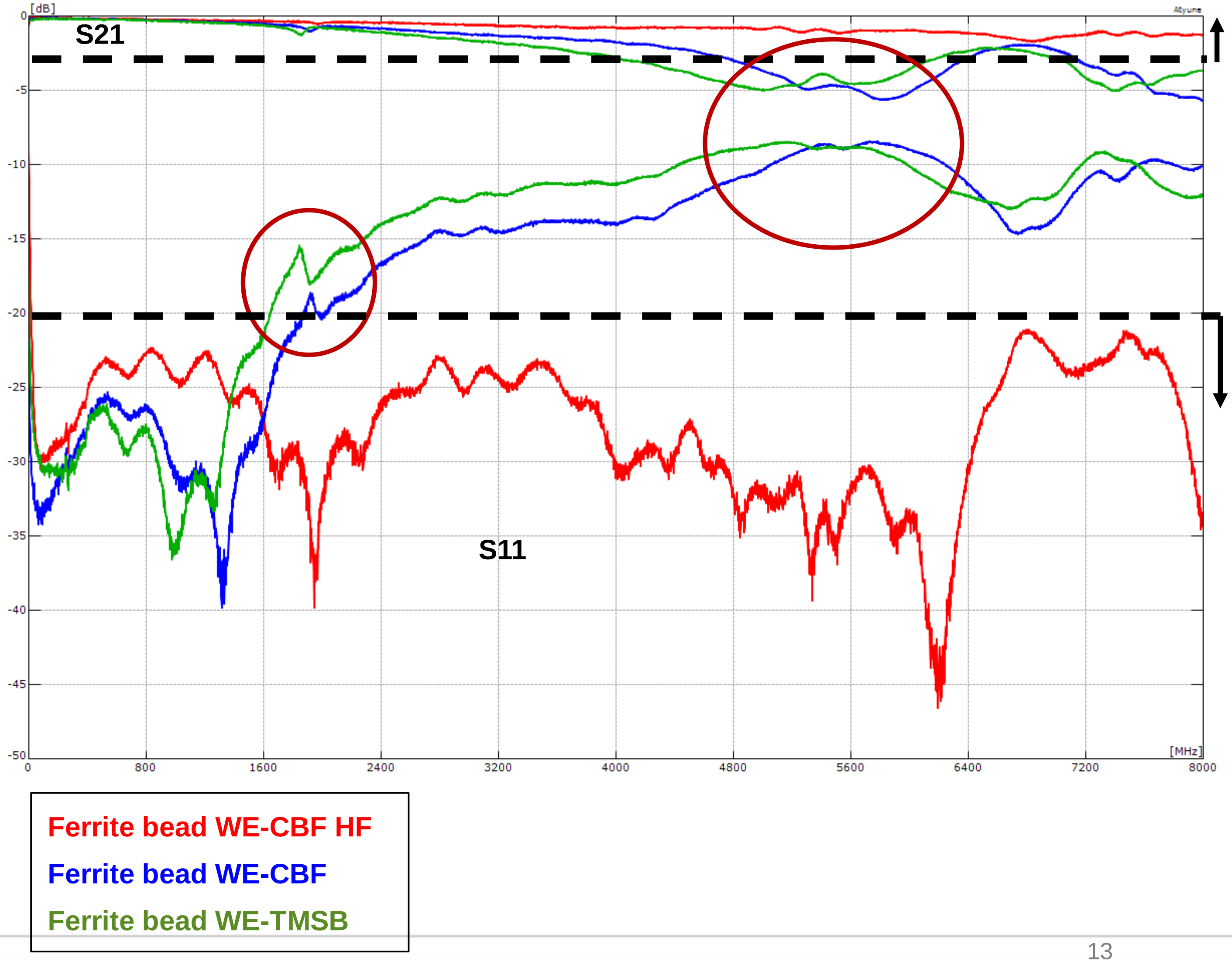
- **Conclusion:**
  - Ferrite saturation
    - ↓Impedance
  - Use two ferrite beads in series
    - Doubles impedance
  - Choose the right component
    - High impedance
    - Saturation current



# Low Current

## *Selecting the best fit*

- **Used chip beads:**
  - CBF HF – 742863160
  - CBF – 742792656
  - TMSB – 74269262601
- **Results:**
  - All broadband & good for LF
  - Freq. restriction due to:
    - Parasitic capacitances
    - Resonances



# Low Current

## *Choosing the right component*

REDEXPERT® | FERRITES FOR PCB ASSEMBLY | APPLICATIONS | HOW TO | SHARE | ITEMS | MELANIE

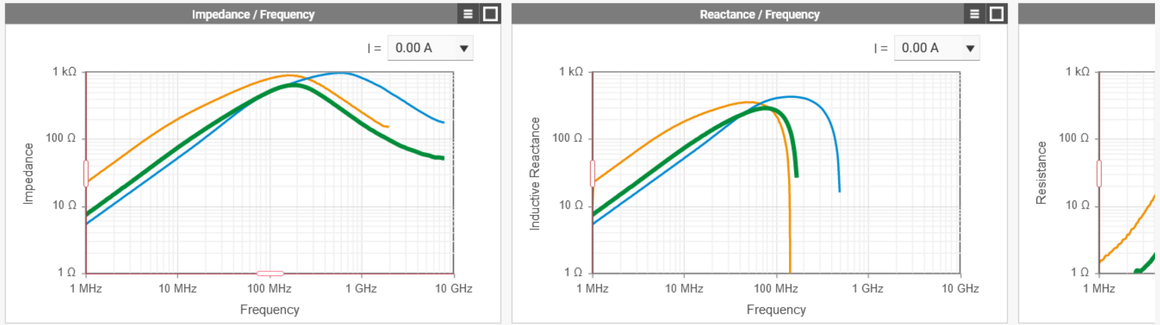
System
Pulse

100 / 360 items

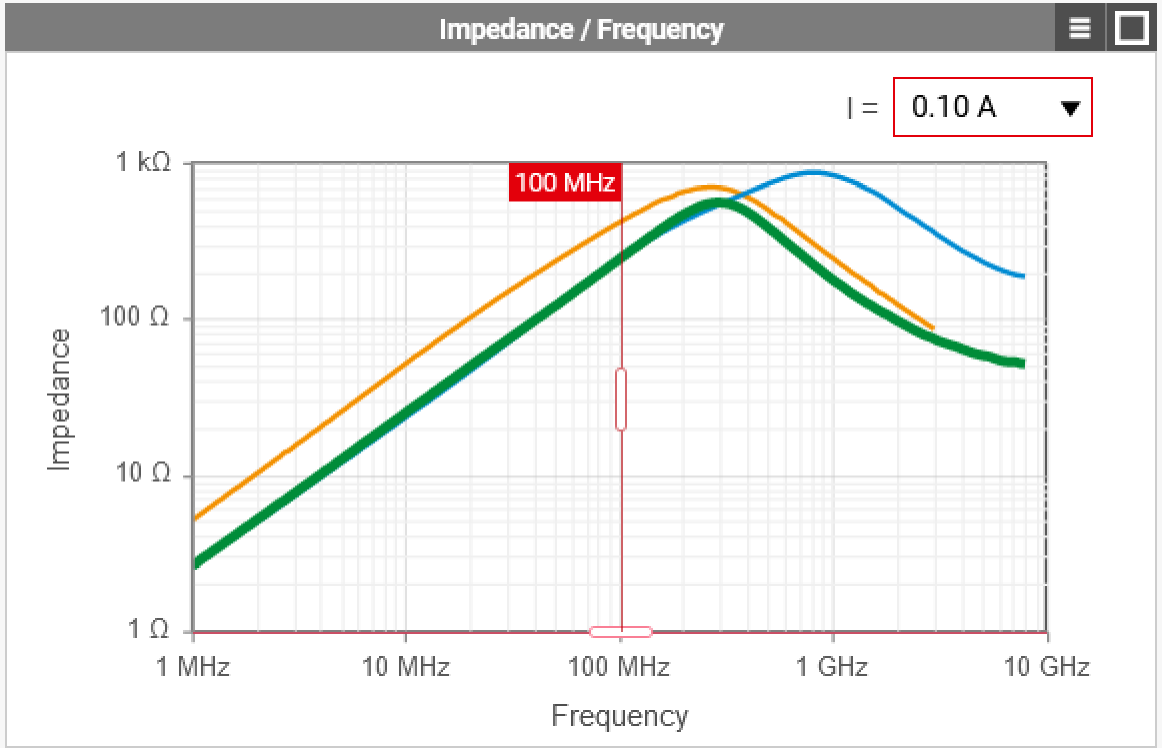
| Order Code | Series | Size | Spec | Type | Z@100MHz | $Z_{max}$ | $R_{DC}$ | $I_R$ | L | W | H | Pin L... | Lines | Assembli... | AEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74269262601 | WE-TMSB | 0603 | PDF | High Current | 600 Ω | 634 Ω @184 MHz | 89.0 mΩ | 1.50 A | 1.60 mm | 0.800 mm | 0.800 mm | | 1 | SMT | |
| 74273001 | WE-MLS | 7650 | PDF | 3 lines | 264 Ω | 264 Ω @100 MHz | 2.00 mΩ | 4.00 A | 7.62 mm | 5.08 mm | 10.0 mm | 5.80 mm | 3 | THT | |
| 74273002 | WE-MLS | 1111 | PDF | 4 lines | 249 Ω | 260 Ω @300 MHz | 2.00 mΩ | 4.00 A | 10.9 mm | 5.49 mm | 10.0 mm | 3.19 mm | 4 | THT | |
| 742730021 | WE-MLS | 1111 | PDF | 4 lines | 170 Ω | 200 Ω @1.00 GHz | 2.00 mΩ | 4.00 A | 11.2 mm | 11.2 mm | 5.00 mm | 4.25 mm | 4 | THT | |
| 742730022 | WE-MLS | 1111 | PDF | 4 lines | 248 Ω | 275 Ω @400 MHz | 2.00 mΩ | 4.00 A | 11.2 mm | 11.2 mm | 8.00 mm | 2.75 mm | 4 | THT | |

742863160 — WE-CBF HF · 0603 — 600 Ω
742792656 — WE-CBF · 0603 — 750 Ω
74269262601 — WE-TMSB · 0603 — 600 Ω
Click and type or drop an Order Code here

Show Panel: Z vs. F | X vs. F | R vs. F | I vs. PL | I vs. N




ABOUT WÜRTH ELEKTRONIK SITEMAP CONTACT IMPRINT COPYRIGHT © 2020 WÜRTH ELEKTRONIK GMBH. ALL RIGHTS RESERVED.

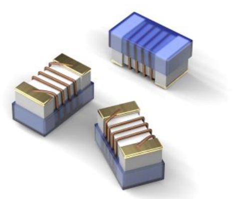


# Low Current
## *Summary*

WÜRTH ELEKTRONIK

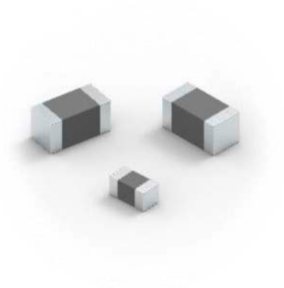
### Components

- Coil – WE-KI



- Resonances
- Not for low freq.

- Ferrite – WE-CBF HF



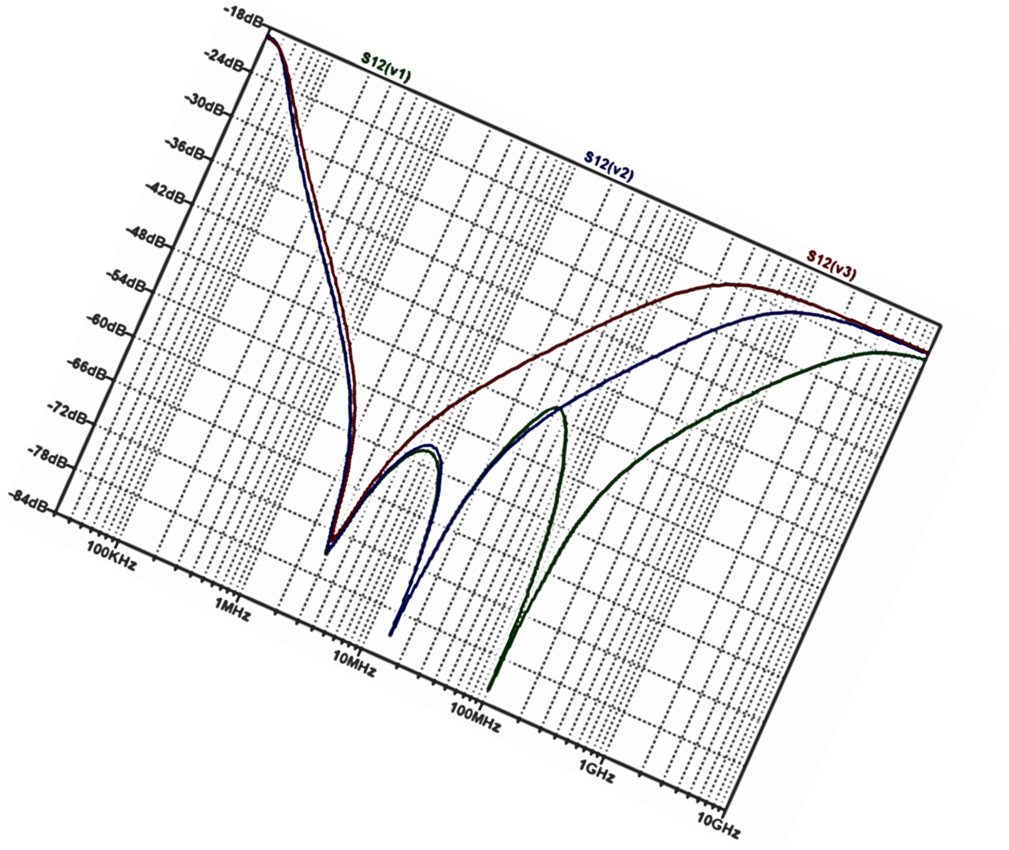
- No resonances
- Broadband



### Conclusion

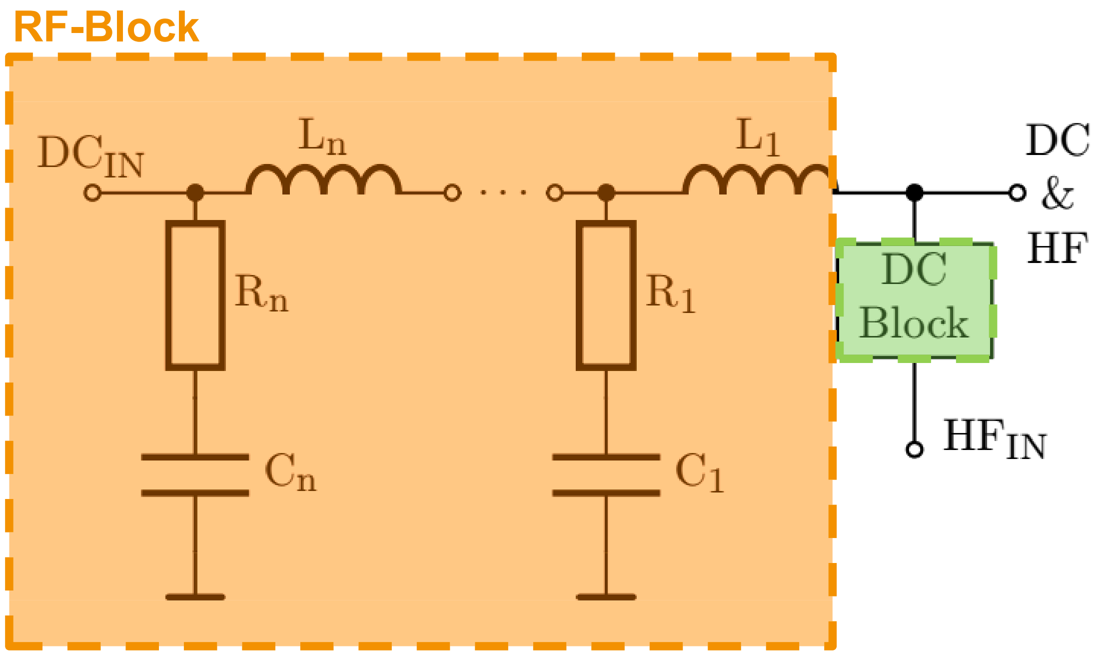
- Compare different inductors and ferrites
- Measurement data with DC-Bias available
- Ferrites improve broadband RF throughput

- **High Current**
  - *Concept*
  - *Simulation example*
  - *Components*



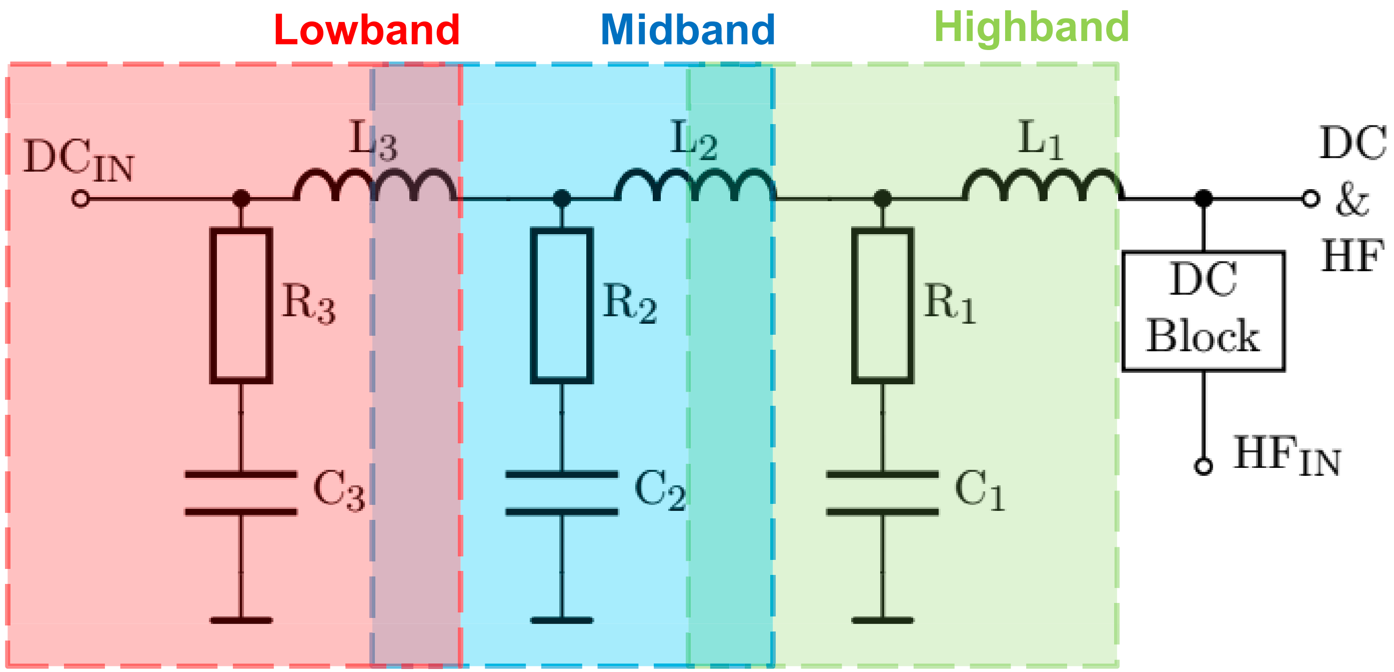
# High Current
## *Concept – Bias Tee (1)*

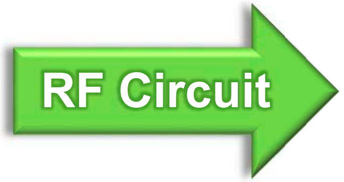
- **Theory:**
  - DC-Block & RF-Block
- **Characteristic RF-Block:**
  - DC: Low R = $R_{DC}$
  - RF: High Z
- **Broadband:**
  - Cascade RF-Block

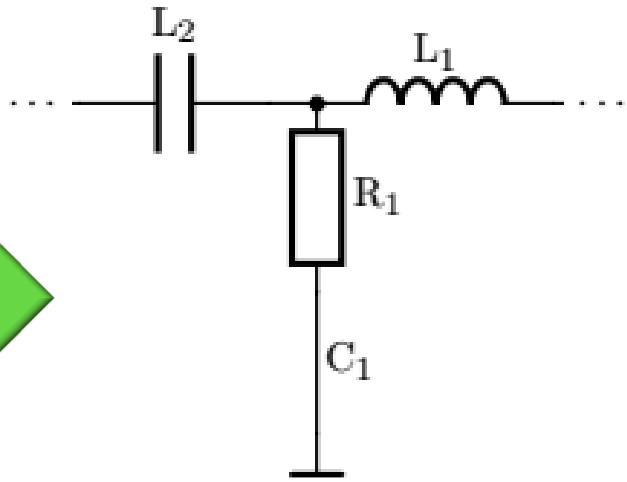


# High Current

## *Concept – Bias Tee (2)*



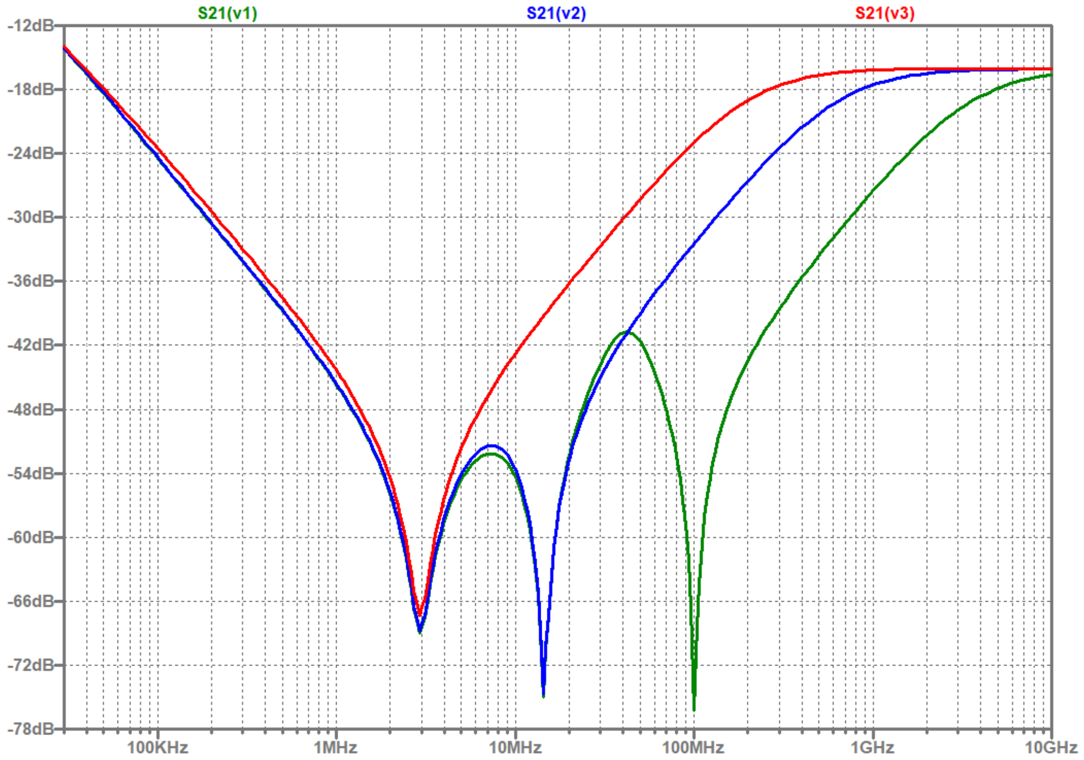



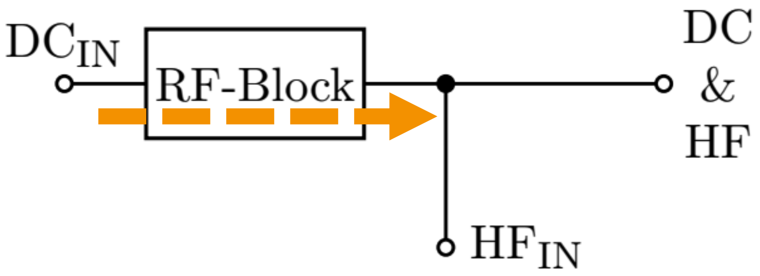



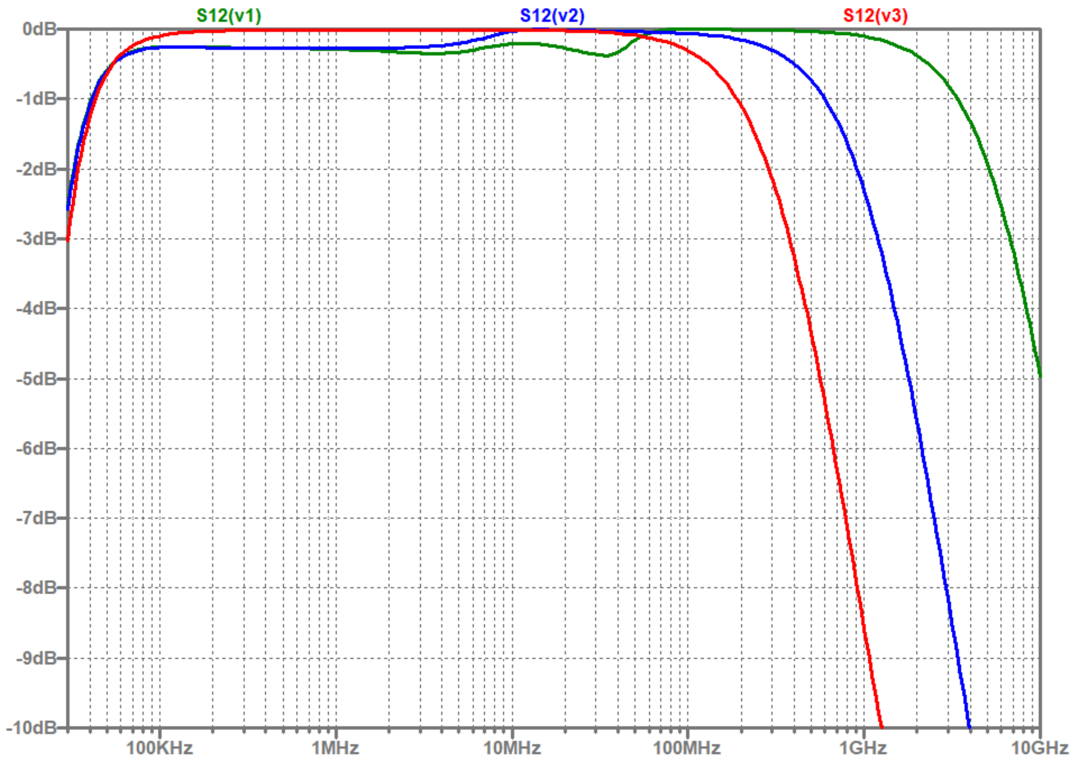

- **Capacitors & Inductors**
  - $C_3 > C_2 > C_1$
  - $L_3 > L_2 > L_1$
- **Resistors**
  - Low $R_3 \rightarrow$ low $Z_{DCin}$
  - $R_3 << R_2 \leq R_1$
  - accordingly to $Z_{ind}$
- **At resonance frequency**
  - $L_1 \rightarrow$ ind. & $L_2 \rightarrow$ cap.
  - $C_1 \rightarrow$ short
  - $R_1$ damps $Q_{L1L2}$

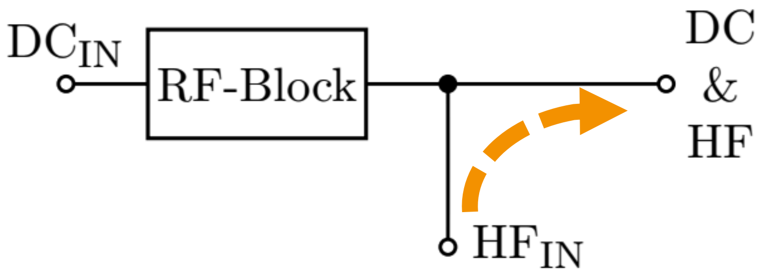
# High Current

## *Simulation – 3rd order Bias-Tee*



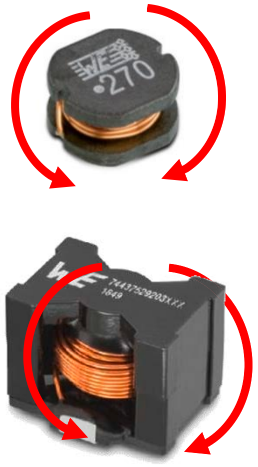



# High Current
## *Components*

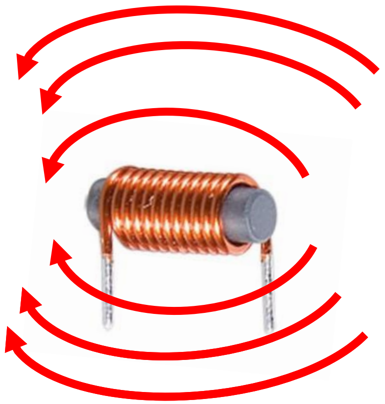
WÜRTH ELEKTRONIK

- **Inductors:**
  - Unshielded & Semishielded for high current
    - Constant L → No saturation over current
    - Very low $R_{DC}$ → small voltage drop
    - E.g: PD2, PD4, HCF or SD
  - Be aware of coupling

Smaller H-Field



Wider H-Field



- **Capacitors:**
  - Stable over voltage
  - MLCC: e.g. NP0
  - Electrolytic: not for bipolar applications

# High Current
## *Summary*

### Theory – RF-Block

- For DC: lowest possible $R_{DC}$
- For RF: high impedance
- Broadband: cascading

- Values:
- $C_3 > C_2 > C_1$
- $L_3 > L_2 > L_1$
- $R_3 << R_2 \leq R_1$

### Components

**Inductor**

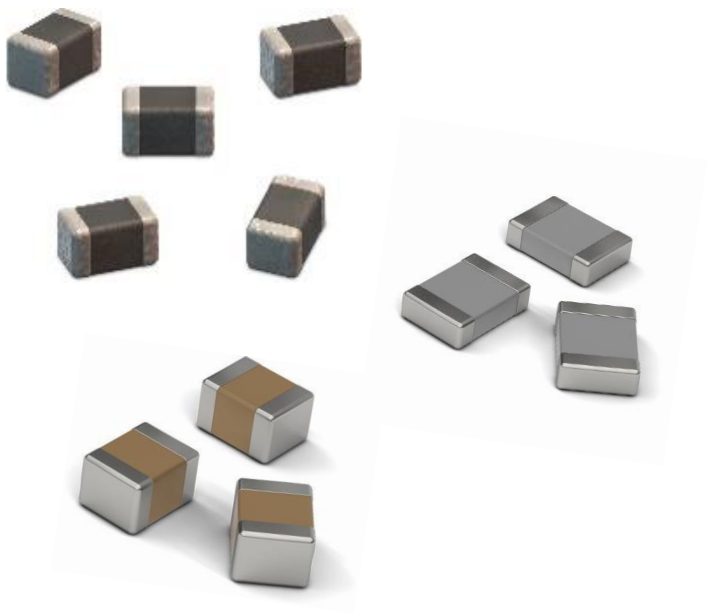
- Semi & Unshielded
- Low $R_{DC}$
- Coupling!

**Capacitor**

- MLCCs – NP0
- Electrolytics
  - Polarisation!

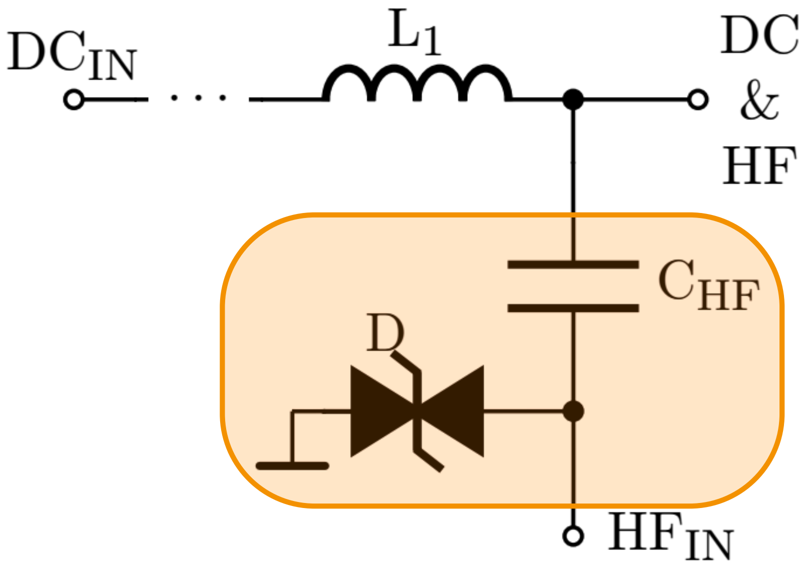
## DC-Block

- *Concept*
- *Standard*
- *Extreme Range*



# DC Block
## *Concept*

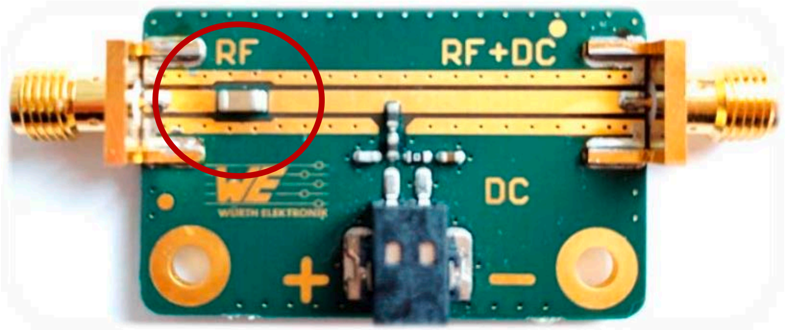
- **Capacitor:**
  - Blocks DC to RF Source
  - Determines voltage & frequency range
- **ESD-Protection:**
  - Needed if separate input or output
  - E.g. bidirectional

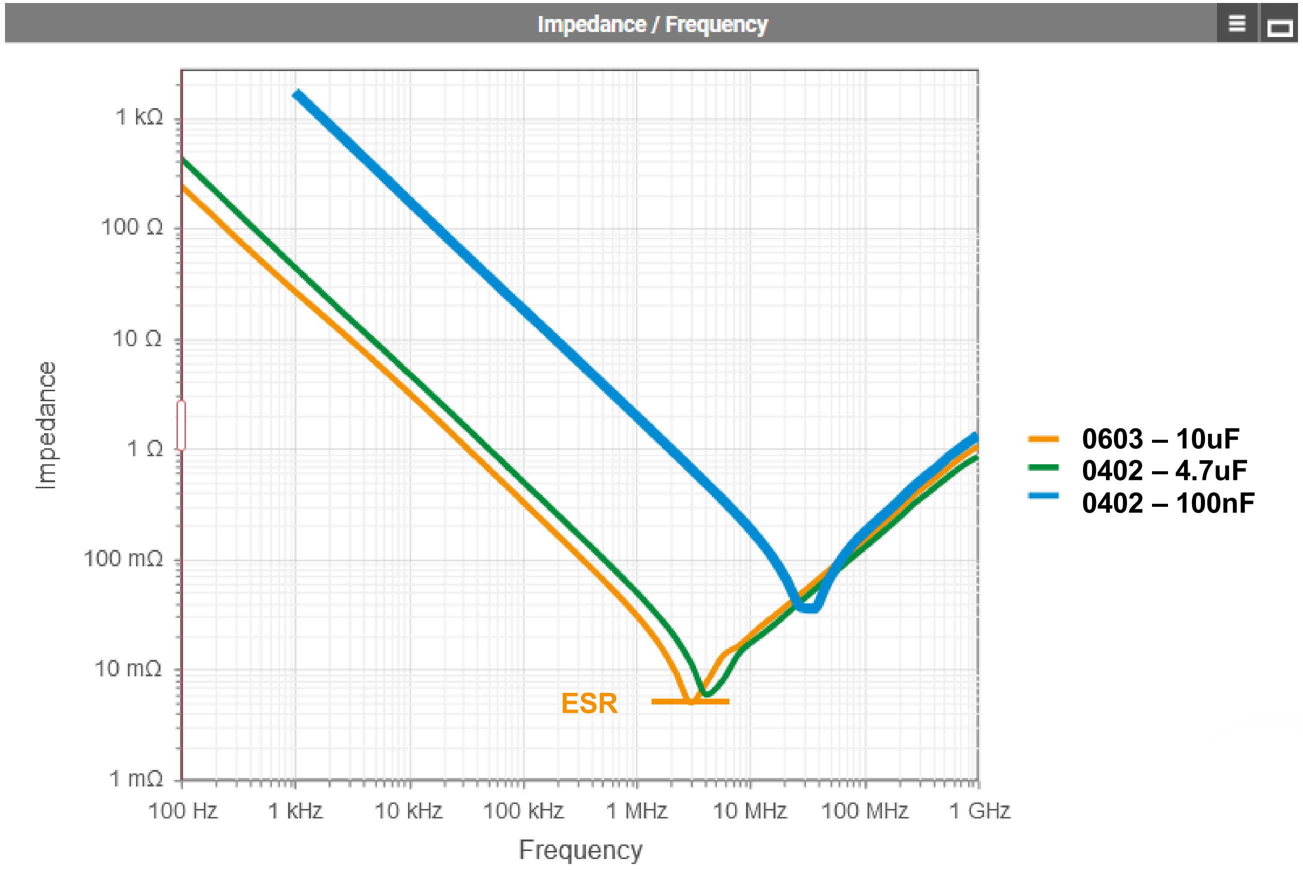


# DC Block

## *Standard*

- **MLCCs:**
  - Broadband needed → used above SRF
  - Use highest value of biggest possible size
    - Low ESR
    - Low ESL



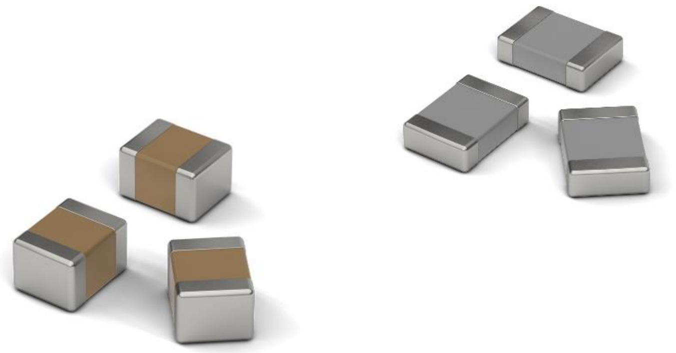



# DC Block

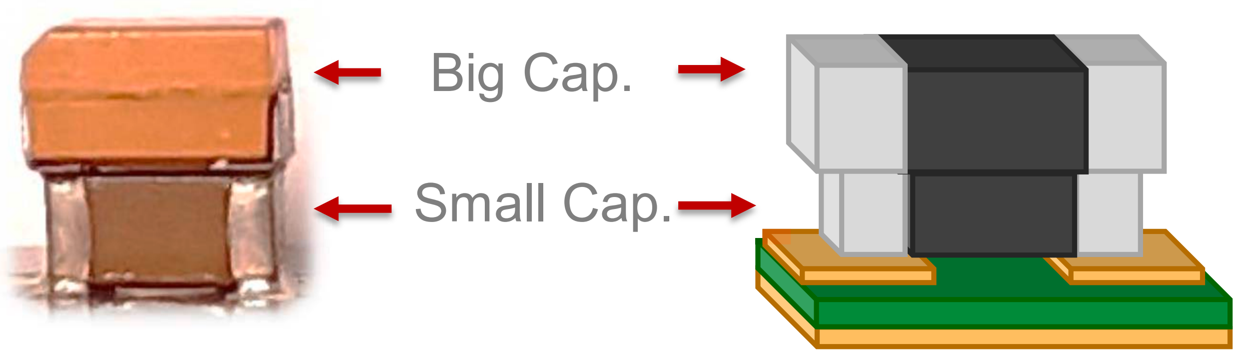
## *Extreme Range*

WÜRTH ELEKTRONIK

- **High voltage:**
  - Safety & High Voltage Types MLCCs like *CSMH or CSSA*
  - Bigger in size → Line impedance!



- **Extreme broadband:**
  - Combine two different capacitors
    - E.g. MLCCs and electrolytic
    - Be aware of resonances




  - Use special capacitor types

# DC Block
## *Summary*

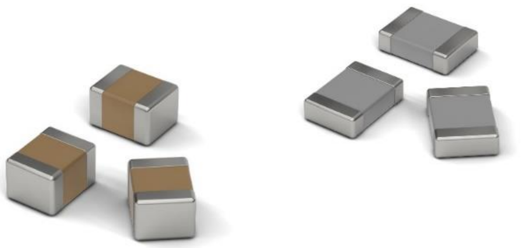
## Overview

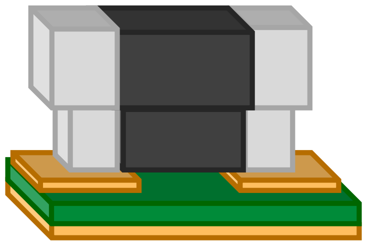
- Blocks DC to RF Source
- Low ESR
- Low ESL

**MLCCs**
Use highest value of biggest possible size

## Extreme Range

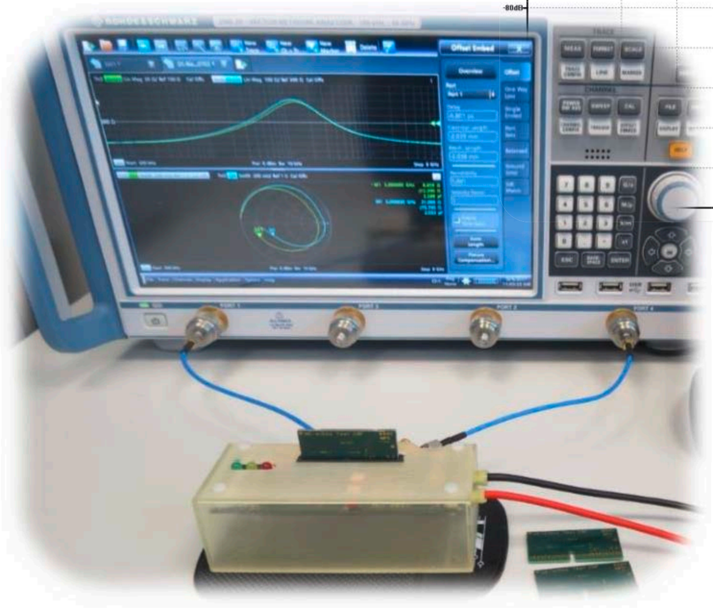
- High Voltage
  - High Voltage MLCCs
- Extreme broadband
  - Two Capacitors

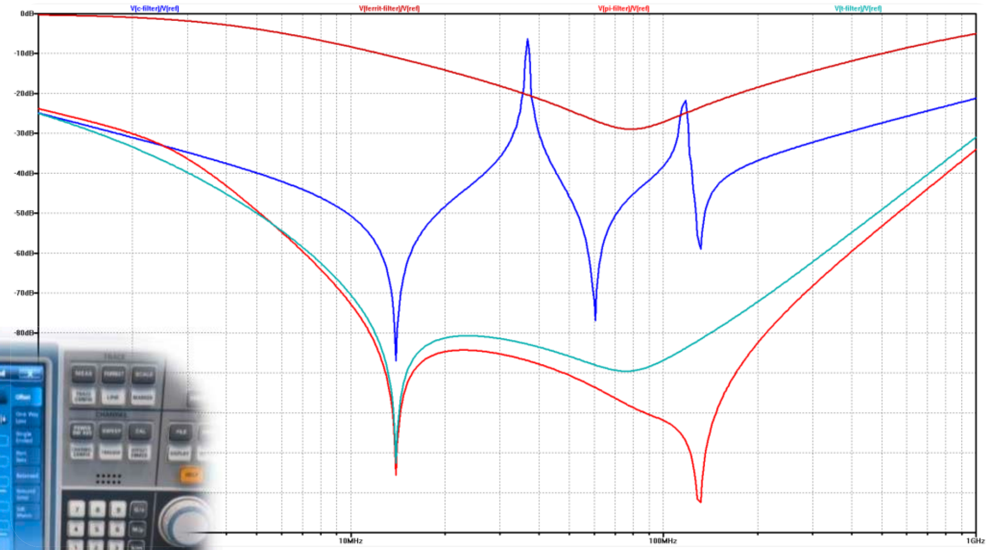




WÜRTH ELEKTRONIK

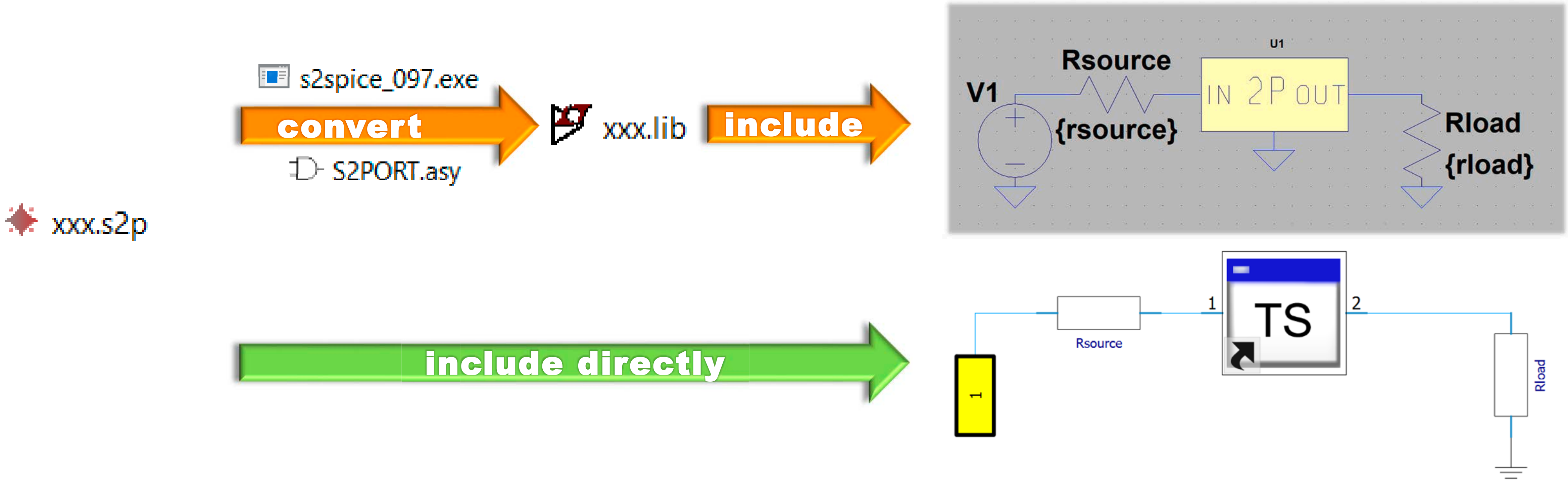
- **Measurement to simulation**





# Measurement to simulation

- **Include measurement data e.g. touchstone (s1p,s2p…)**
  - Simulate load & source impedance change
  - Behaviour with other modules



## ➢ Final Summary

# Final Summary

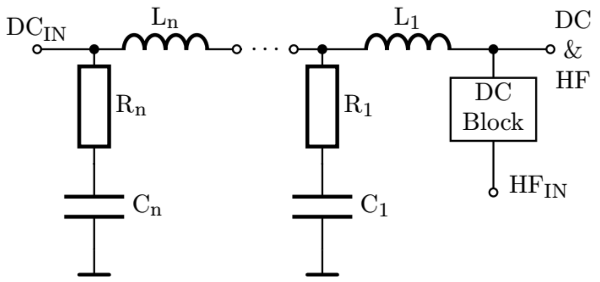
## Low Current

- RF Coil 
  - Resonances
  - Not for low freq.
- Ferrite 
  - No Resonances
  - Broadband

- **Ferrites improve broadband RF throughput**

## High Current

- Cascading → broadband




- Inductors
  - Semi & Unshielded
  - Low RDC
- Capacitors
  - Stable over voltage

**Great RF throughput & Disturbtion free power line**