

# CM/DM NOISE SEPARATION USING OSCILLOSCOPES FOR MORE EFFICIENT EMC FILTER DESIGN

**ROHDE & SCHWARZ**

Make ideas real



# MOTIVATION

- ▶ A Conducted Emission Compliance Test As Part Of The EMC-Directive Is An Essential Task To Perform For Power Converter Designs >> EMI Input Filter
- ▶ The Design And Validation Of An EMI Input Filter Is Typically An Iterative Task During The Design
- ▶ Conducted Emission Tests Are Often Performed As Pre-Compliance Test To Obtain An Early Feedback
  
- ▶ For An Effective Iterative Filter Design, It Is Essential To Know Details Of The Total Noise Spectrum
  - Frequency And Magnitudes Are Not Sufficient
  - Understanding Of The Propagation Method Of The Noise Source (Common or Differential Mode)

# DO YOU REMEMBER?



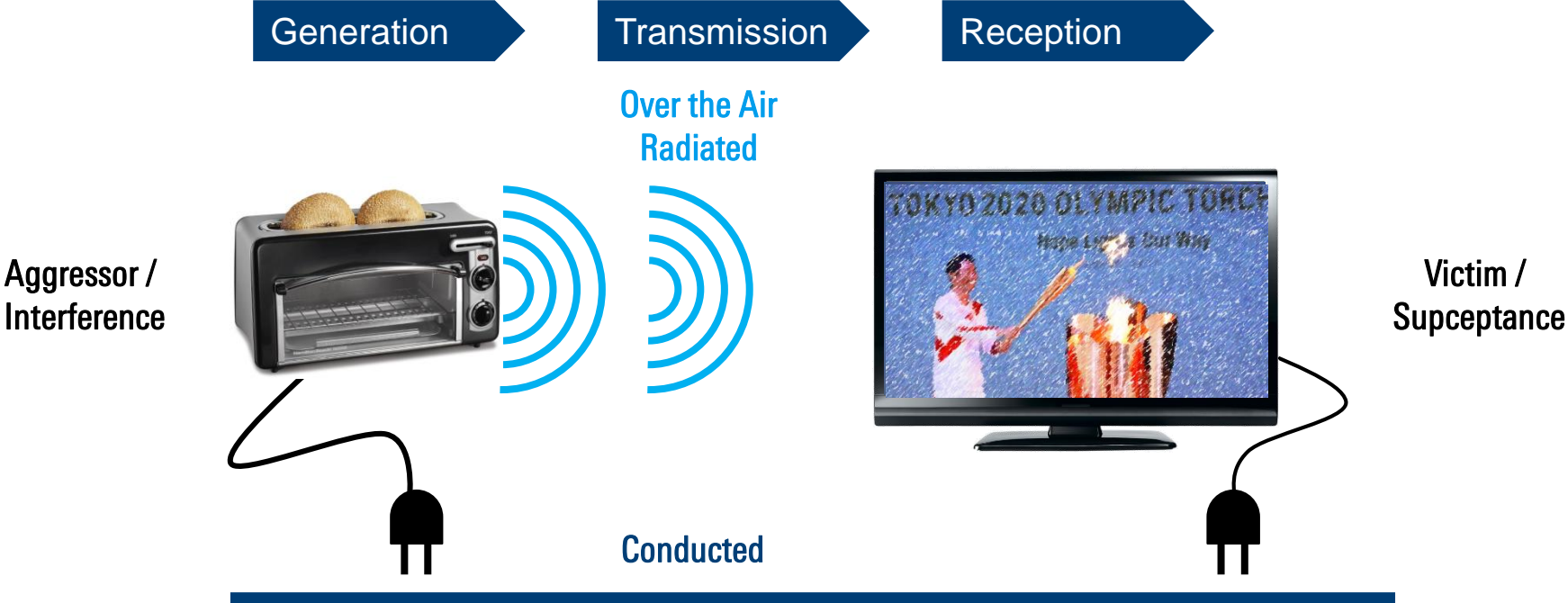
Radio Frequency Interference

# WHAT IS EMI?

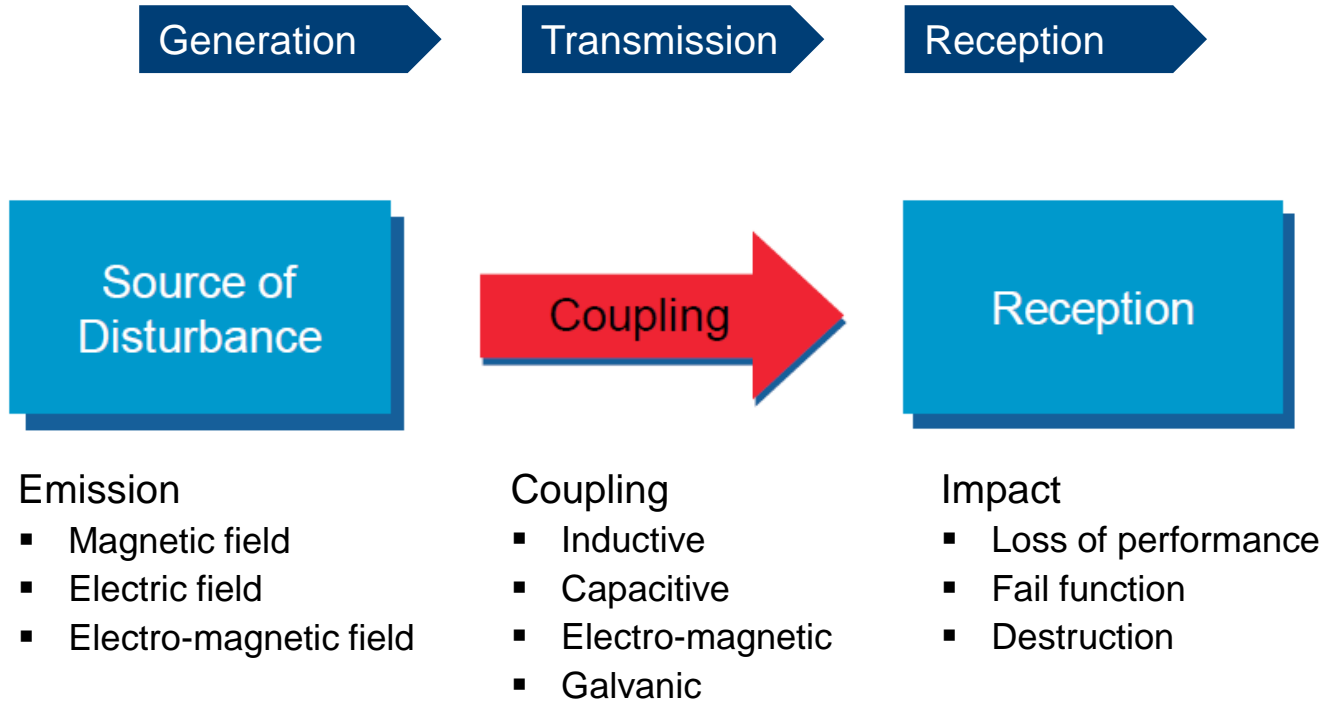
- ▶ EMI = ElectroMagnetic Interference
  - Unintended / undesired radio frequency emissions from a device (equipment under test)
- ▶ These emissions can create problems for other electric or electronic devices
- ▶ Regulations and standards specify acceptable emission levels over various frequency ranges



# AGGRESSOR AND VICTIM



# ASPECTS OF AN EMI PROBLEM



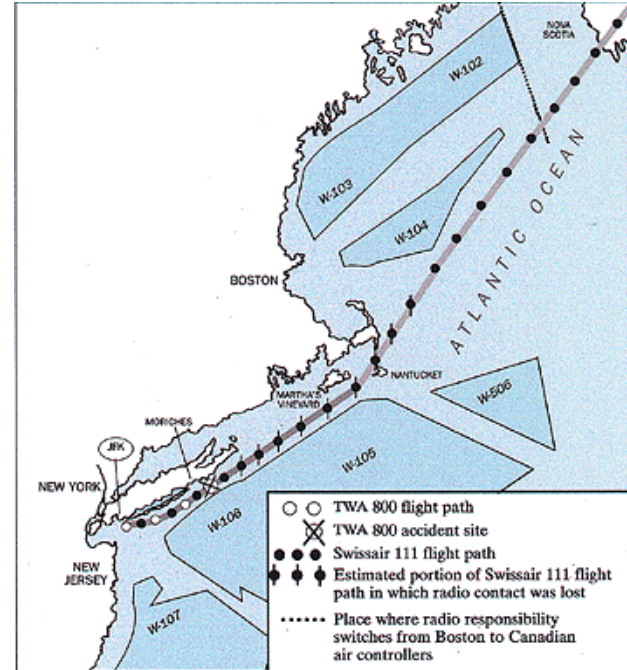
# COMMERCIAL EMC PROBLEMS



TWA 800, 1996  
230 people on board died in the crash



Swissair 111, 1998  
229 people on board died in the crash



*Schematic chart of the flight paths of TWA 800 and Swissair 111 along the Bette route, based on information provided by the FAA. The World Aeronautical Chart, 27th edition, 1997, issued by the Department of Commerce, identifies such areas as those marked W-102 through W-107 as follows: "Warning: National Defense Operating Areas operations hazardous to the flight of aircraft conducted within these areas."*

# PUSHING THE LIMIT OF EMI

More powerful computing power

Faster and higher bandwidth communication

Complex technology integration

Power consumption and longevity





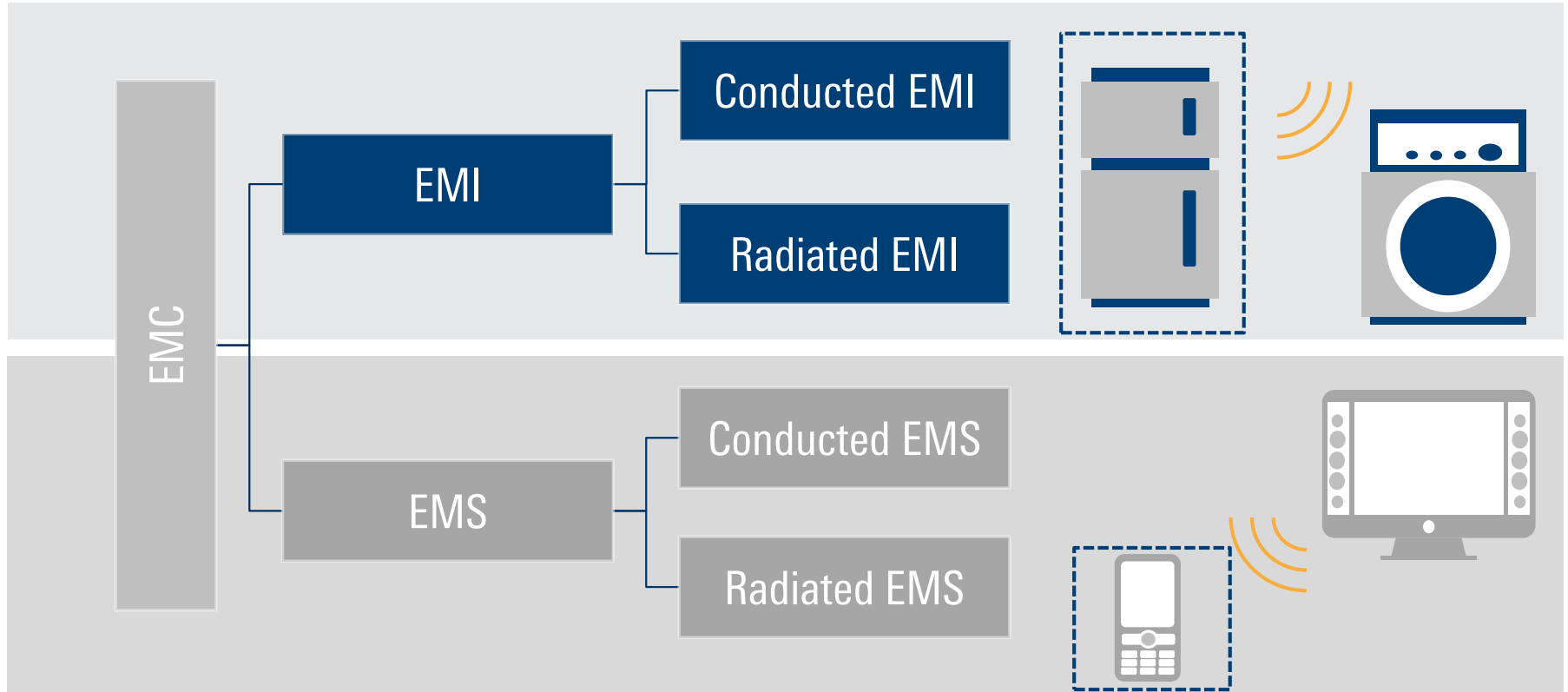
# ELECTROMAGNETIC COMPATIBILITY

- ▶ Capability of a device or system to operate in an electromagnetic environment and not disturb or be disturbed by other devices
- ▶ Required to conform to industry specific standards

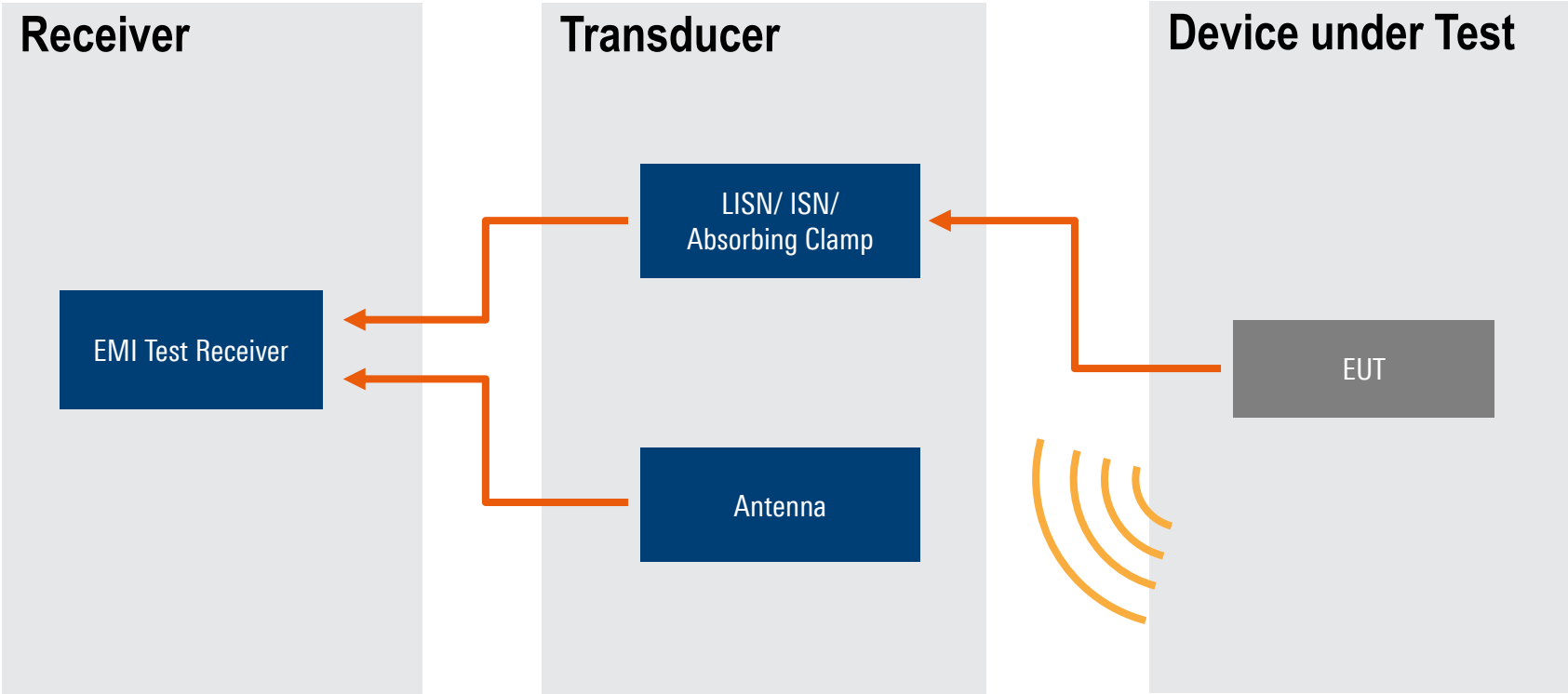
**EMC = EMI + EMS**



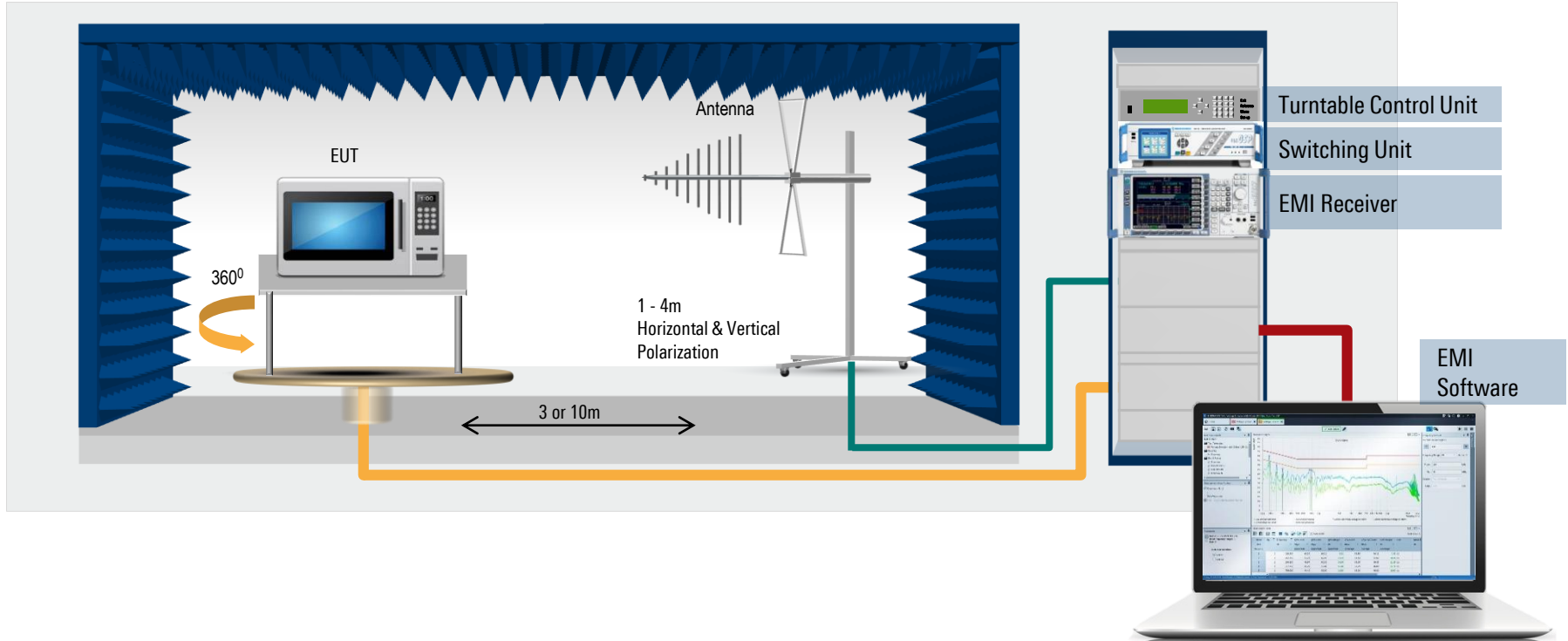
# ELECTROMAGNETIC COMPLIANCE



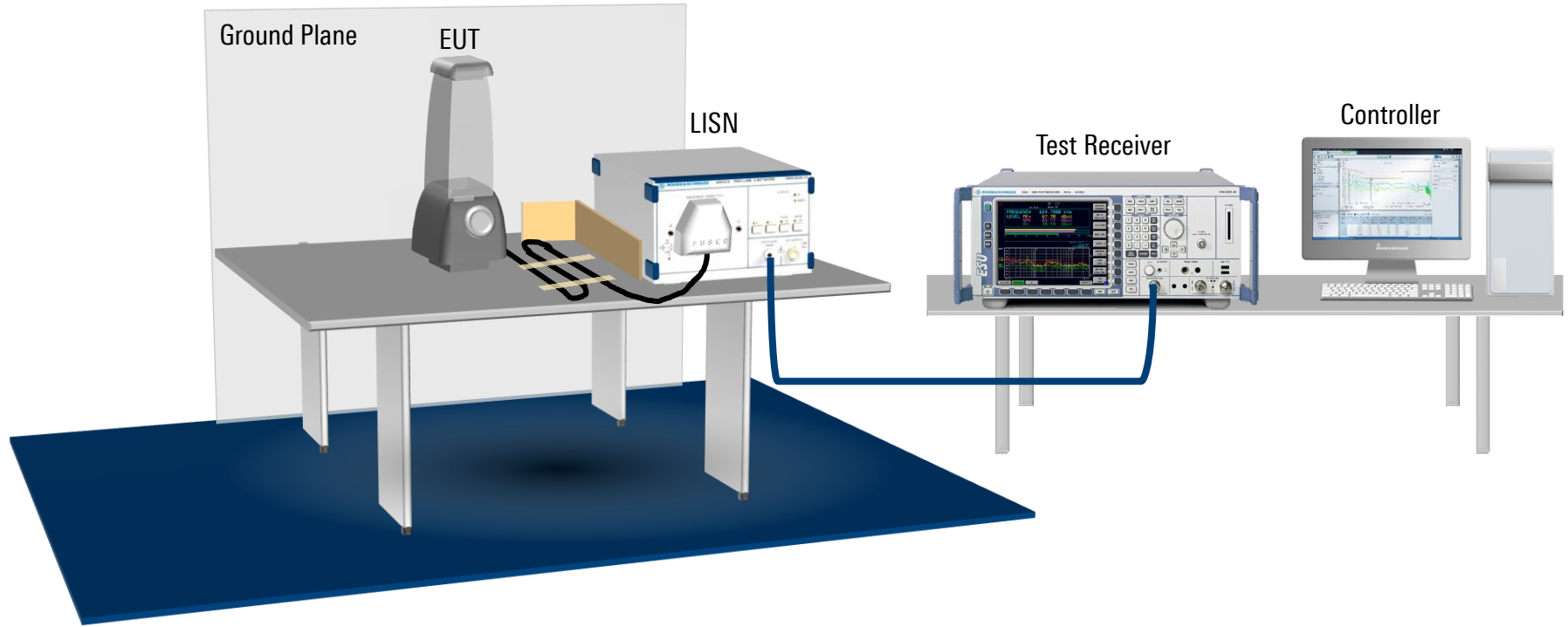
# SYSTEM CONFIGURATION



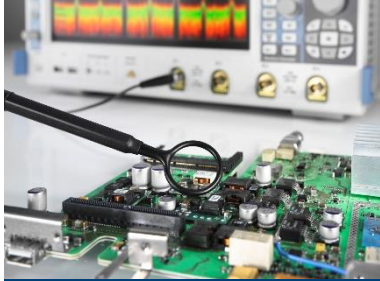
# COMPLIANCE RADIATED EMISSION TEST



# COMPLIANCE CONDUCTED EMISSION TEST

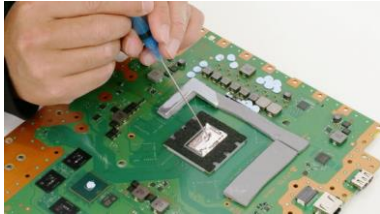


# STAGES OF EMC TESTING



EMI Debugging

Circuit



Pre-Compliance Setup

Prototype



Compliance EMC Test

Pre-Production



# WHICH TOOLS TO USE?



# FROM COMPLIANCE TO EMI DEBUGGING

## EMI Receiver

- ▶ 6 dB Filters
- ▶ Pre-selector available
- ▶ Highest selectivity
- ▶ CISPR compliant demodulation
- ▶ Demodulation of complex signals possible
- ▶ Time domain analysis, frequency sweep time to a few seconds



## Spectrum Analyzer

- ▶ 3 dB Filters
- ▶ High selectivity
- ▶ High sensitivity
- ▶ Analysis on wide frequency range possible (today up to 10 GHz internal analysis BW)
- ▶ Demodulation of complex signals possible



## Oscilloscope

- ▶ 3 dB Filter
- ▶ Analysis of whole frequency range
- ▶ Measures down to 100 kHz
- ▶ Trigger capabilities, channel separation
- ▶ Mask test in frequency and time domain
- ▶ Gated FFT
- ▶ Multi-channel coherent receiver

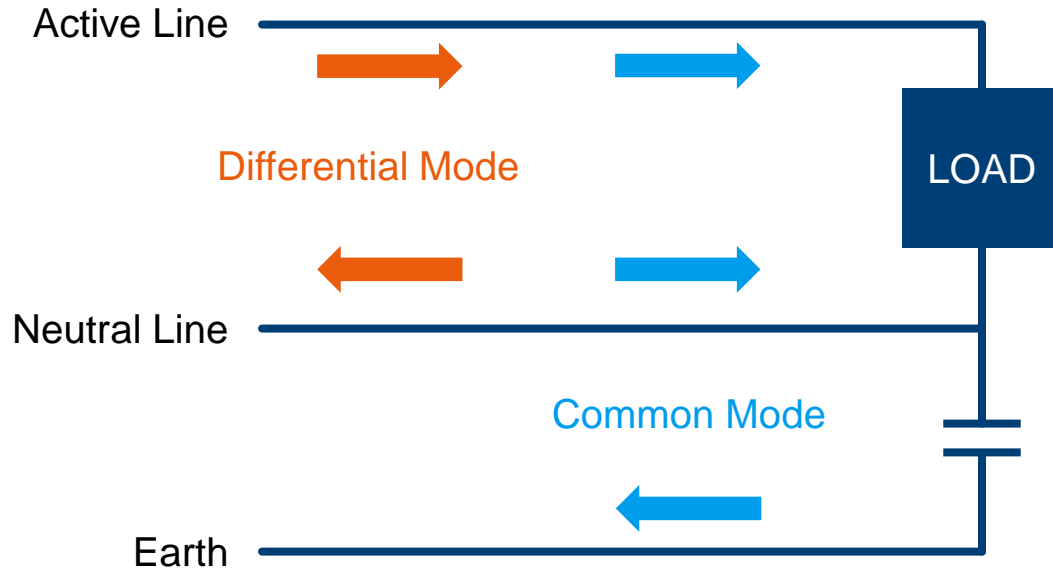




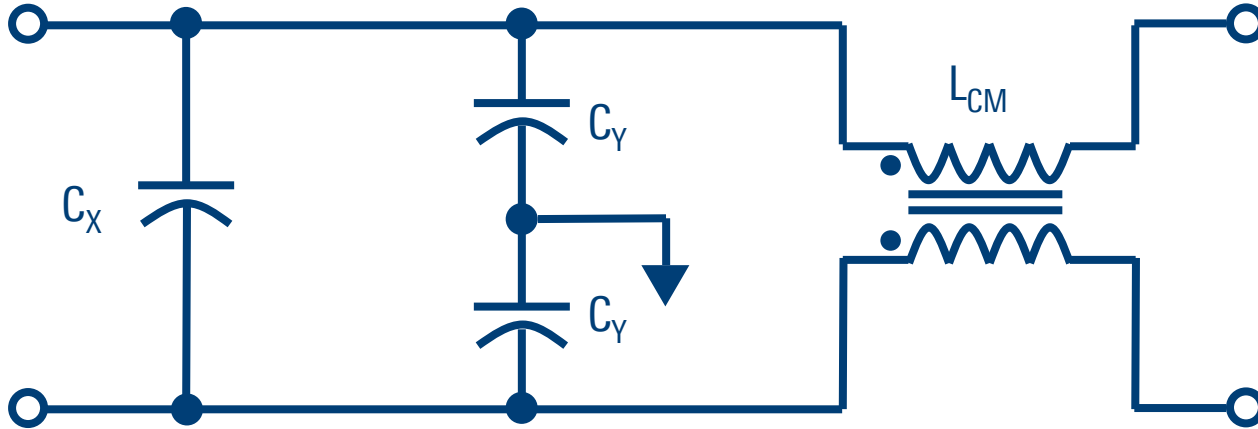
# Source of interference

kind of interference	dominant source	frequency range	radiated or conducted
<b>low frequency interferences</b>	fundamental wave and harmonics of the controller switching frequency	10kHz to 40MHz	conducted
<b>broadband interferences</b>	dI/dt and dU/dt of the FET (silicon) switching edges and parasitic resonant circuits	40MHz to 200MHz	conducted and radiated
<b>high frequency interferences</b>	reverse recovery of the schottky diode	over 200MHz	radiated

# CONDUCTED EMISSION

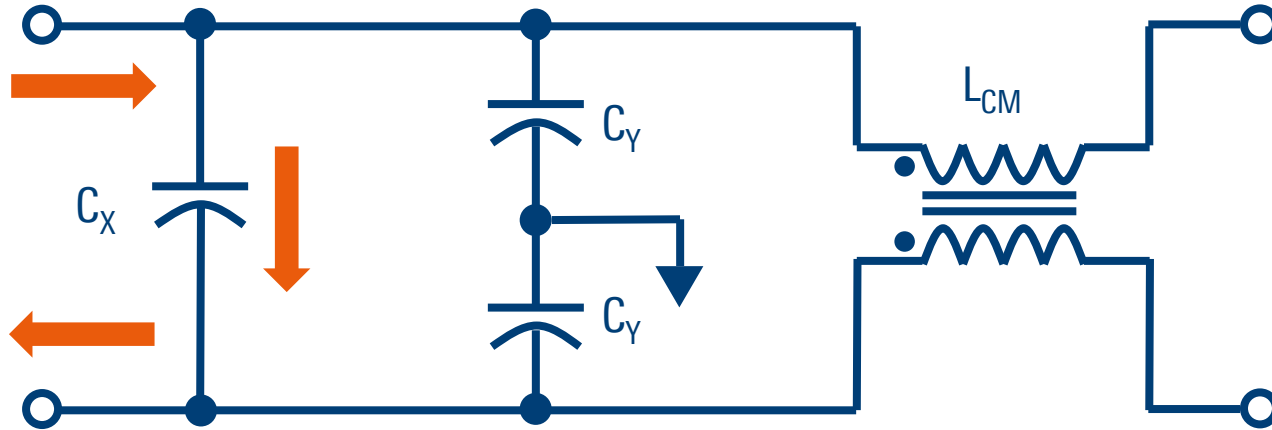


# EMI FILTER CIRCUIT

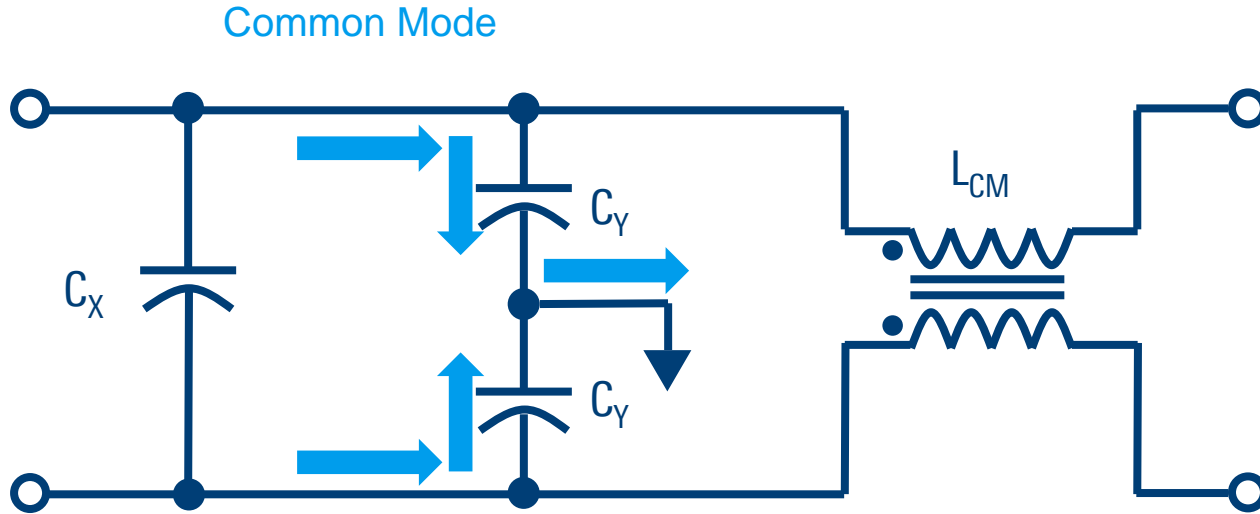


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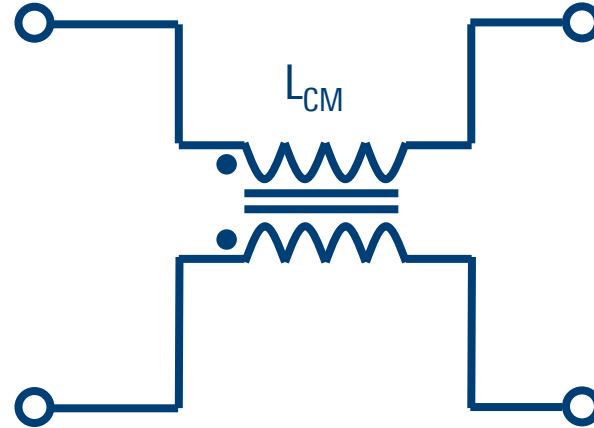
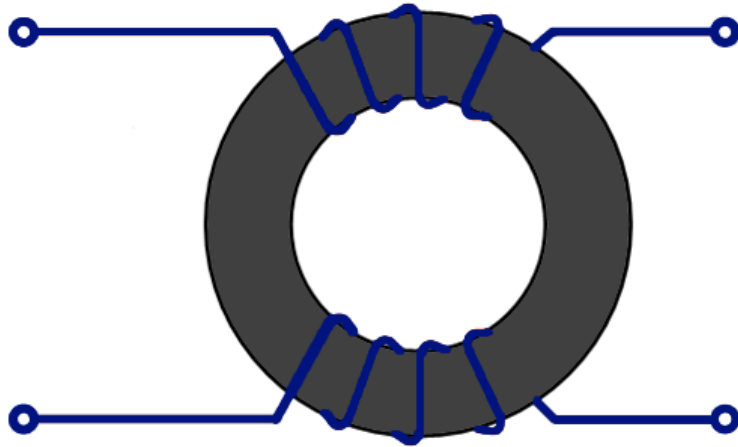
Differential Mode



# EMI FILTER CIRCUIT

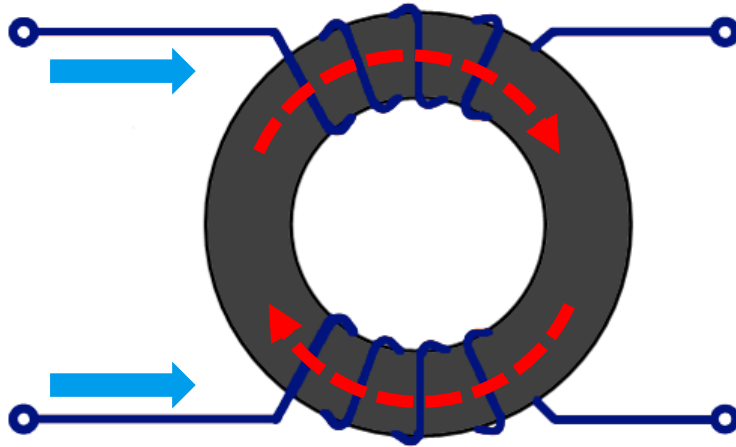


# EMI FILTER CIRCUIT – CM CHOKE

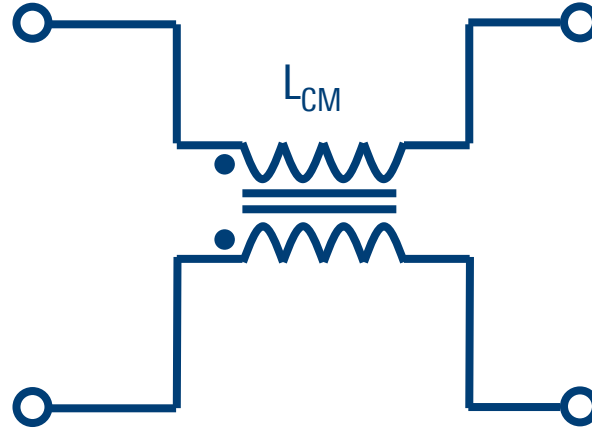


# EMI FILTER CIRCUIT – CM CHOKE

Common Mode

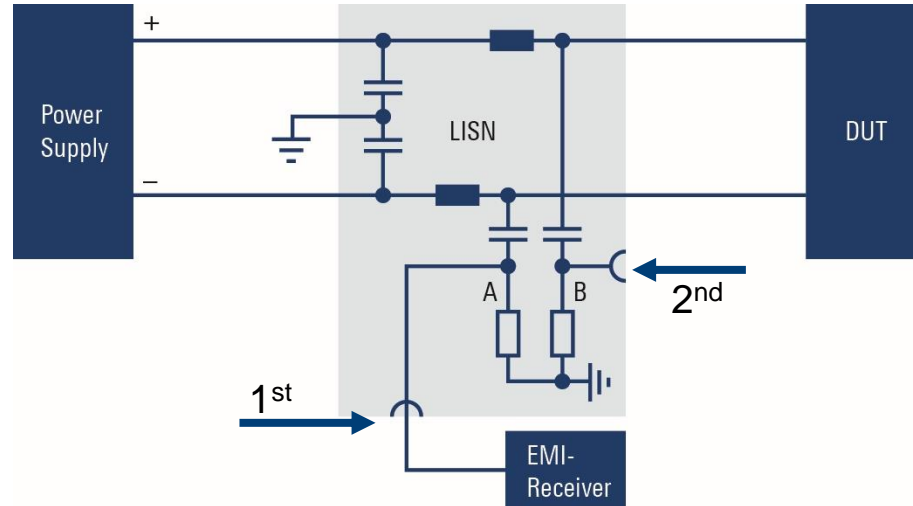


Flux impede CM current



# LIMITATION OF STANDARD CE-MEASUREMENT SETUP

- ▶ The Standard Measurement Setup Provides Only A Combination Of Different Noise Sources.
- ▶ The Setup In Combination With EMI-Receivers Are Not Suitable To Debug.

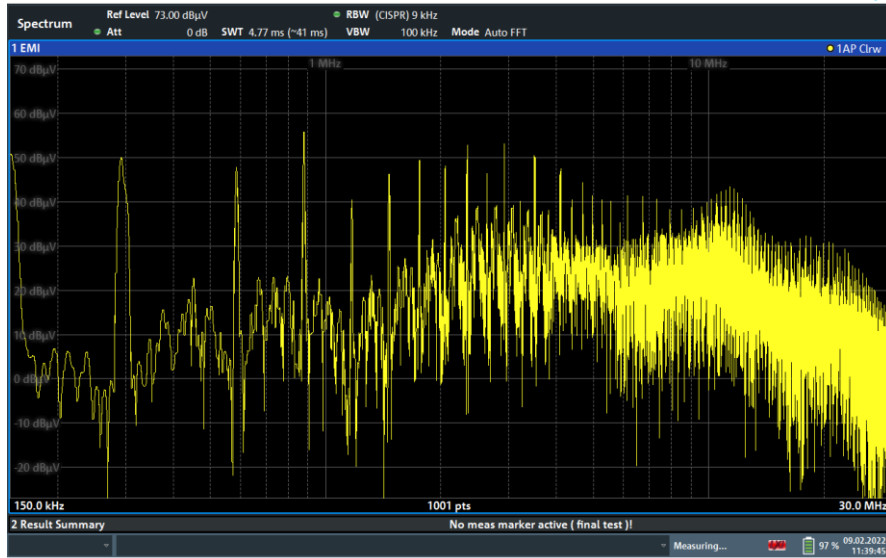




# CONDUCTED EMISSION MEASUREMENT

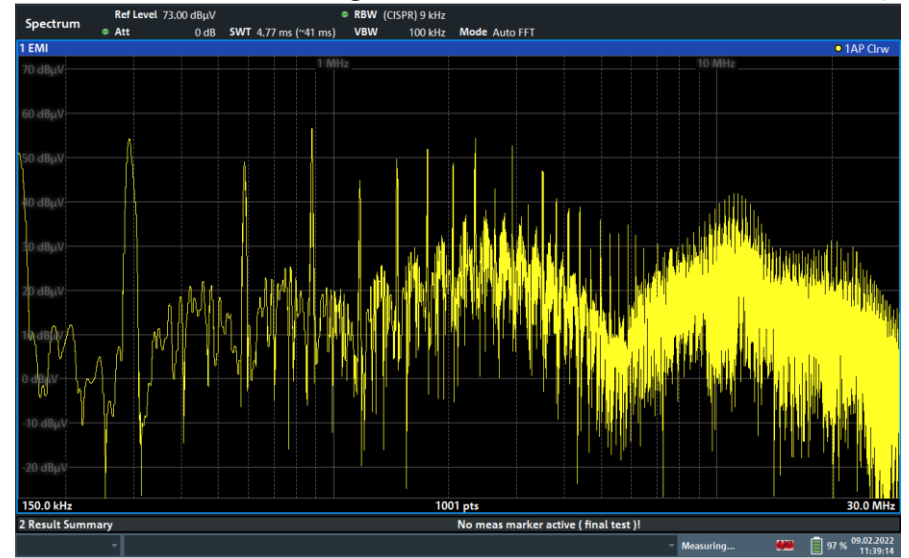
DC-DC Isolated Flyback Stage (  $V_{in} = 24V$ ,  $V_{out} = 5V$ ,  $I_{out} = 2.5A$ ,  $F_{sw} = 300kHz$  )

## Positive Conductor



11:39:46 09.02.2022

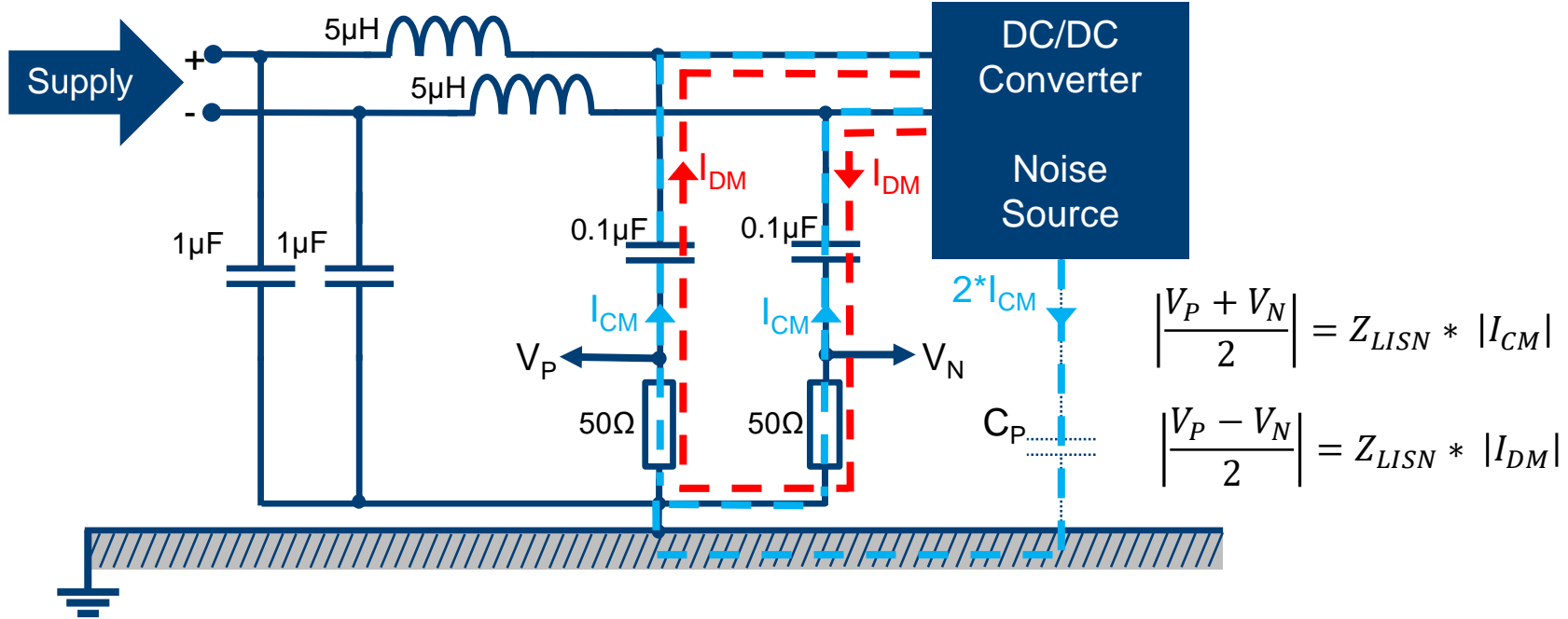
## Negative Conductor



11:39:14 09.02.2022



# COMMON AND DIFFERENTIAL MODE THEORY



# SOFTWARE SOLUTION

## ► What Is Required To Implement This SW Solution

- Multiple FFT Is Required
- Low Noise Frontend
- Powerful Hardware
- 2 Channels

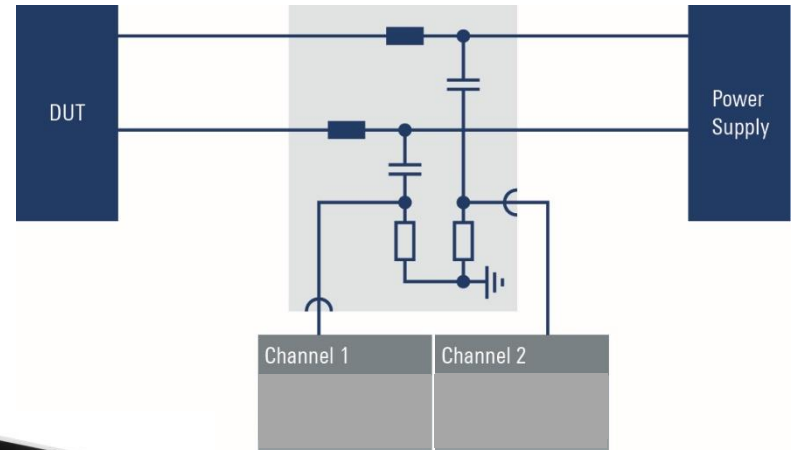
>> An Oscilloscope Can Offer These Capabilities

## ► Pros

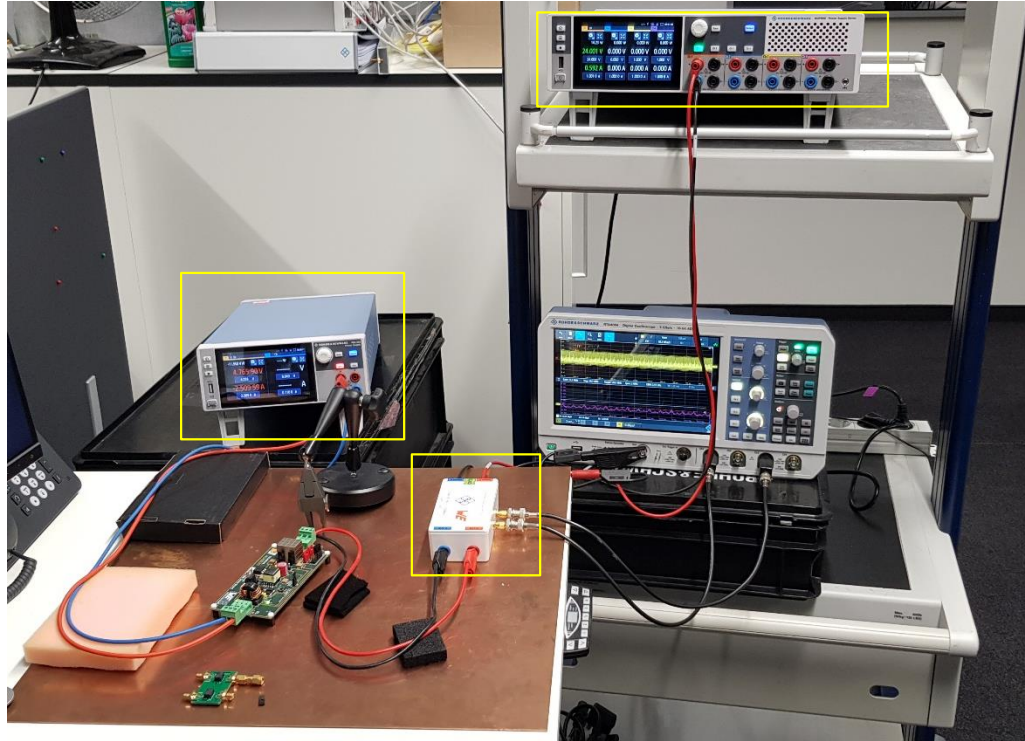
- Time / Freq Domain Correlation
- No Extra Hardware Is Required

## ► Cons

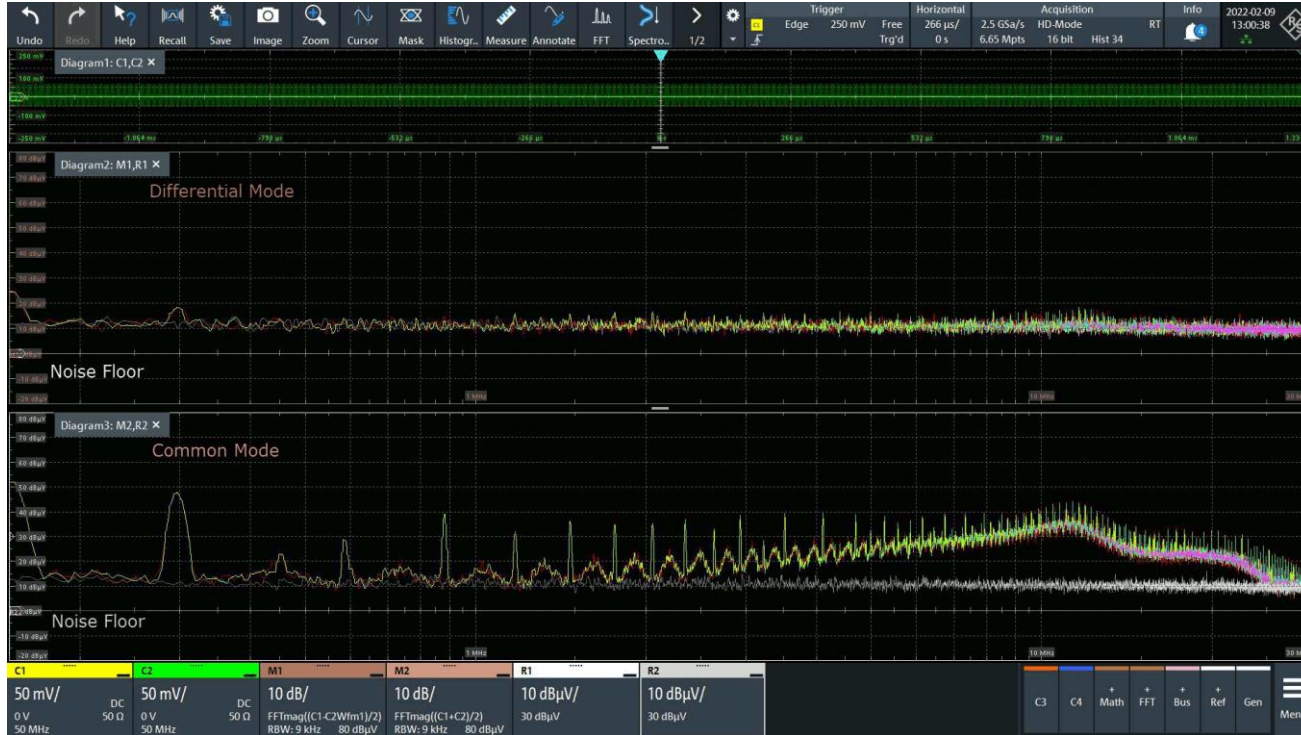
- Noise Level (~0dBuV)



# CONDUCTED EMISSIONS SETUP

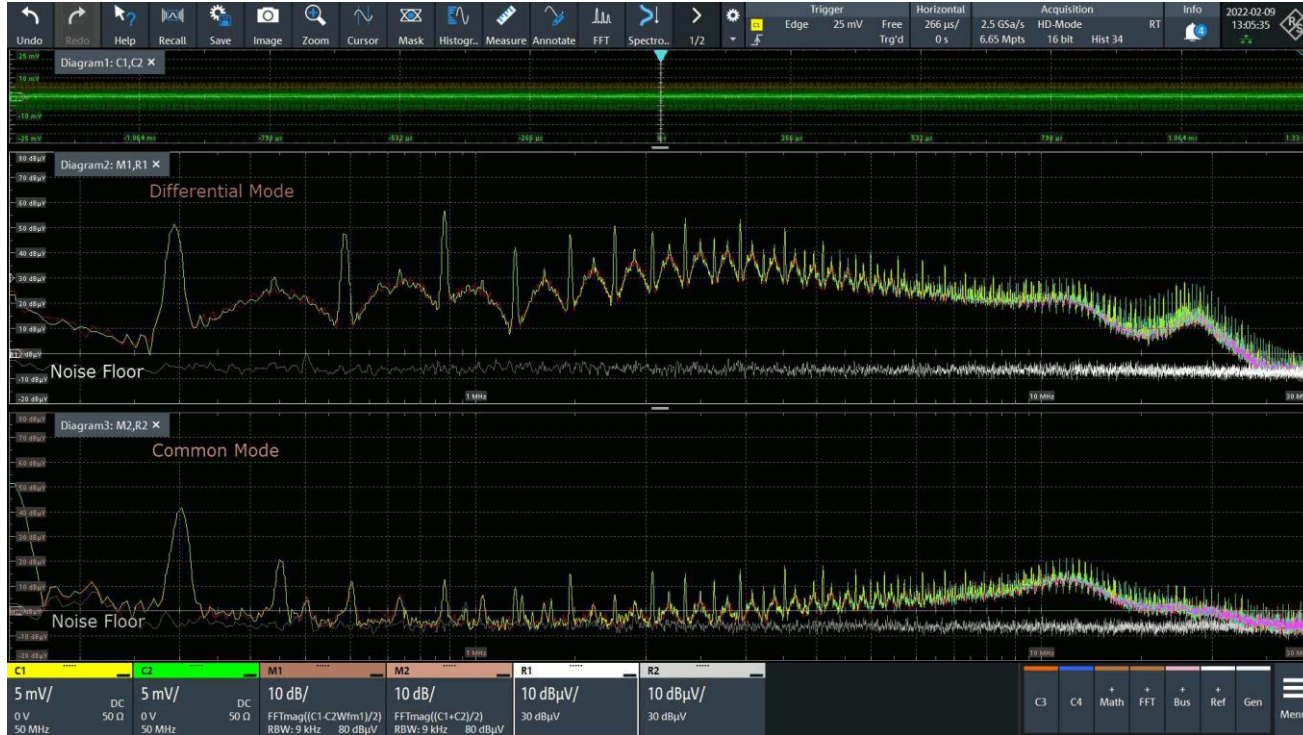


# DM FILTER EFFECT ( X-CAPACITOR )



DM Filter disabled

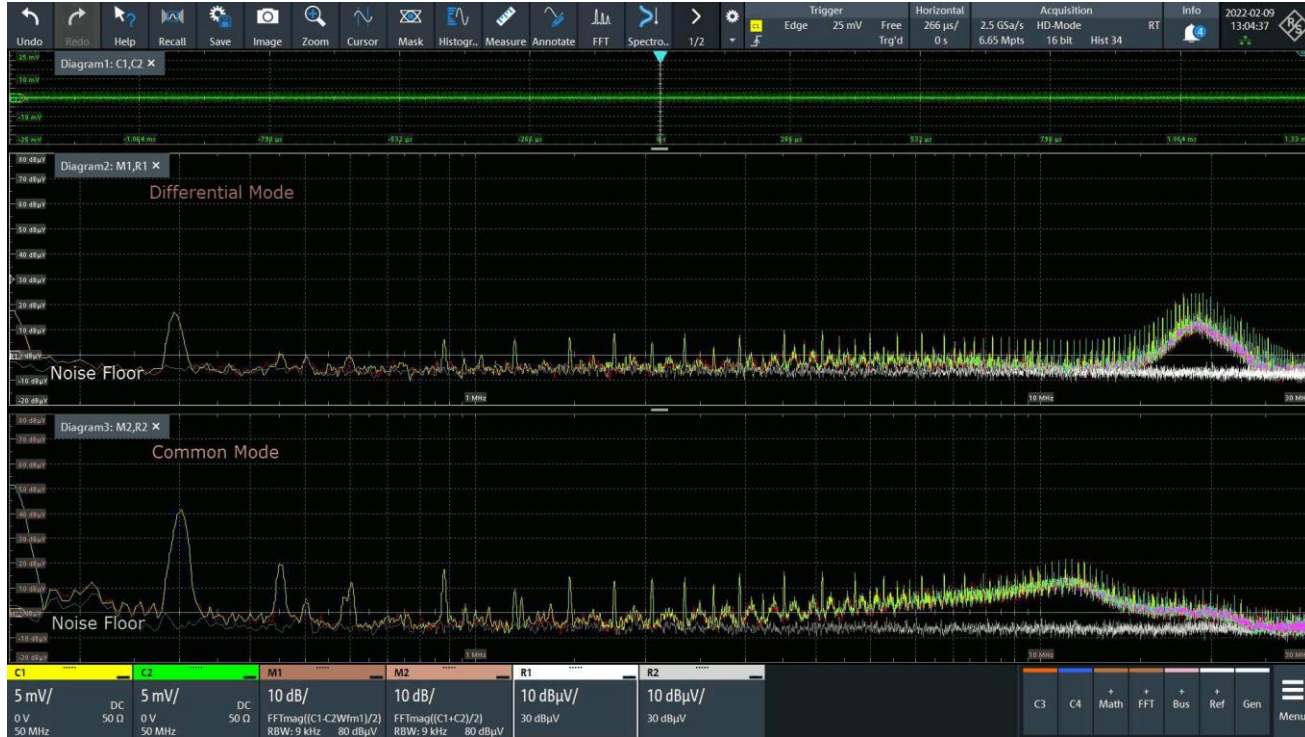
# CM-MODE FILTER EFFECT (Y-CAPACITOR)



Off filter disabled

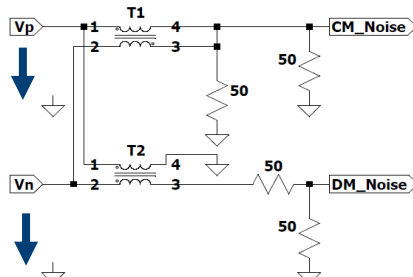
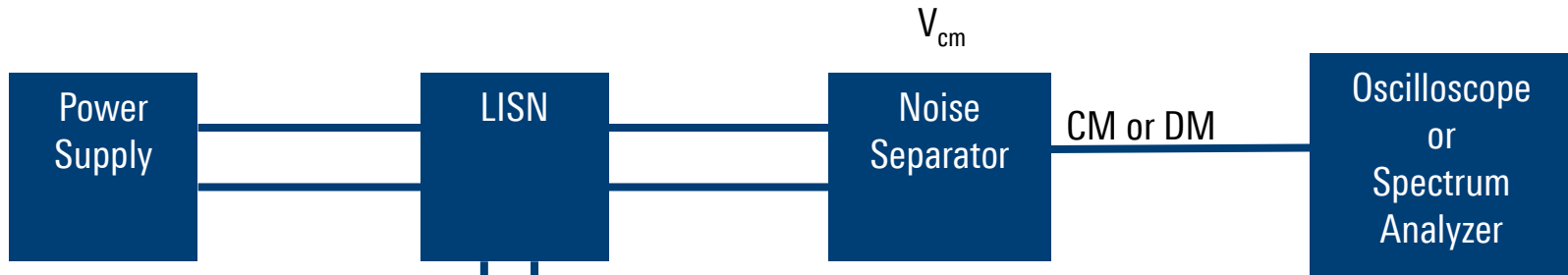


# CM/DM-FILTER APPLIED



CM & DM Filter  
@ 50mV/DDW

# HARDWARE SOLUTION



Adv: Also one port device like a Spectrum Analyzer can be used  
 Dis: The measurement can be performed only in a sequential way



# CONCLUSION

- ▶ The oscilloscope is A great tool to debug EMI and optimize filter designs
- ▶ The setup is relatively simple but the user needs to consider some impacts:
  - Vertical scale – noise level
  - Ground plane to close the cm-path
  - Sampling rate should be high enough  $\gg$  nyquist criterium

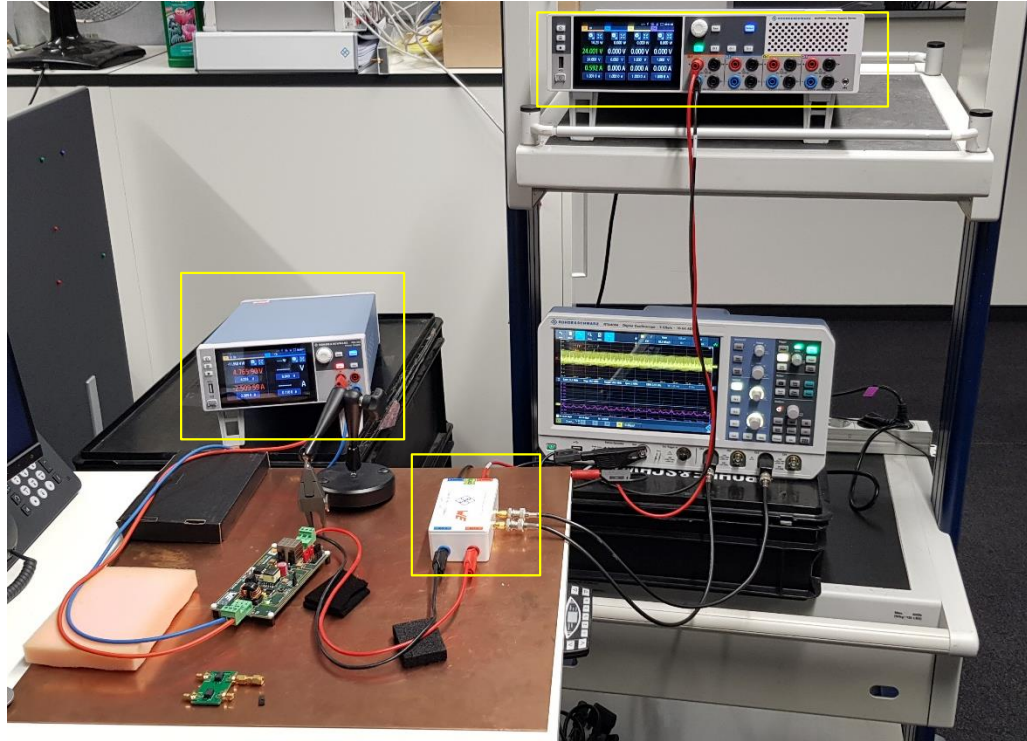
Find further information:

[EMC Pre-Compliance and Compliance Solutions](#)

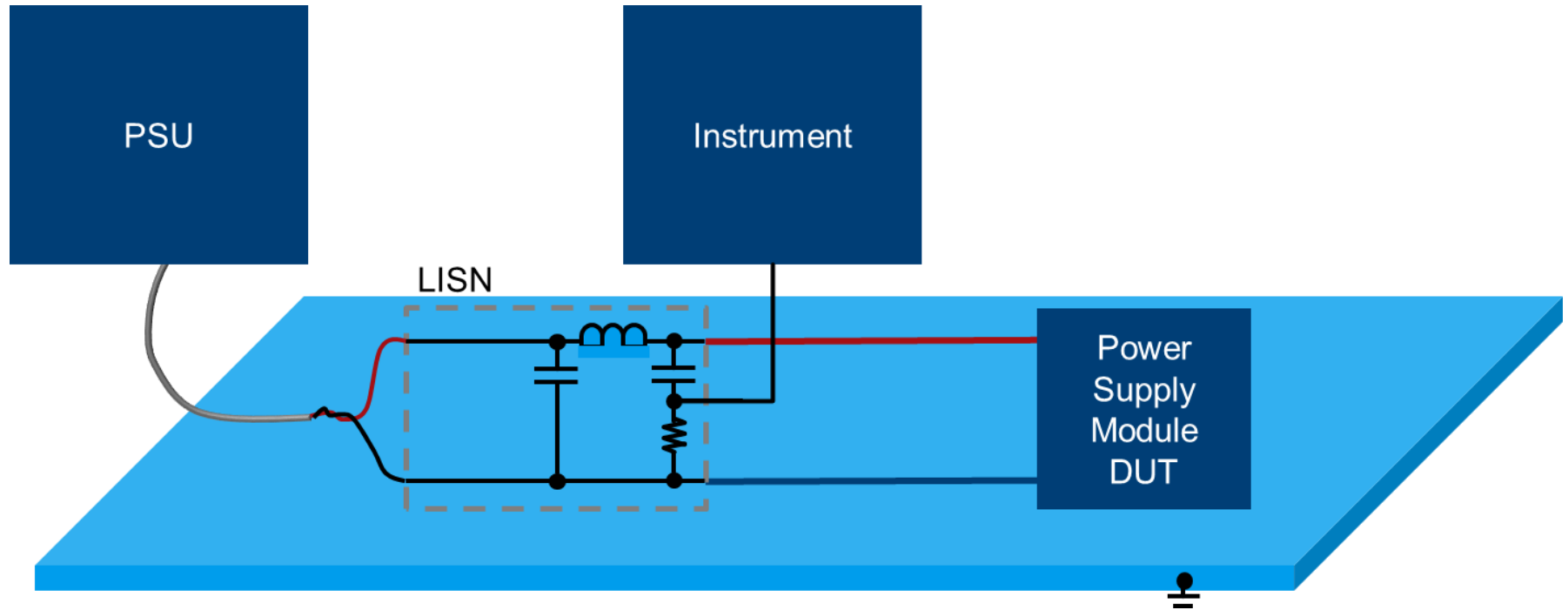
[EMI Debugging with Oscilloscopes](#)

**THANK YOU**

# DEMO SETUP



# BASIC EMI CONDUCTED EMISSIONS SETUP



# FPL1000



Rohde & Schwarz

# CHOOSE PREFERRED SCOPE



RTM3000



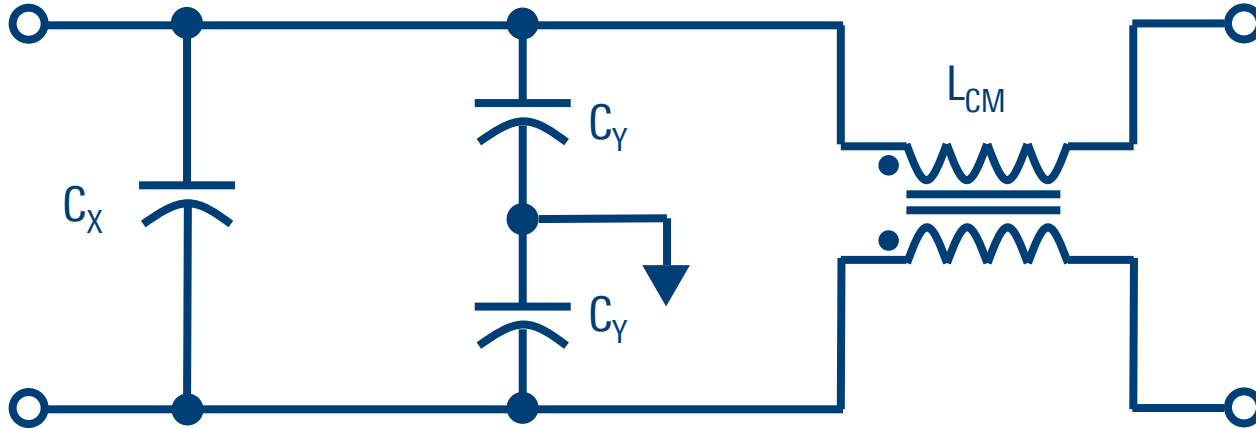
MXO 4



RTD6

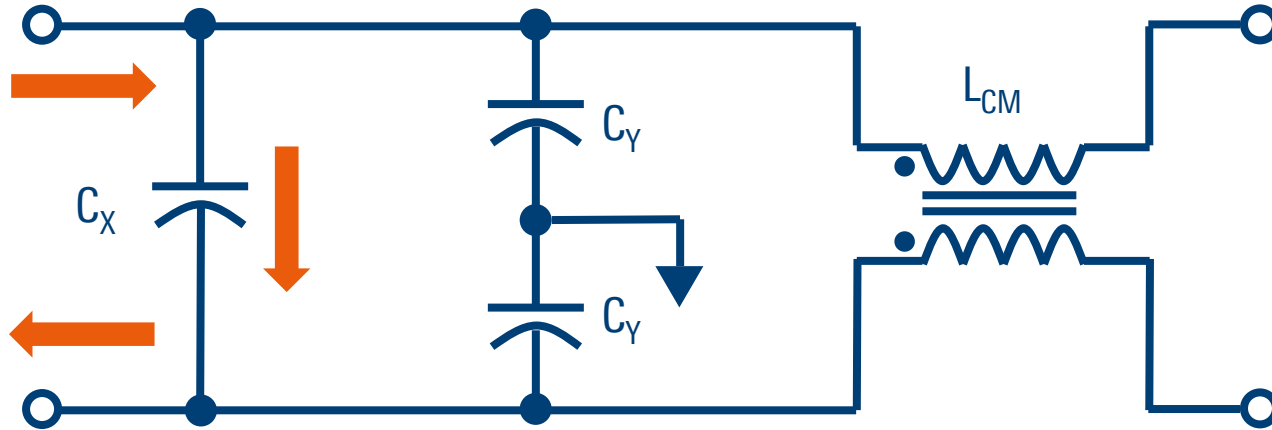


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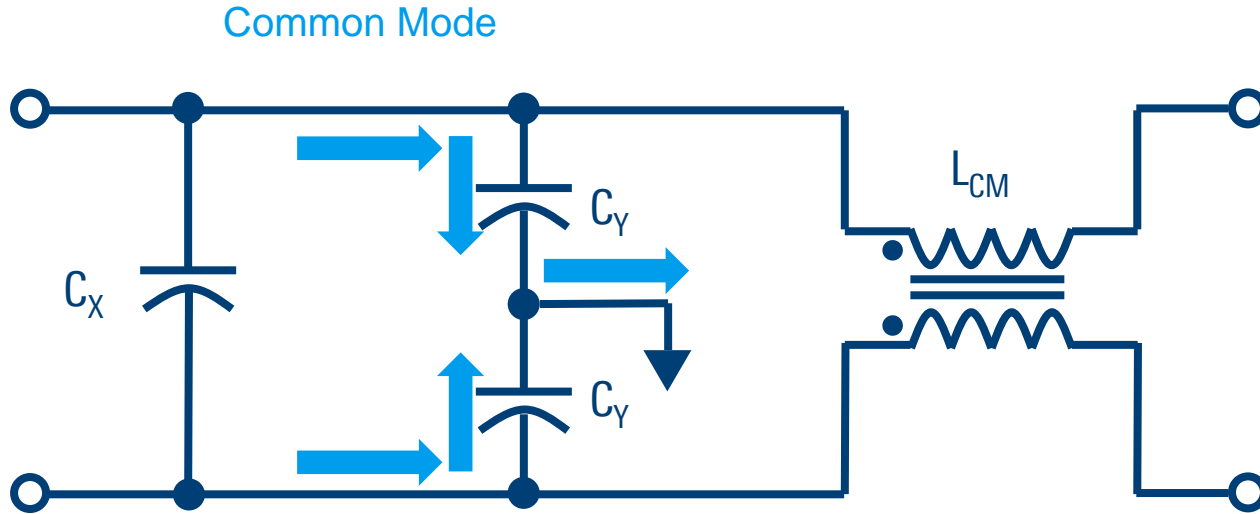
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Differential Mode

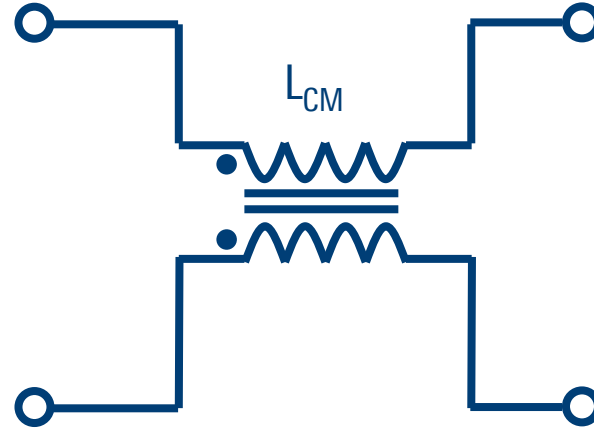
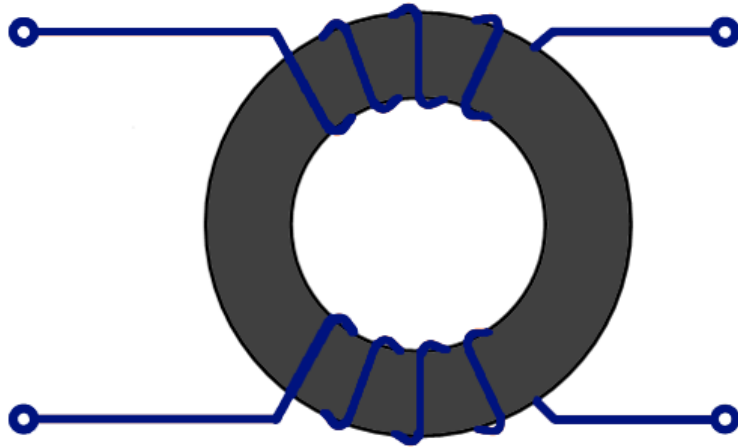




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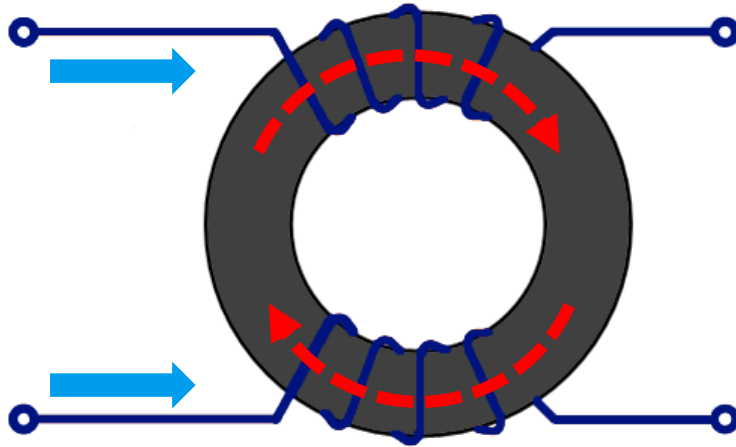


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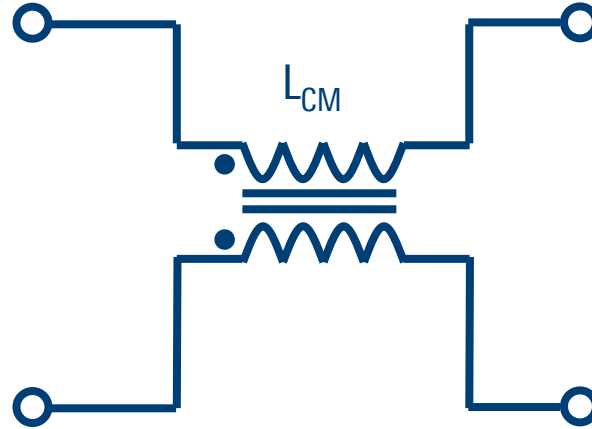


# EMI FILTER CIRCUIT – CM CHOKE

Common Mode

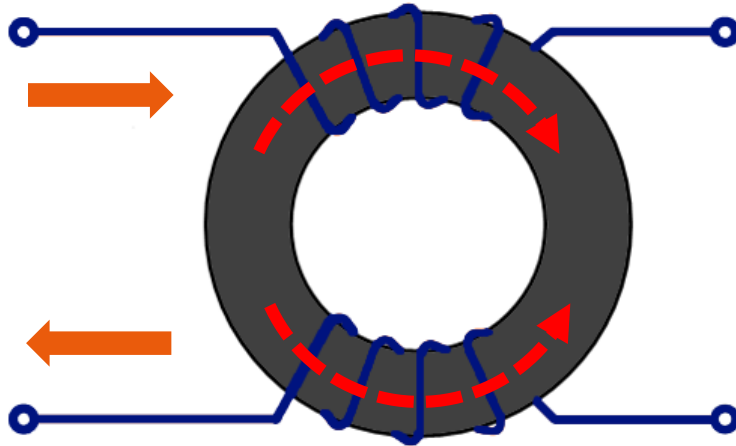


Flux impede CM current

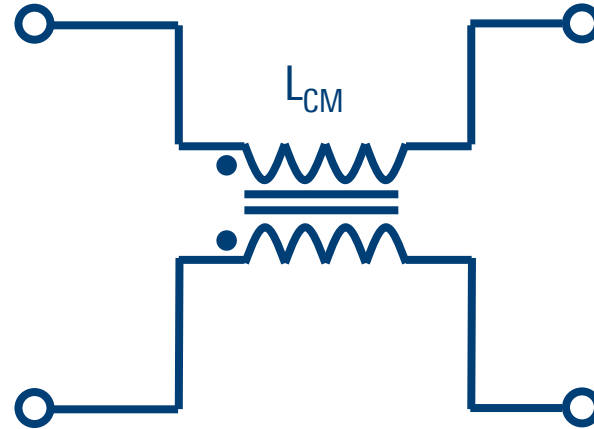


# EMI FILTER CIRCUIT – CM CHOKE

Differential Mode



Flux cancel DM current



# WÜRTH FILTER DESIGN KIT



# COMPONENT FILTER RESPONSE

