DIGITAL WE DAYS 2023

DESIGN OF THE MDI FOR POWER OVER SINGLE PAIR

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

TODAY'S SPEAKERS

PRESENTATION
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Simulations Manager

MODERATION
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Marketing Department

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AGENDA

1. From Ethernet to SPE
2. Technical data
3. From automotive to industrial
4. SPE – in detail
5. From PoE to **S**PoE

TERMS AND ABBREVIATION

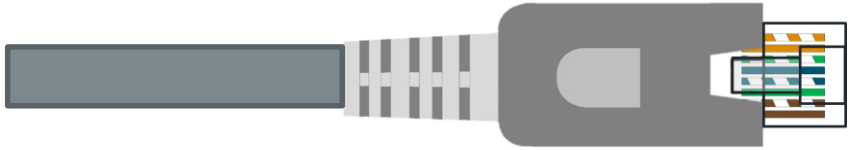
- **SPE** = **S**ingle **P**air **E**thernet
- **PoE** = **P**ower **o**ver **E**thernet
- **PoDL** = **P**ower **o**ver **D**ata **L**ine
- **SPoE** = **S**ingle **P**air **P**ower **o**ver **E**thernet

1. FROM ETHERNET TO SPE

Multi Pair Ethernet

2- Pairs: 100BASE-TX *(IEEE802.3 Clause 25)*

4- Pairs: 1000BASE-T *(IEEE802.3 Clause 40)*

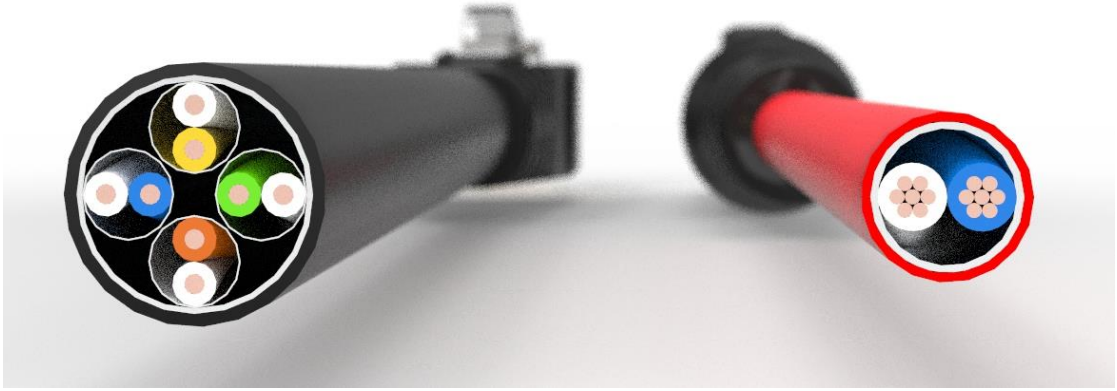


Cost reduction

Automotive Ethernet

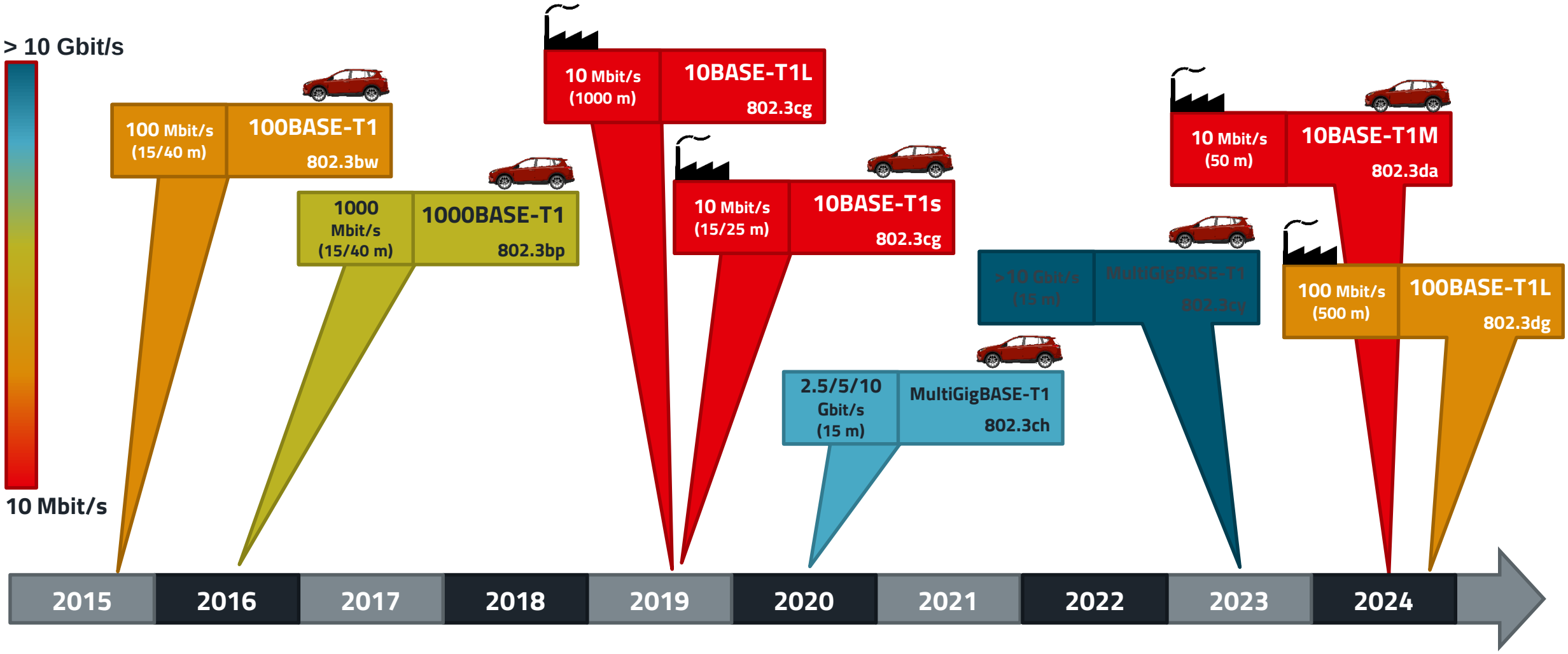
1- Pair: 100BASE-T1 *(IEEE 802.3bw)*

1- Pair: 1000BASE-T1 *(IEEE802.3bp)*



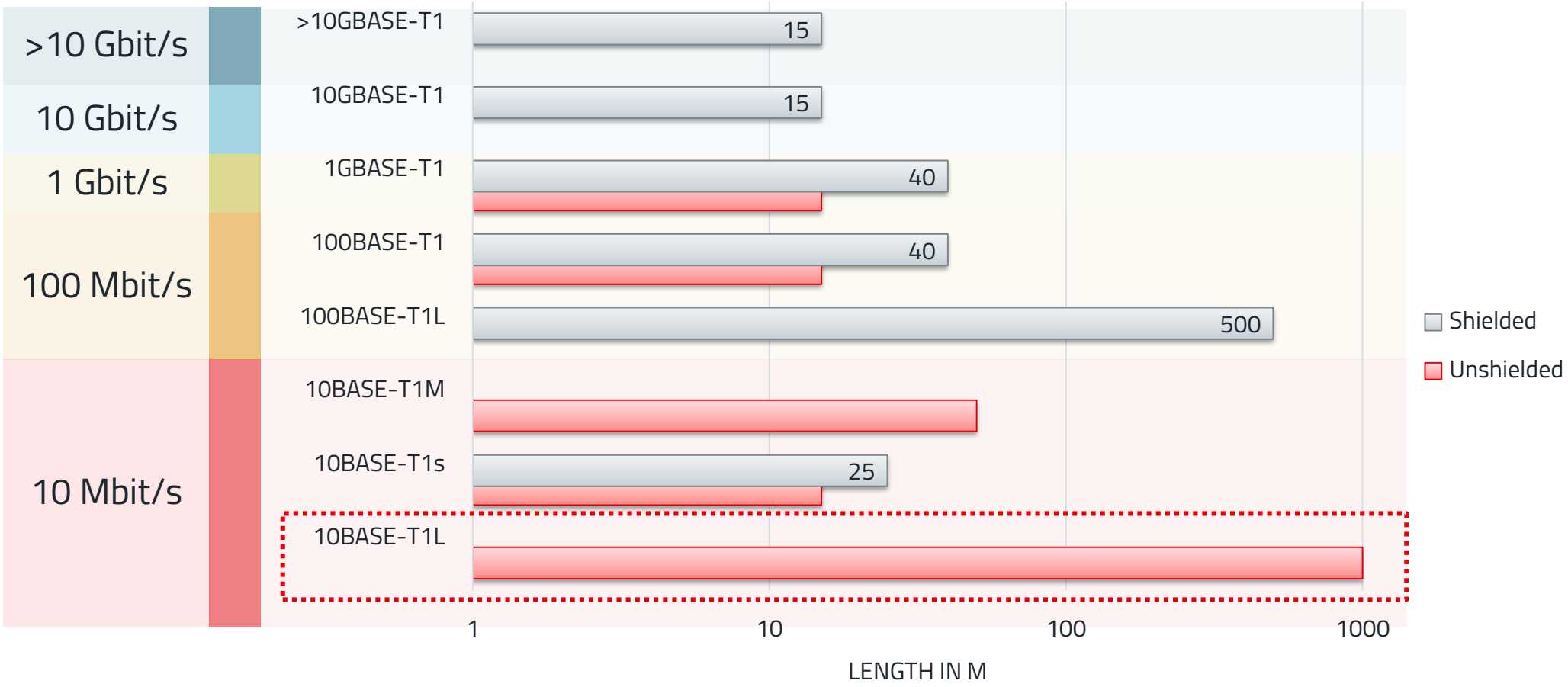
1. FROM ETHERNET TO SPE

1.1 Single Pair Ethernet History



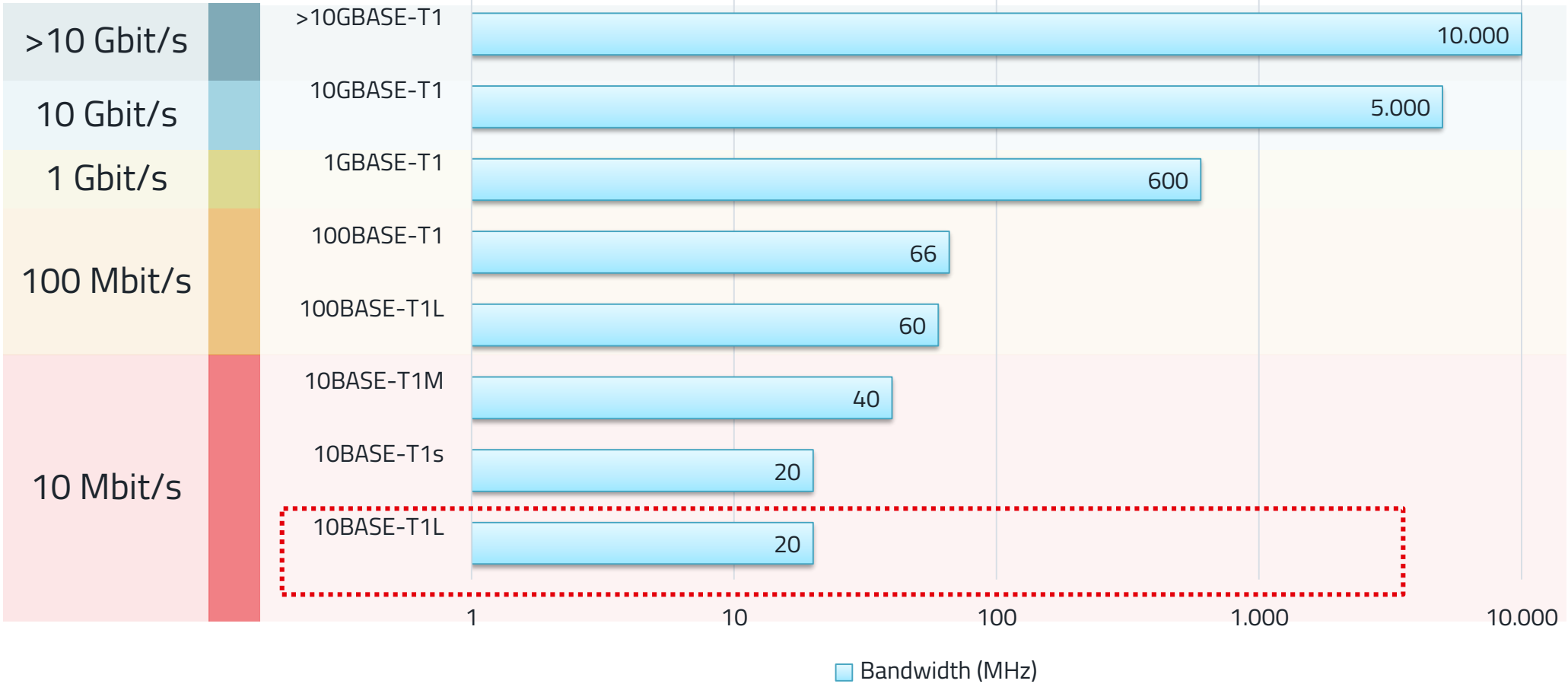
2. SPE – TECHNICAL DATA

2.1 Wiring length



2. SPE – TECHNICAL DATA

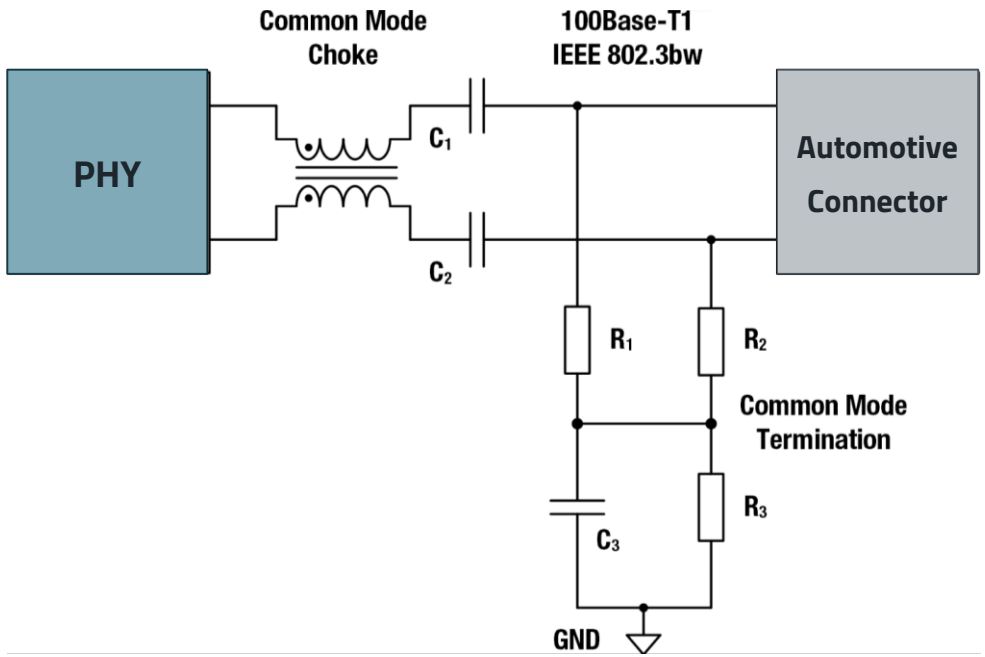
2.2 Bandwidth



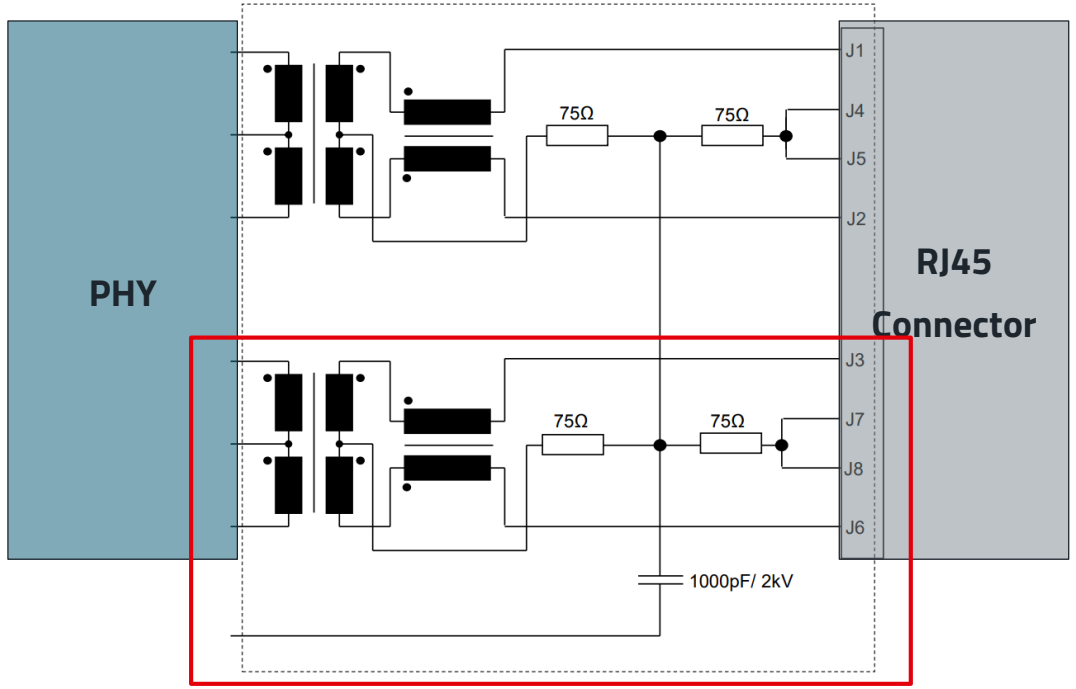
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.1 MDI circuits in comparison

Automotive 100BASE-T1



Industrial Multi Pair Ethernet 100BASE-TX



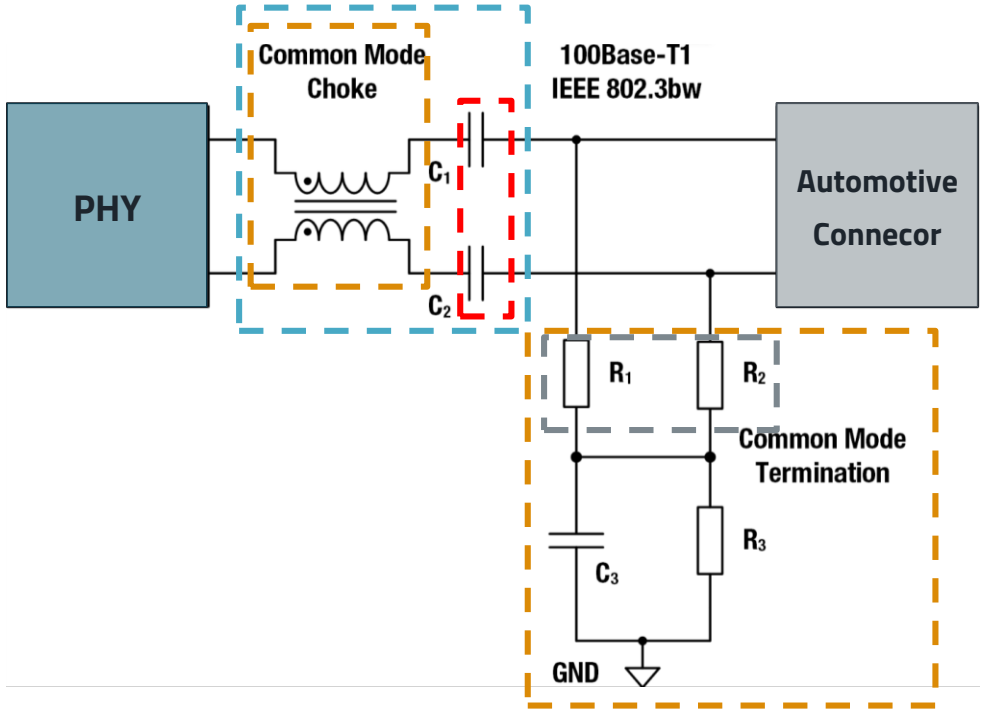
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.2 Design requirements - Automotive

Automotive Requirements

Isolation	60 V
CM Attenuation	✓
Return Loss	✓
Mode Conversion	✓
Cheap & small	✓

Circuit



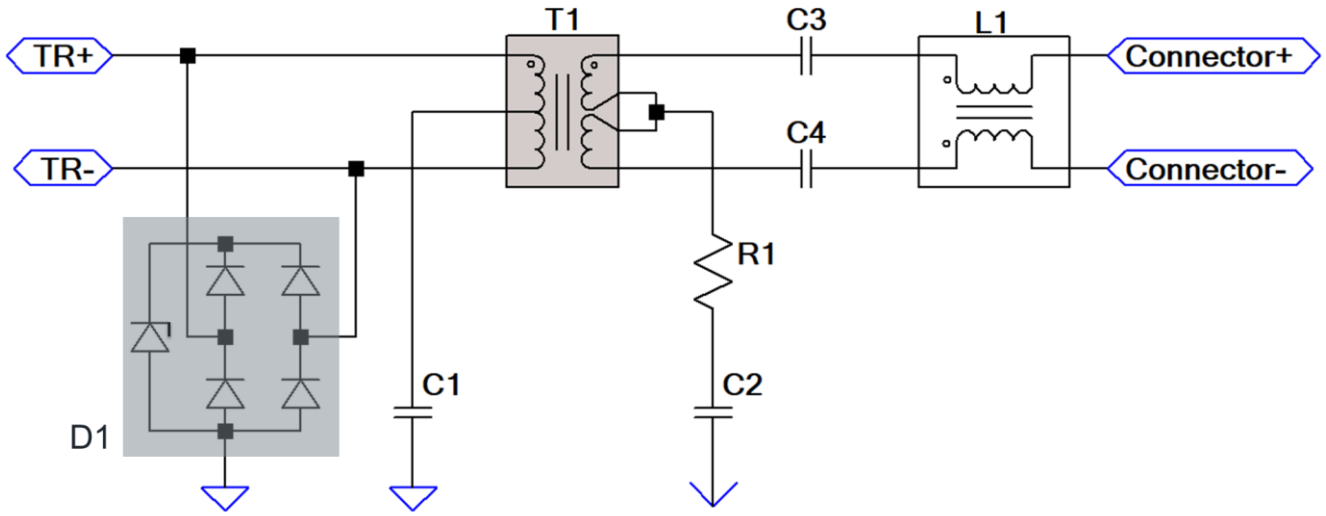
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

- Isolation
- Isolation DC
- CM Attenuation
- Return Loss
- Mode Conversion
- ESD Protection

Circuit



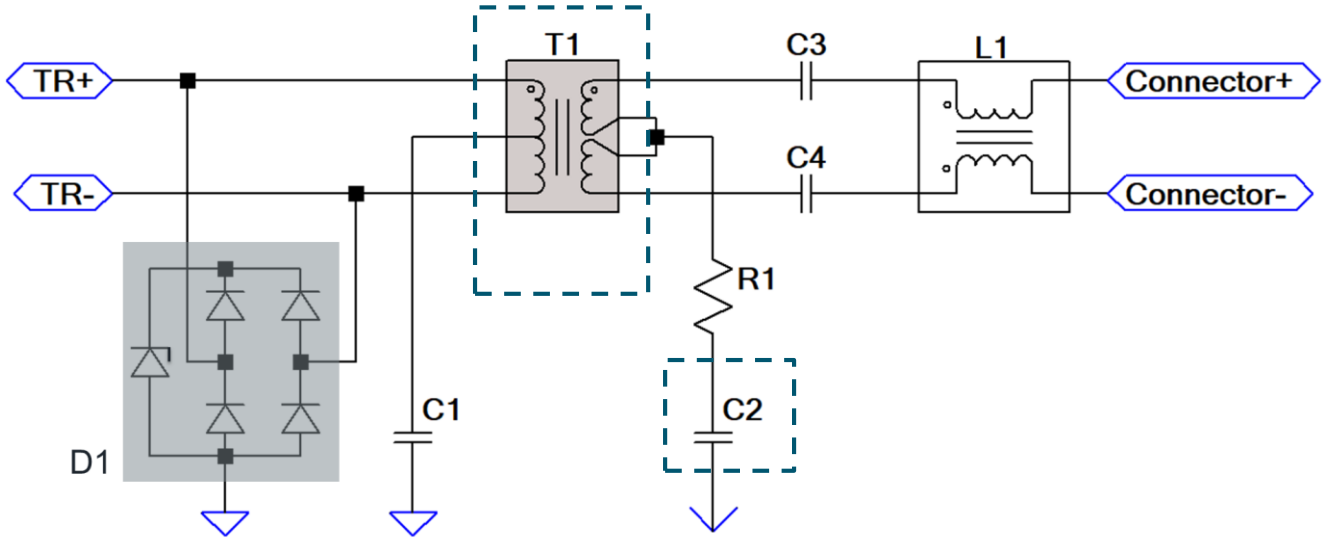
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

Isolation	1500 V
Isolation DC	
CM Dämpfung	
Return Loss	
Moden Umwandlung	
ESD Schutz	

Circuit



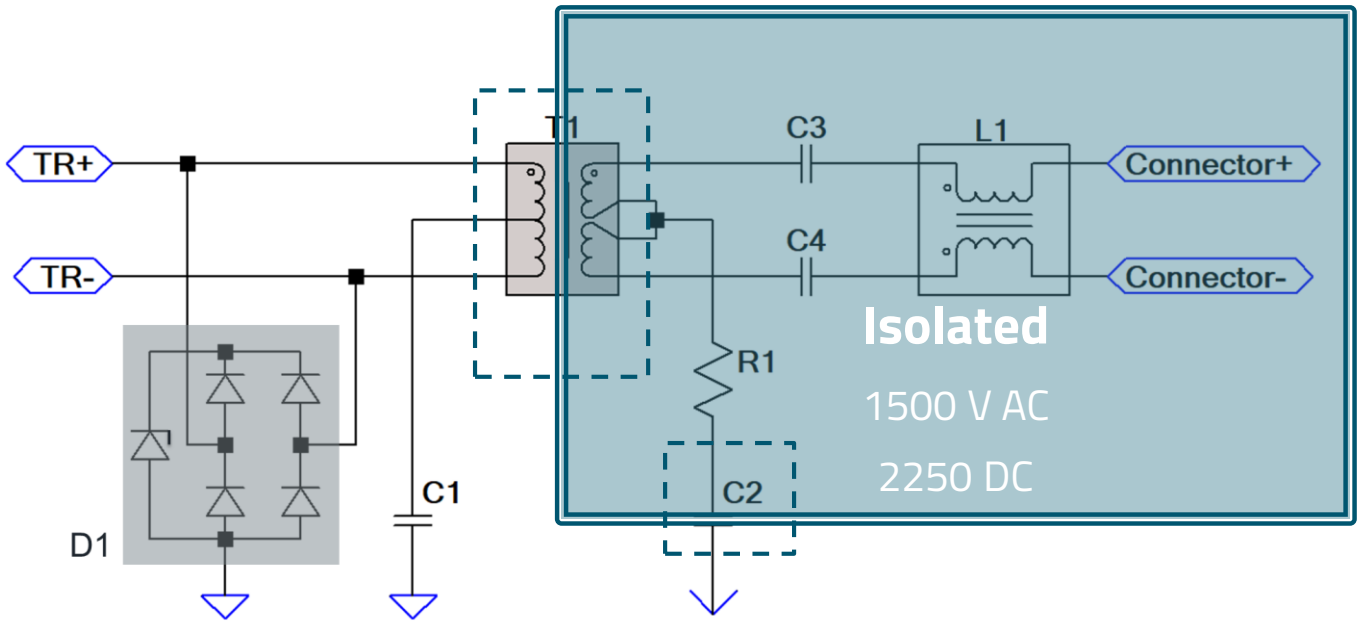
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

Isolation	1500 V
Isolation DC	
CM Attenuation	
Return Loss	
Mode Conversion	
ESD Protection	

Circuit



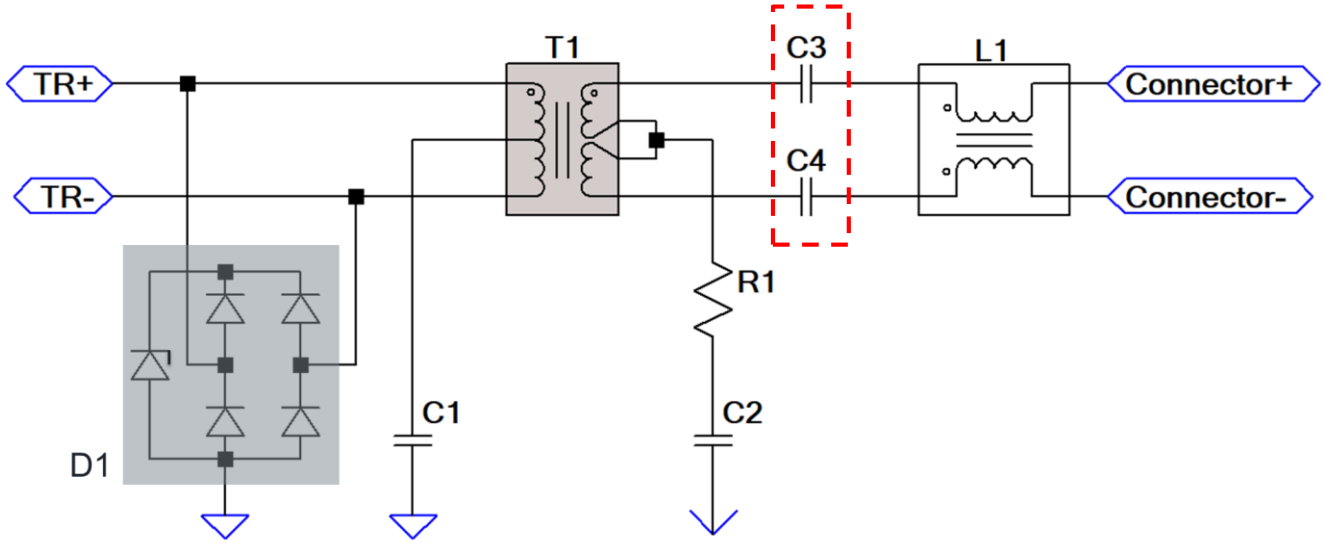
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

Isolation	1500 V
Isolation DC	**60 V**
CM Attenuation	
Return Loss	
Mode Conversion	
ESD Protection	

Circuit



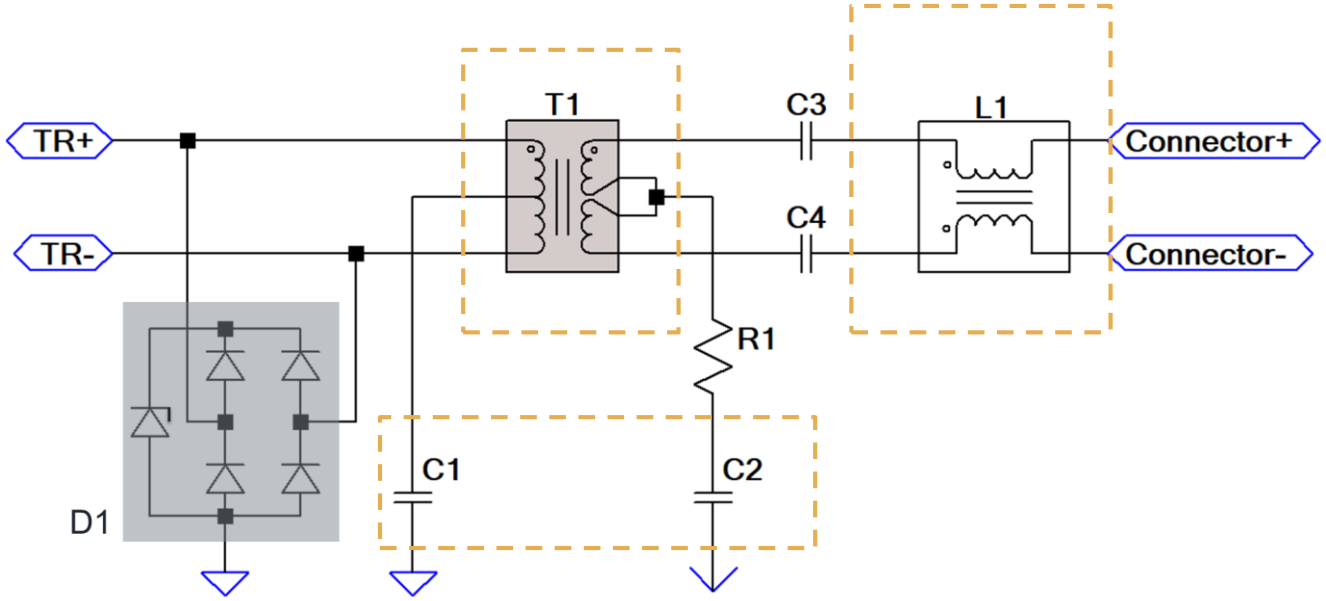
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

Isolation	1500 V
Isolation DC	60 V
CM Attenuation	✓
Return Loss	
Mode Conversion	
ESD Protection	

Circuit



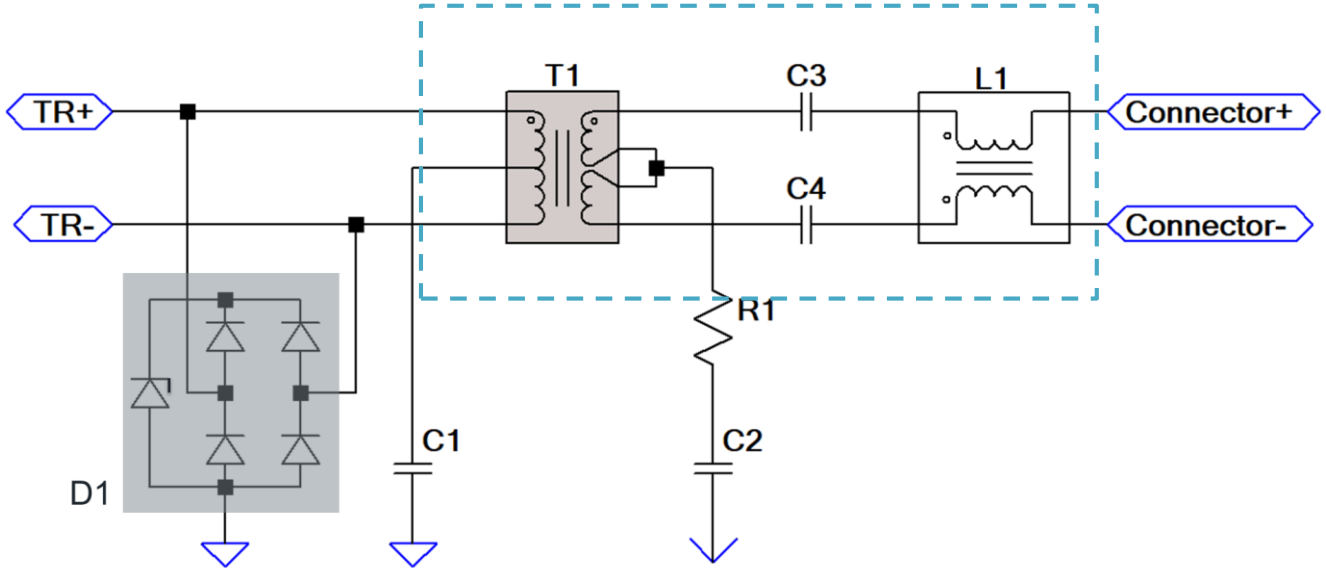
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

Isolation	1500 V
Isolation DC	60 V
CM Attenuation	✓
Return Loss	✓
Mode Conversion	
ESD Protection	

Circuit



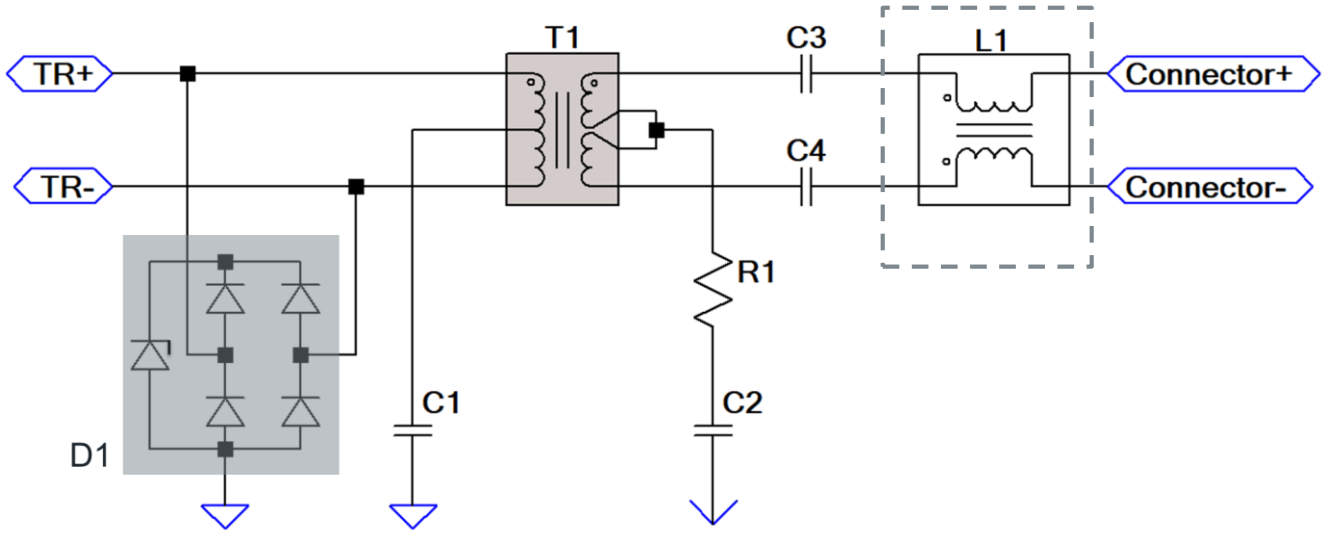
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

Isolation	1500 V
Isolation DC	60 V
CM Attenuation	✓
Return Loss	✓
Mode Conversion	✓
ESD Protection	

Circuit



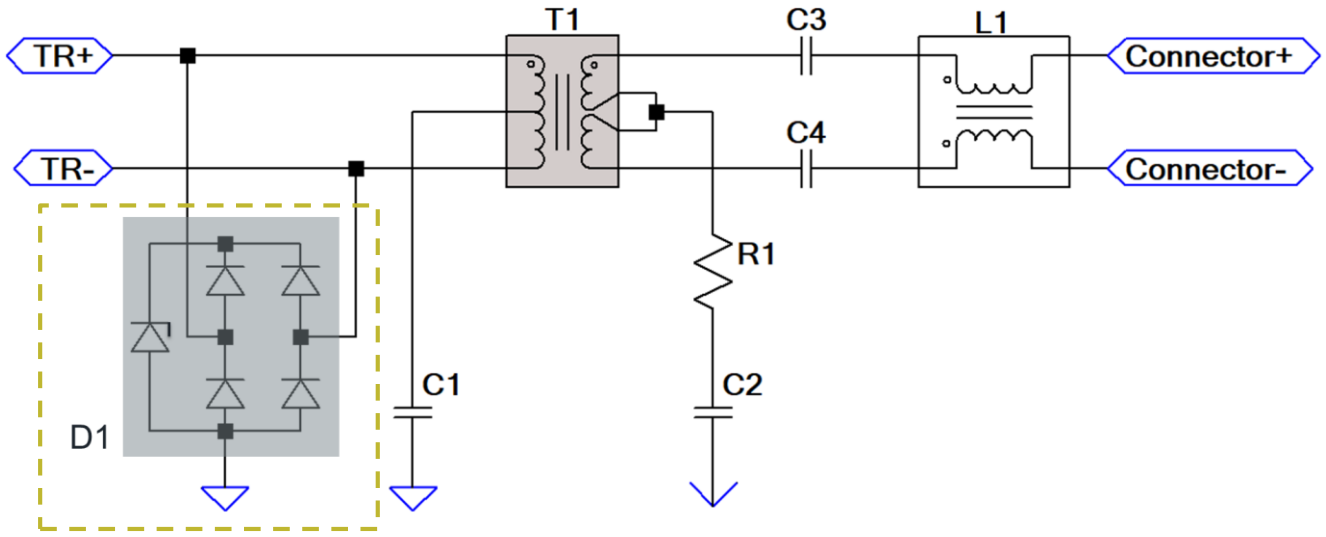
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.3 Design requirements - Industry

Industry Requirements

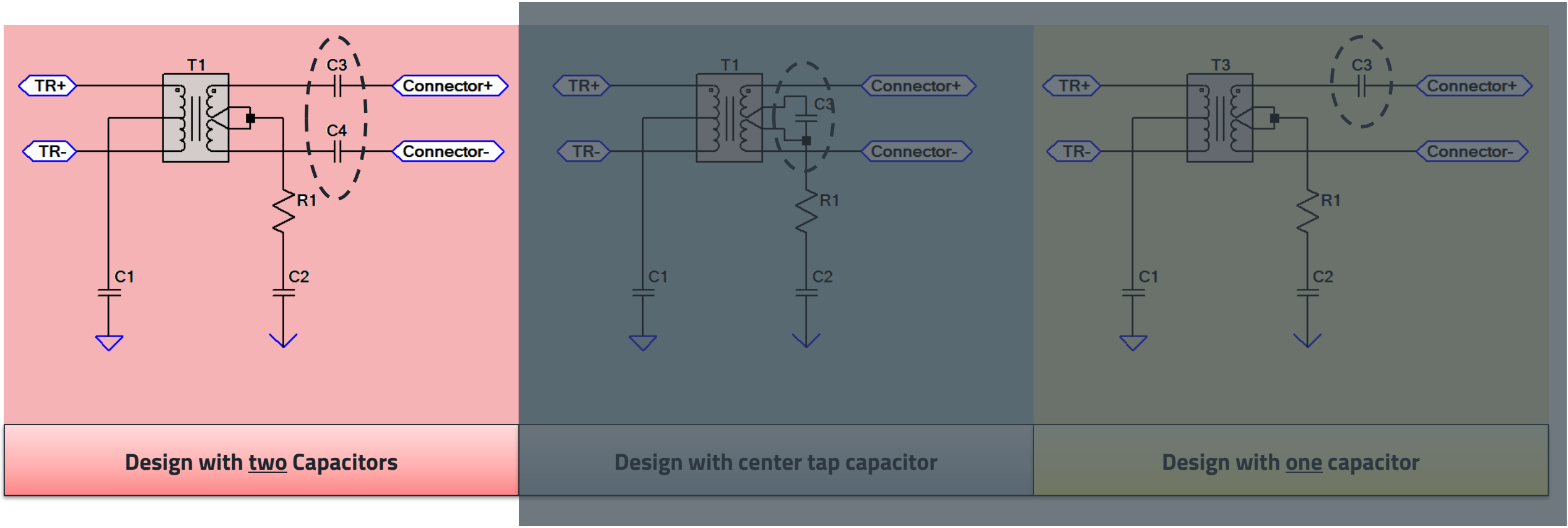
Isolation	1500 V
Isolation DC	60 V
CM Dämpfung	✓
Return Loss	✓
Mode Conversion	✓
ESD Protection	✓

Circuit



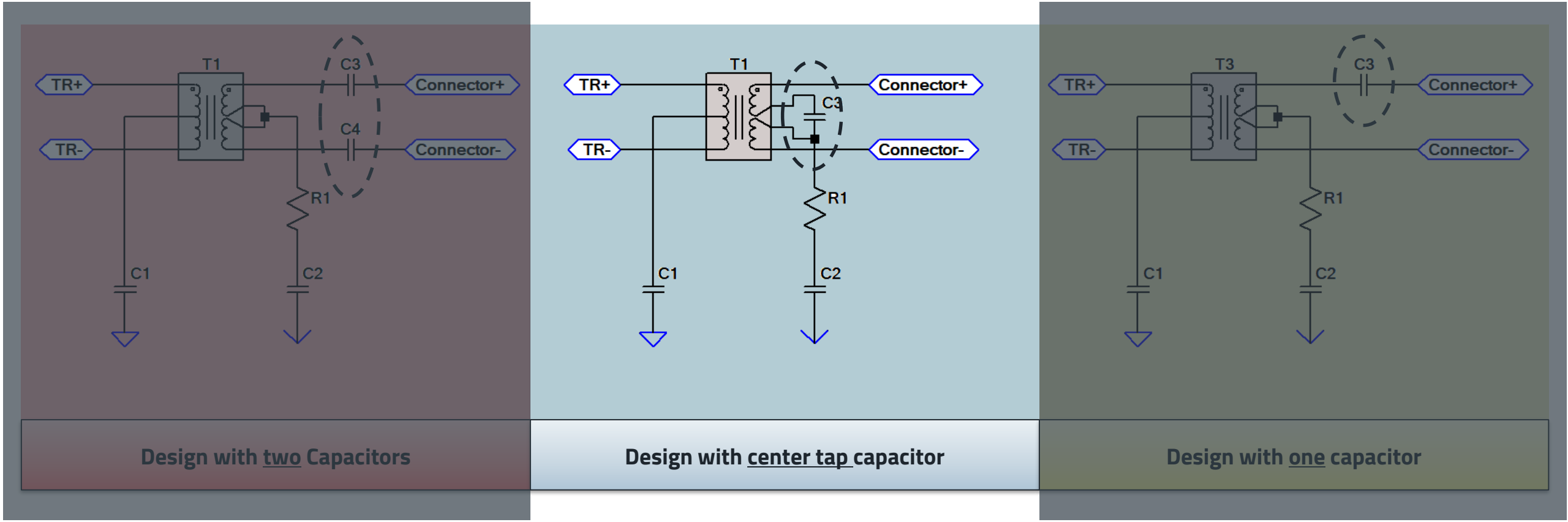
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.4 SPE Circuit – DC isolation capacitor



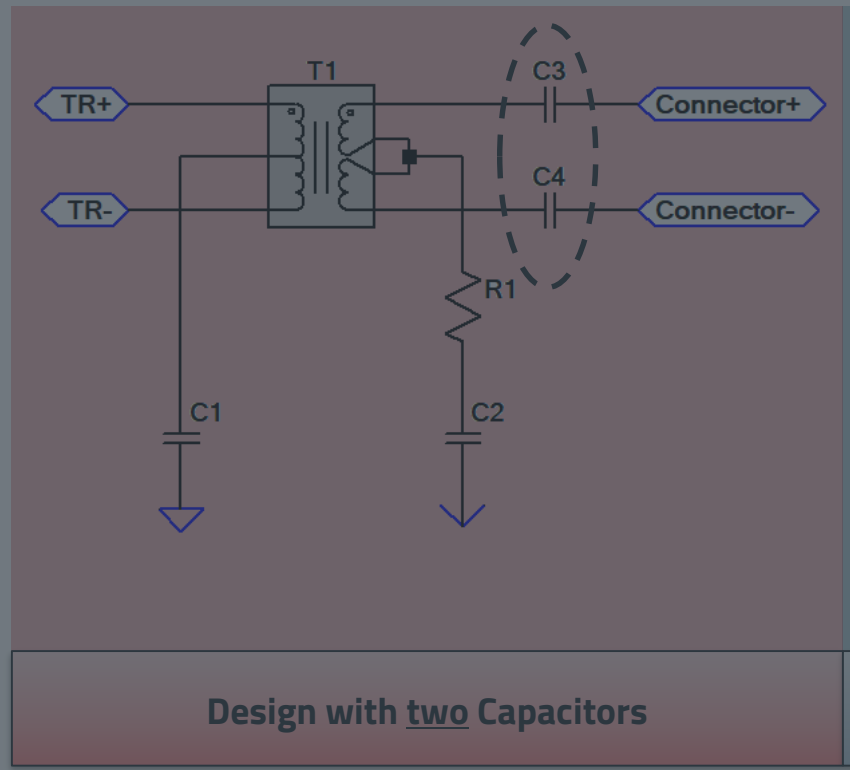
3. FROM AUTOMOTIVE TO INDUSTRIAL

3.4 SPE Circuit – DC isolation capacitor

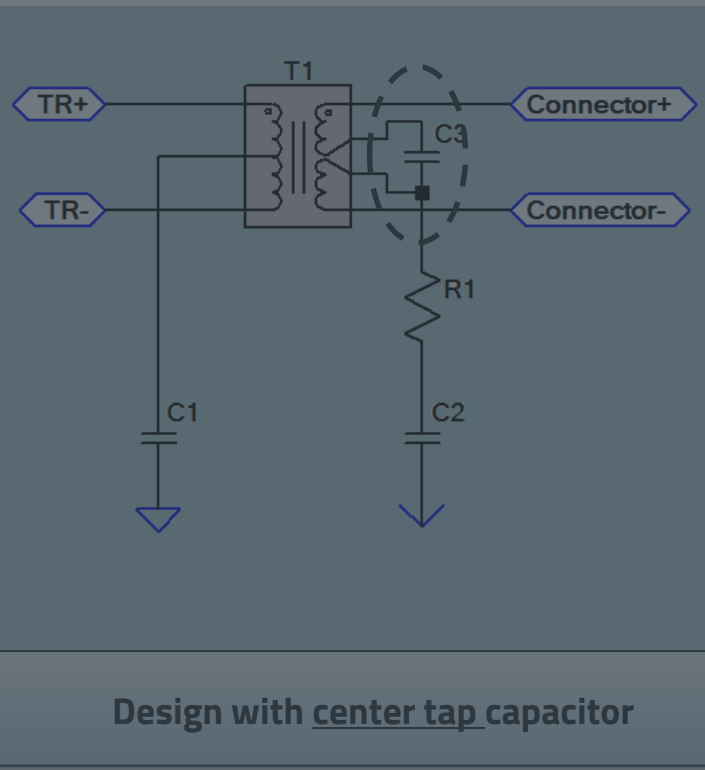


3. FROM AUTOMOTIVE TO INDUSTRIAL

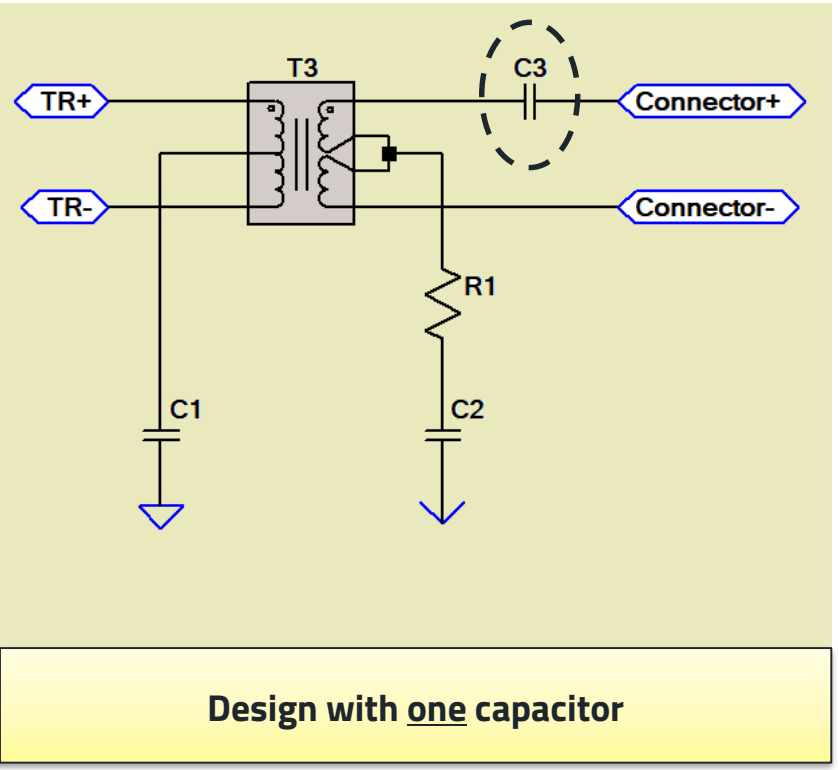
3.4 SPE Circuit – DC isolation capacitor



Design with two Capacitors



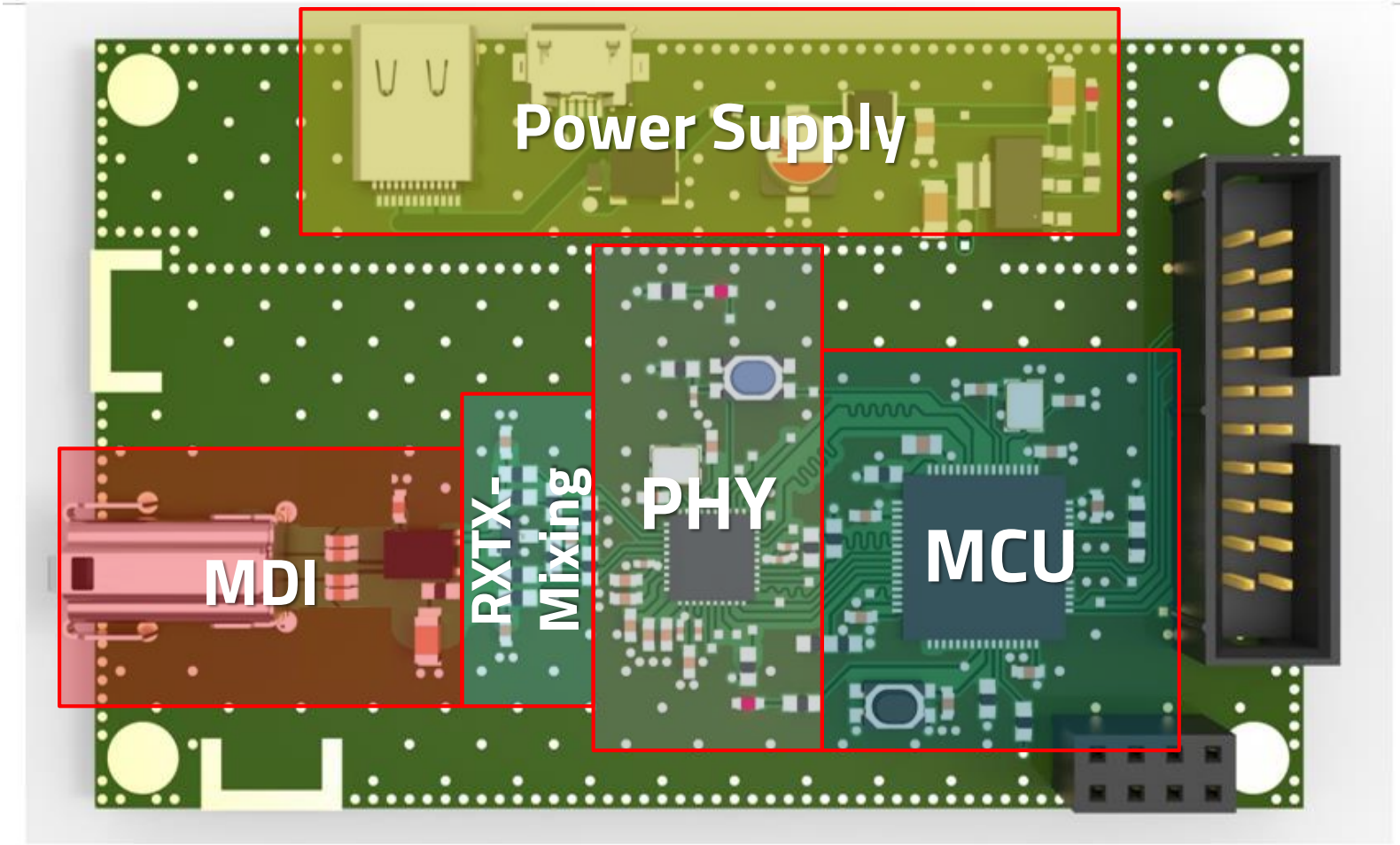
Design with center tap capacitor



Design with one capacitor

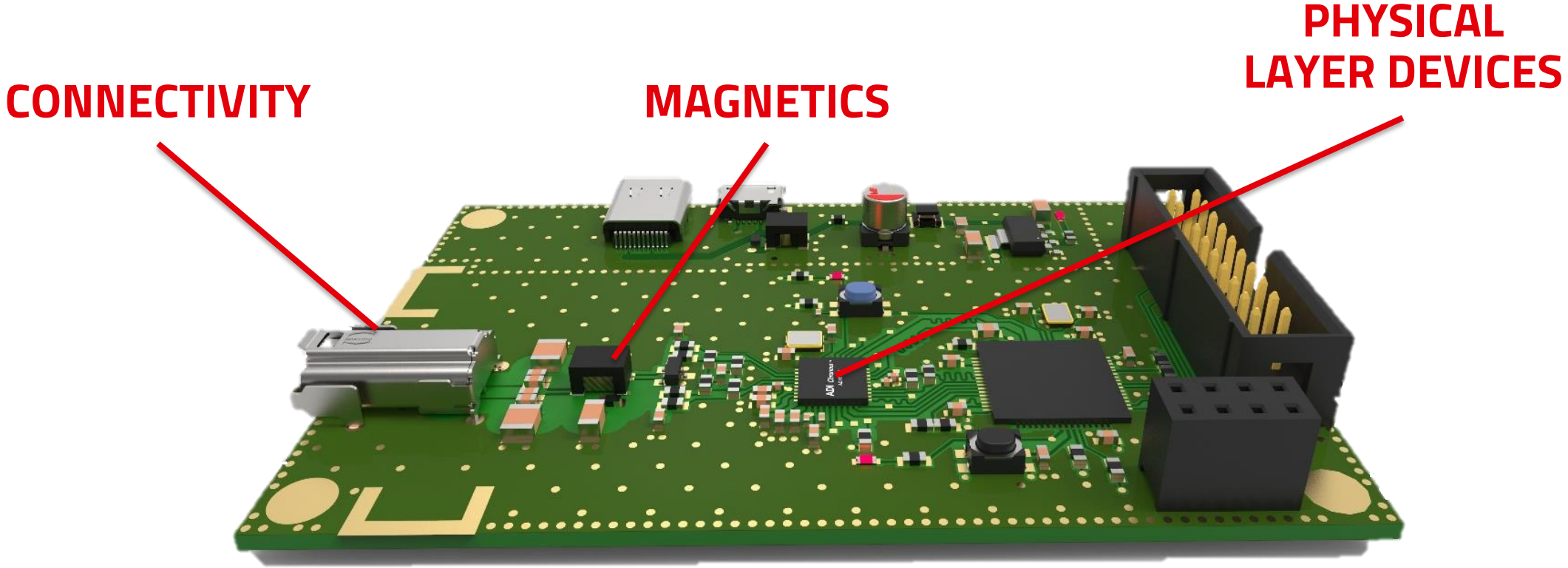
4. SPE – IN DETAIL

4.1 Demo Board for 10BASE-T1L



4. SPE – IN DETAIL

4.1 Demo Board for 10BASE-T1L



4. SPE – IN DETAIL

4.2 PHY ICs for SPE

10BASE-T1L

- **Analog Devices**
  - PHY
    - *ADIN1100*
    - *ADIN1110 (MAC-PHY)*
  - 2-Port Switch
    - *ADIN2111 (MAC-PHY)*
- **Texas Instruments**
  - *DP83TD510E*

10BASE-T1s

- **ONSEMI**
  - *NCN26010 (MAC-PHY)*
- **Microchip**
  - *LAN8650 (MAC-PHY)*
  - *LAN8651 (MAC-PHY)*
  - *LAN8670*
  - *LAN8671*
  - *LAN8672*

4. SPE – IN DETAIL

4.3 SPE Design suggestions

- Before the design: Decide whether pure **data transmission** or **SPoE**.

- For only SPE:

  → small size possible

  → „Upgrading" to SPoE possible, but depending on the power class not useful

- For SPoE:

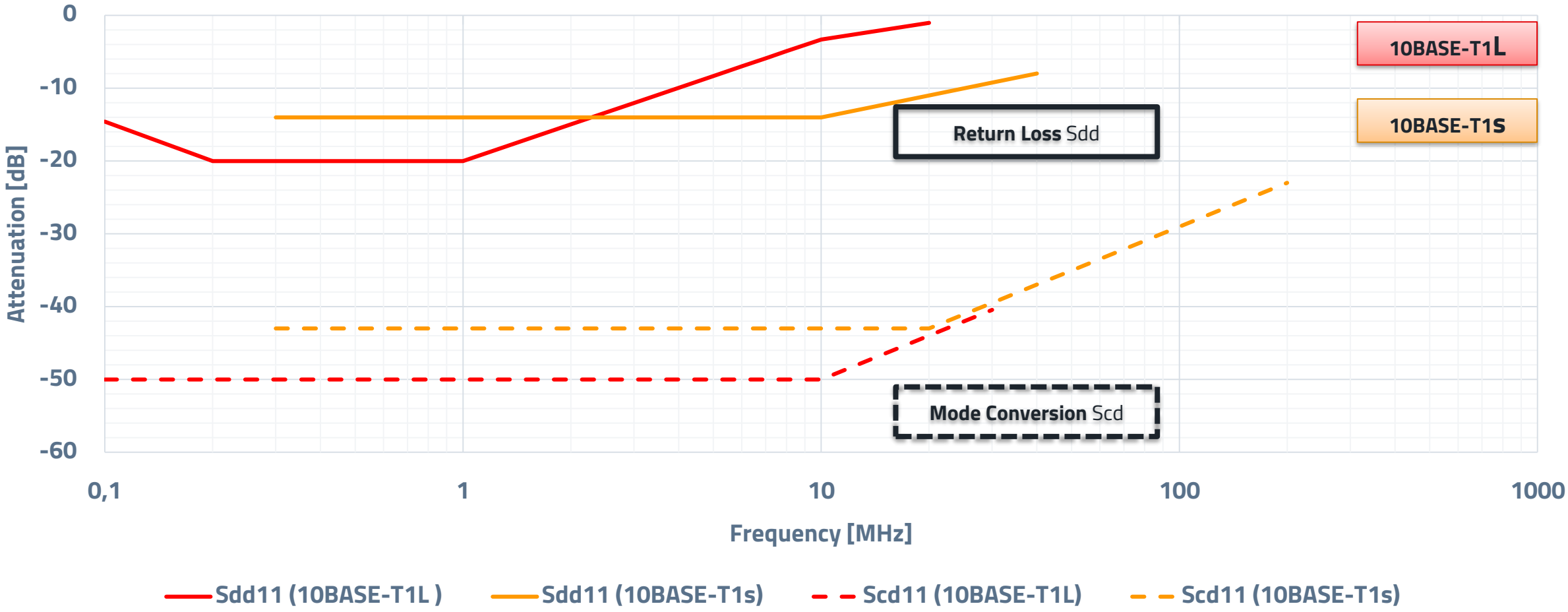
  → Depending on the power class selection of components

  → „Rule of thumb ":

    - Increase Transformer inductance
    - This allows a smaller inductance of the DMC

4. SPE – IN DETAIL

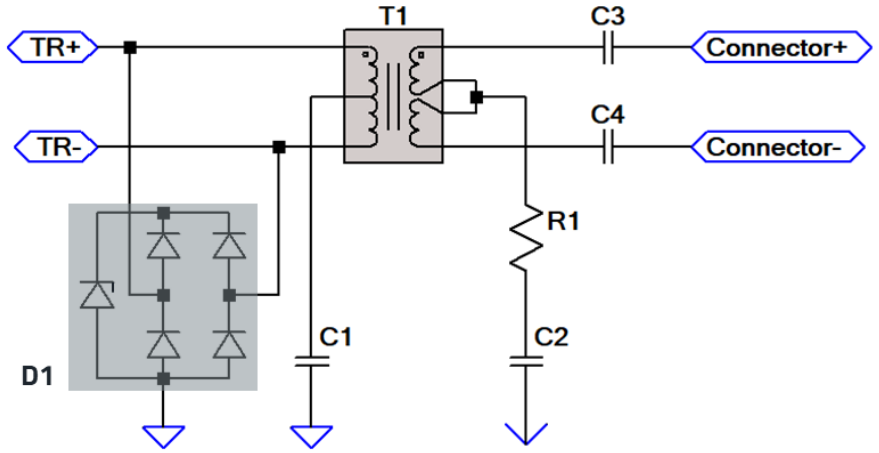
4.4 Limits for 10BASE-T1 according IEEE802.3cg



10BASE-T1L

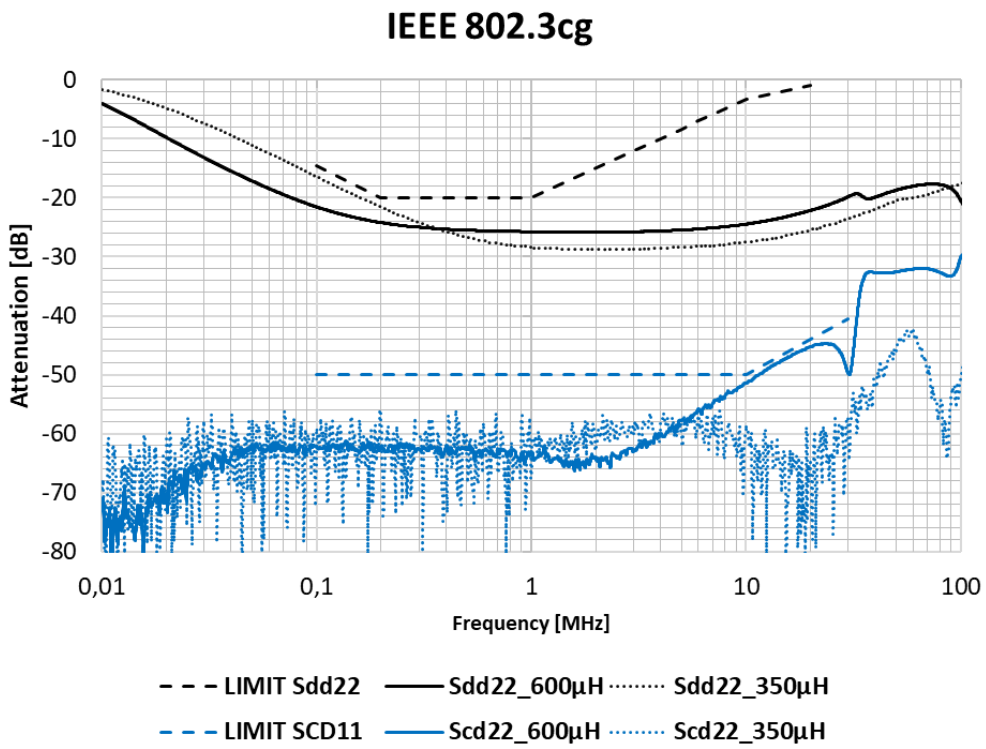
4.5 MDI Components (10BASE-T1L)

Circuit



Name	Value	Isolation	Size	Article number
C1	100 nF	50 V	0402	885012205086
C2	1 nF	2 kV	1206	885342208024
C4, C5	470 nF	100 V	0603	885012207130
T1	600 µH	1500 V	5.35 x 6.55 mm	74930200
T1	350 µH	1500 V	1812	74930000
R1	100 Ω		0603	
D1	3.3 V 0.27 pF	8 / 15 kV	DFN1210-6L	824012823

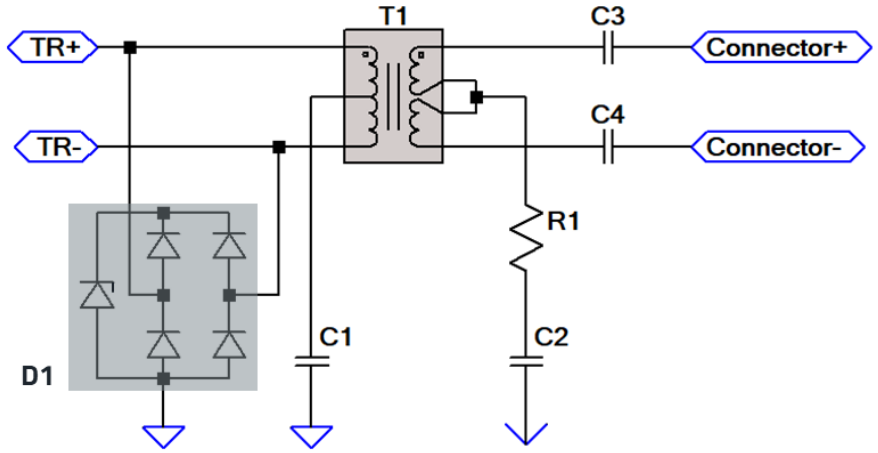
Limits



10BASE-T1S

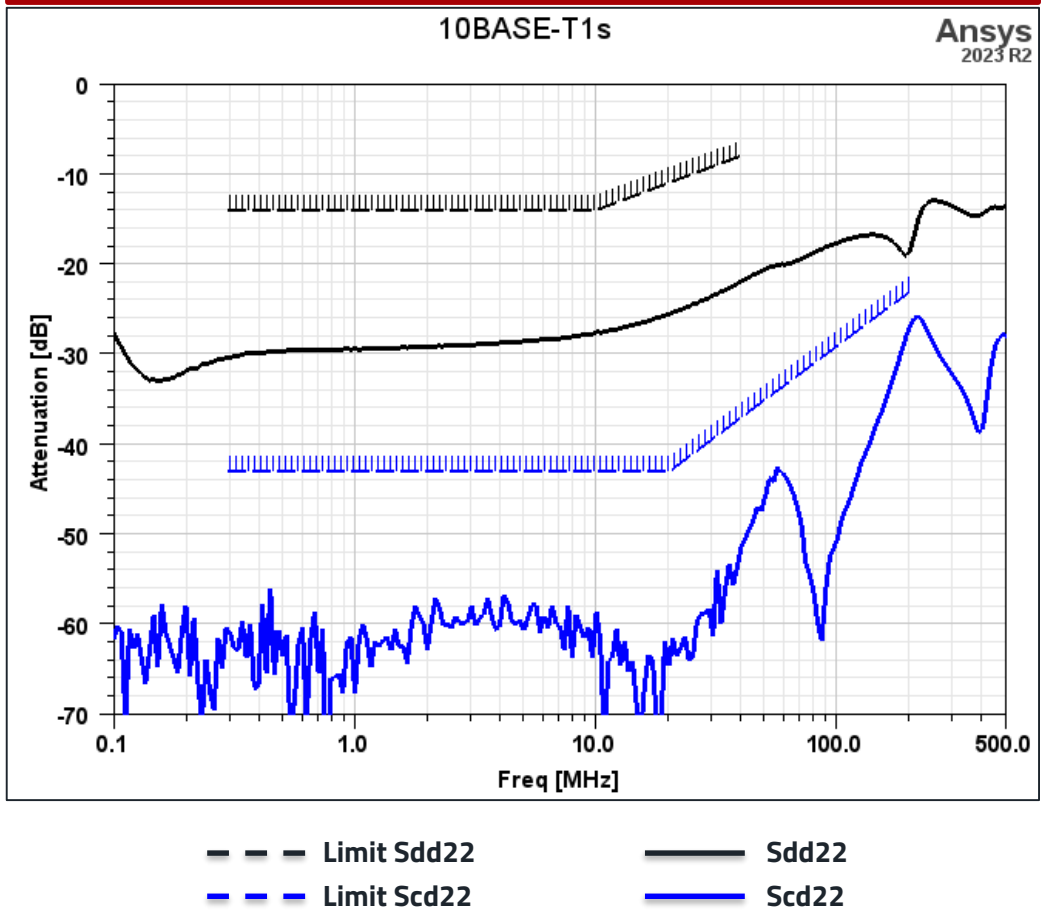
4.6 MDI Components (10BASE-T1s)

Circuit



Name	Value	Isolation	Size	Article number
C1	100 nF	50 V	0402	885012205086
C2	1 nF	2 kV	1206	885342208024
C4, C5	100 nF	100 V	0603	885012206120
T1	350 µH	1500 V	1812	74930000
R1	100 Ω		0603	
D1	3.3 V 0.27 pF	8 / 15 kV	DFN1210-6L	824012823

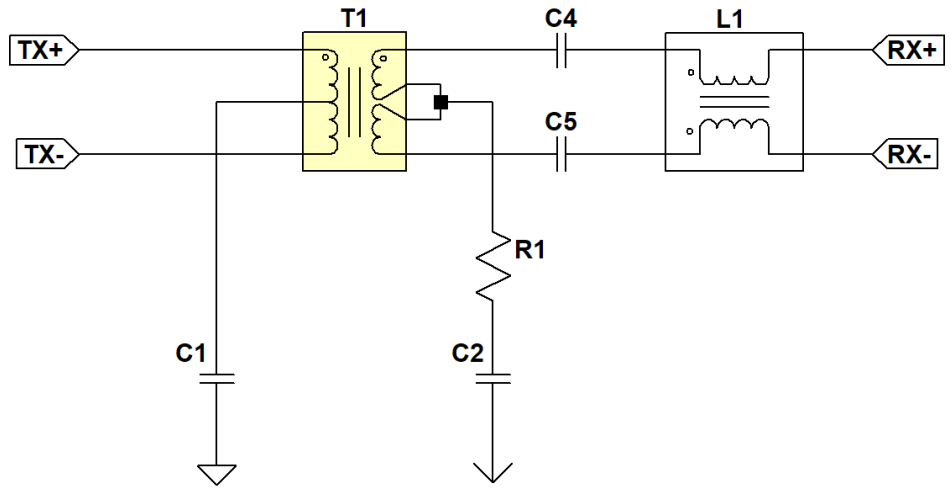
Limits



100BASE-T1

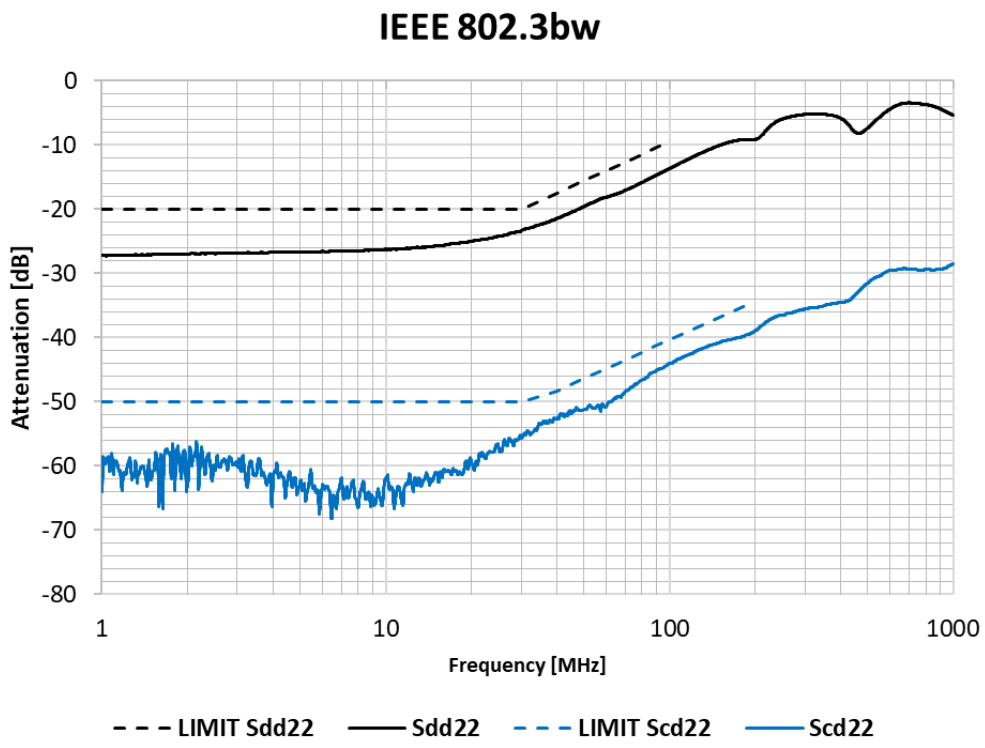
4.7 MDI Components (100BASE-T1)

Circuit



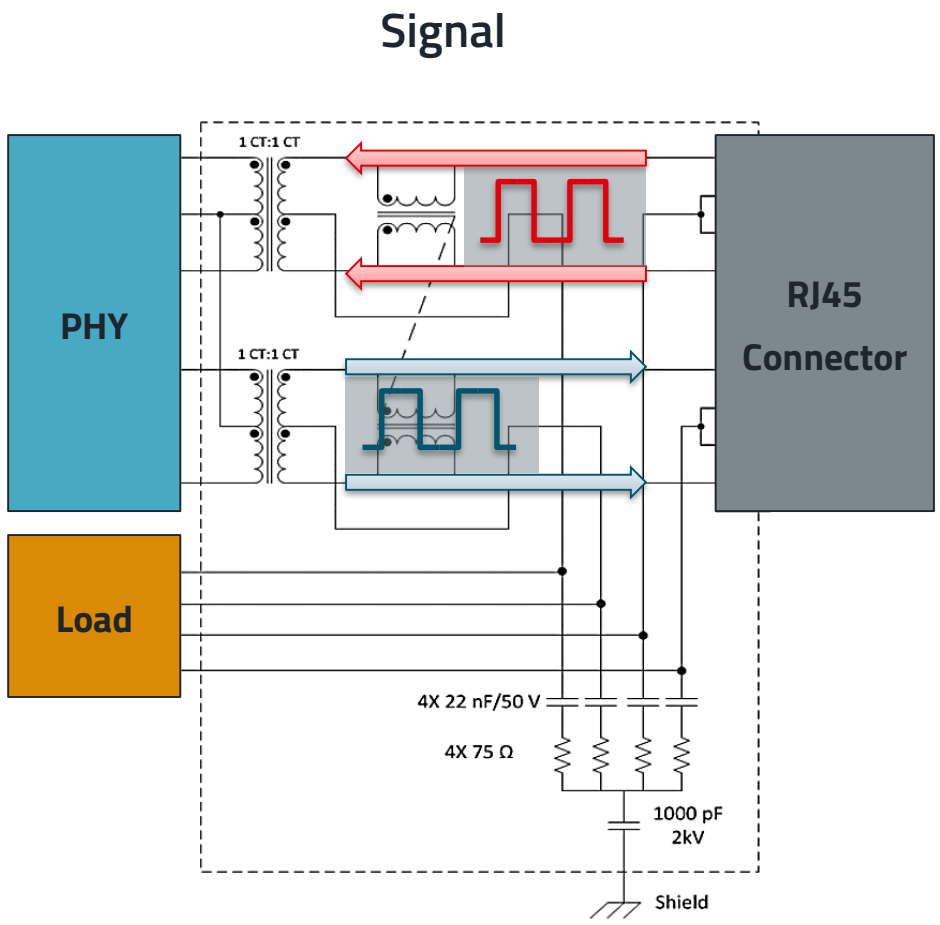
Name	Value	Isolation	Size	Article number
C1	100 nF	50 V	0402	885012205086
C2	1 nF	2 kV	1206	885342208024
C4, C5	100 nF	100 V	0603	885012206120
T1	350 µH	1500 V	1812	74930000
L1	2.57 µH	50 V (DC) 125 V (AC)	1206	744232222
R1	100 Ω		0603	

Limits



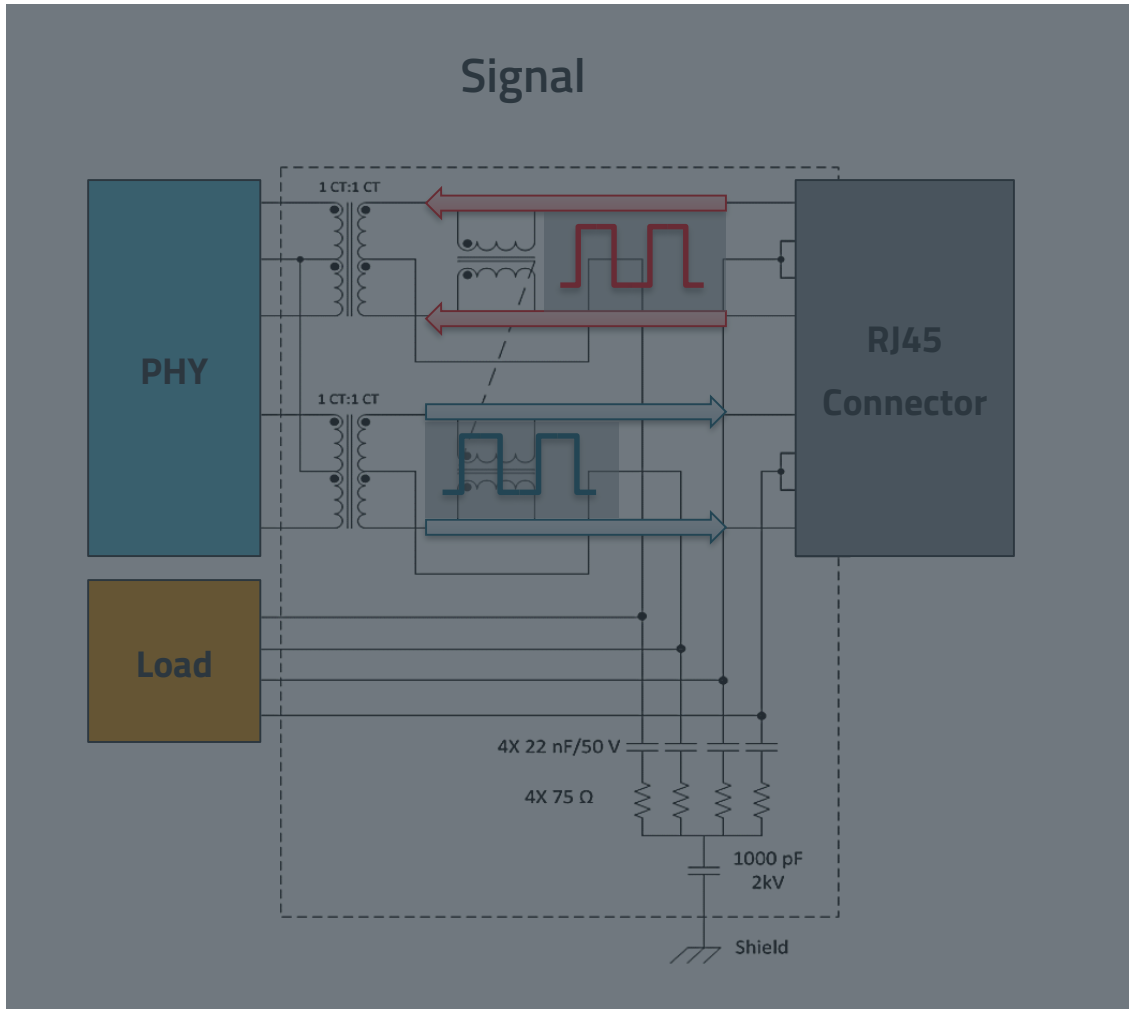
5. FROM POE TO SPOE

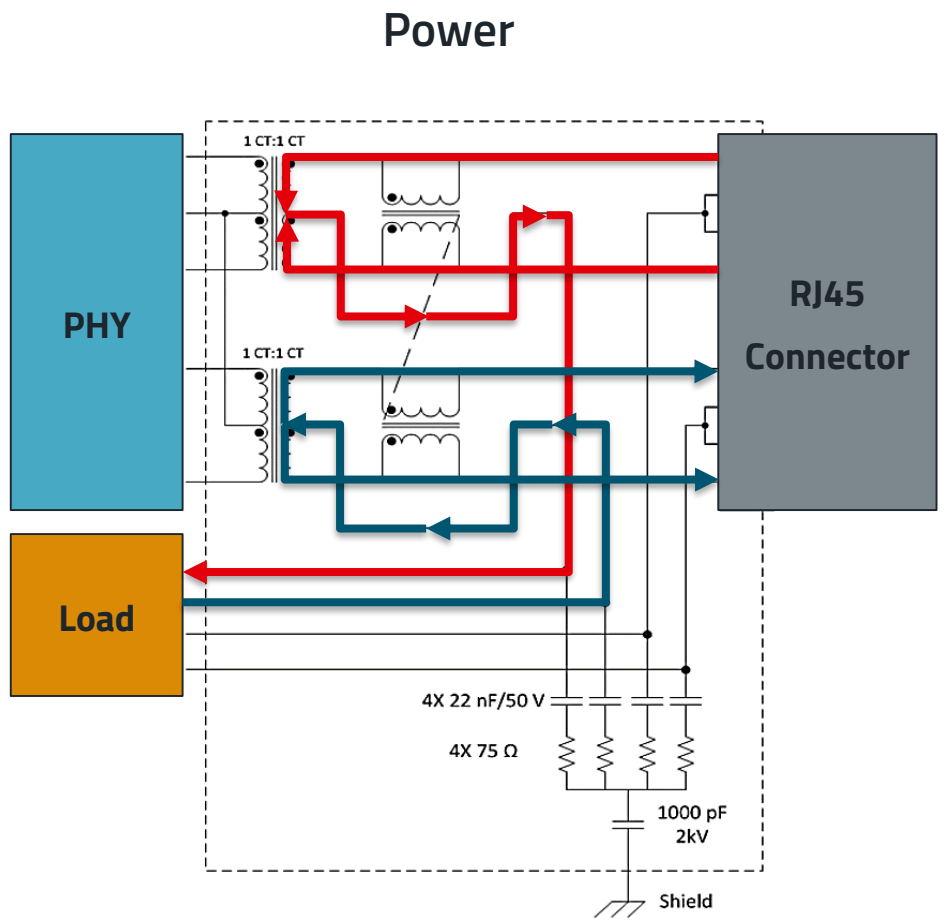
5.1 PoE in standard Ethernet



5. FROM POE TO SPOE

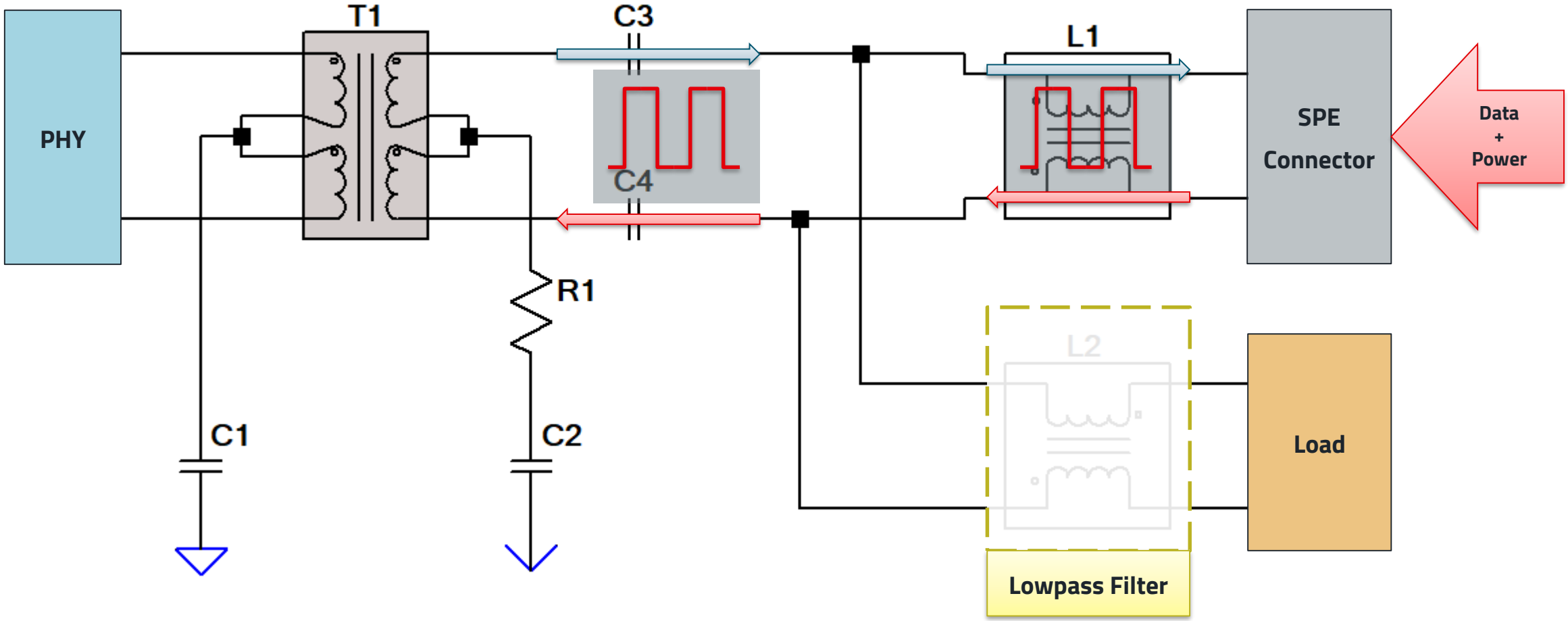
5.1 PoE in standard Ethernet





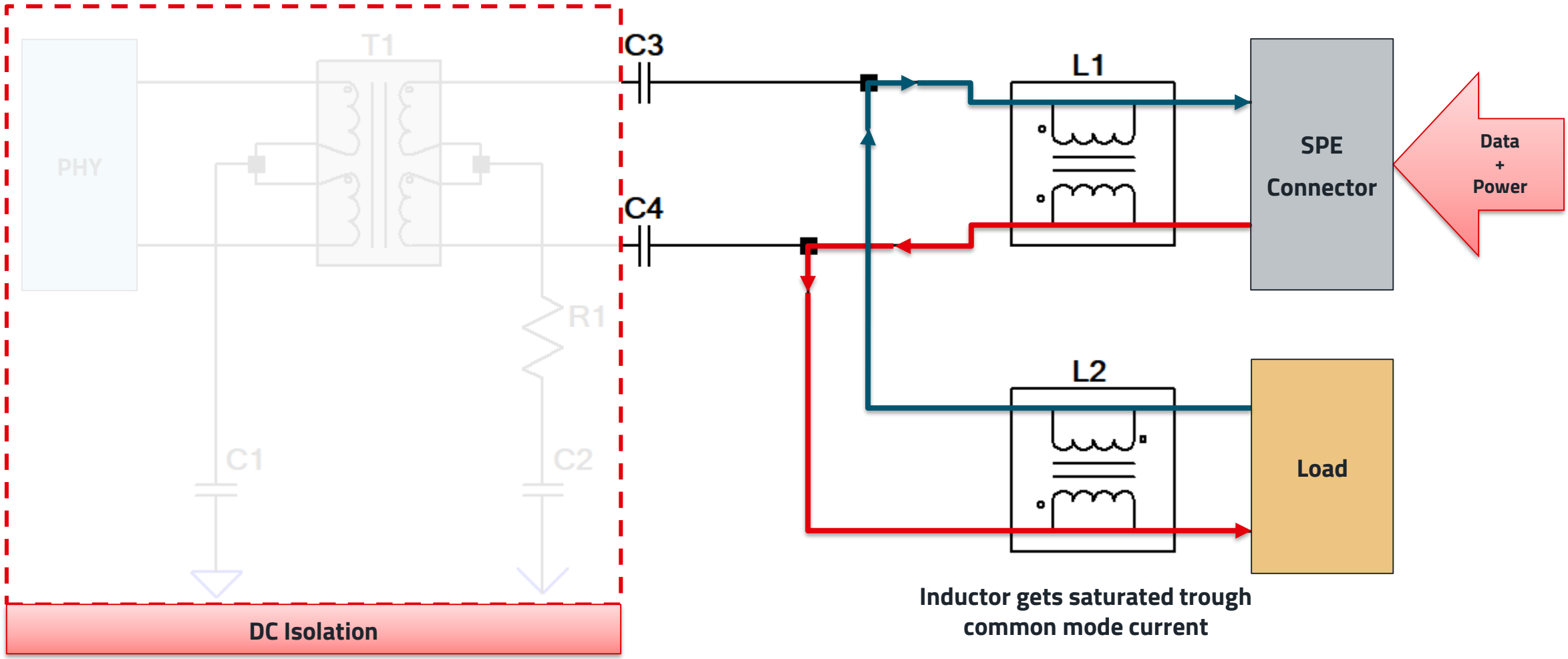
5. FROM POE TO SPOE

5.2 Data in SPoE



5. FROM POE TO SPOE

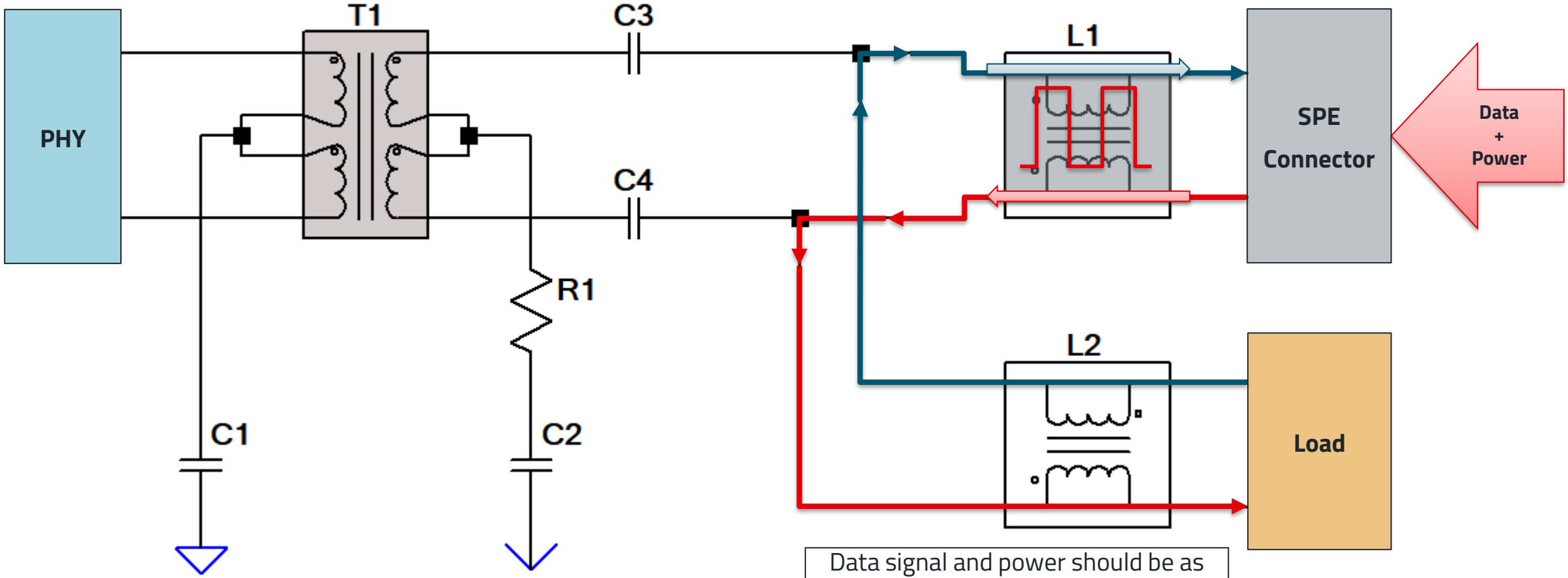
5.3 Power over SPoE



5. FROM POE TO SPOE

5.4 The coupled inductor

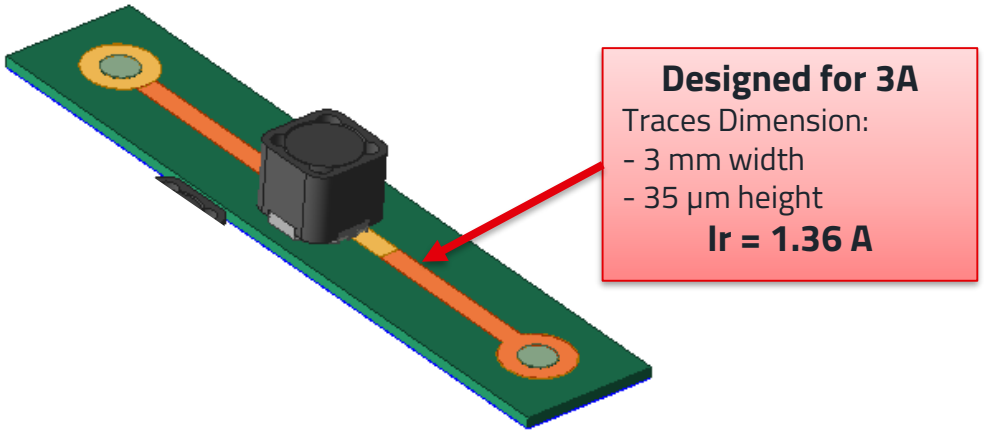
Data signal and power supply come as **Differential signal**



Data signal and power should be as **Common mode signal** run through the coupled inductor.

RATED CURRENT ≠ RATED CURRENT

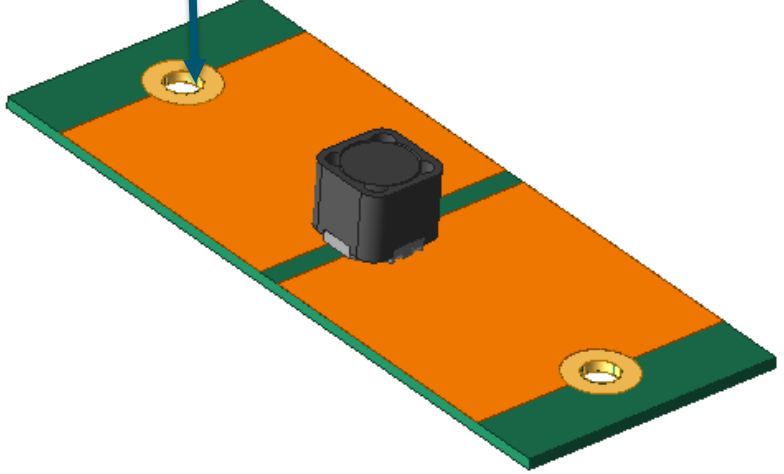
Ir according **IEC 62024-2**

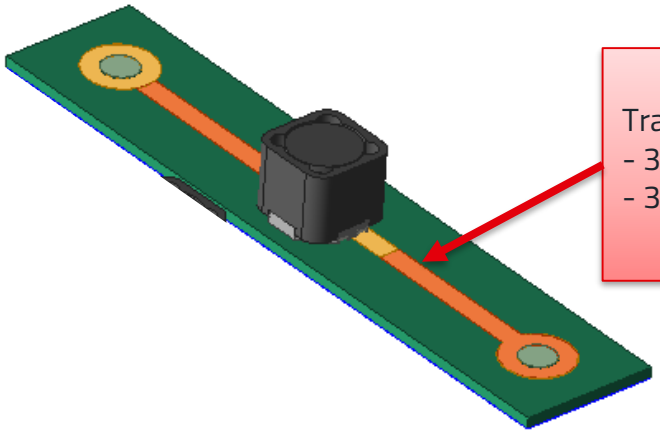


RATED CURRENT ≠ RATED CURRENT

Ir according **IEC 62024-2**

Class B
Traces Dimension:
- **40** mm width
- 35 µm height
Ir = 1.601 A



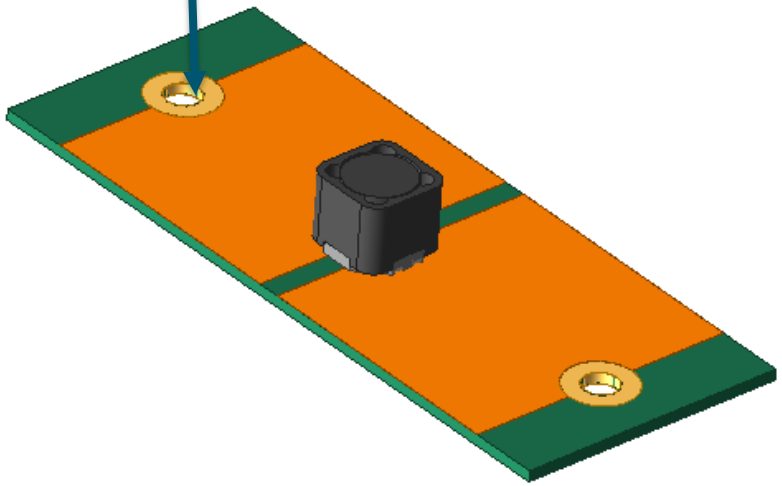


Designed for 3A
Traces Dimension:
- 3 mm width
- 35 µm height
Ir = 1.36 A

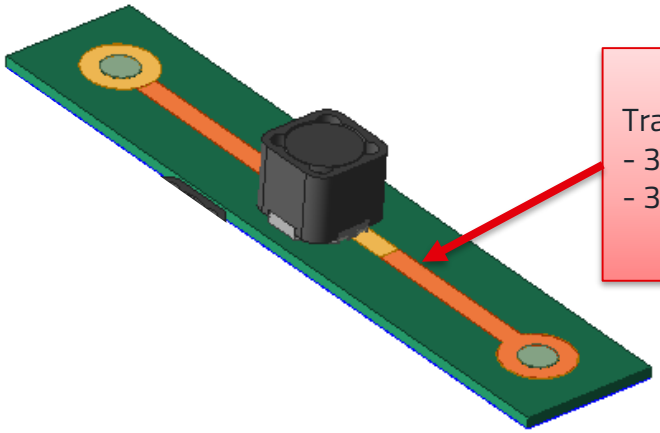
RATED CURRENT ≠ RATED CURRENT

Ir according **IEC 62024-2**

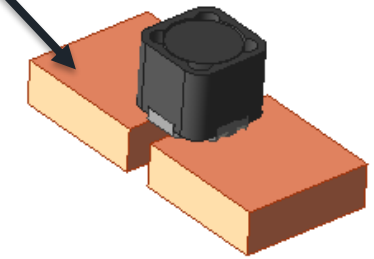
Class B
Traces Dimension:
- **40** mm width
- 35 µm height
Ir = 1.601 A



Designed for 3A
Traces Dimension:
- 3 mm width
- 35 µm height
Ir = 1.36 A



Class ?
"Traces" Dimension:
- 19 mm width
- 6.5 mm height
Ir > 1.9 A



5. FROM POE TO SPOE

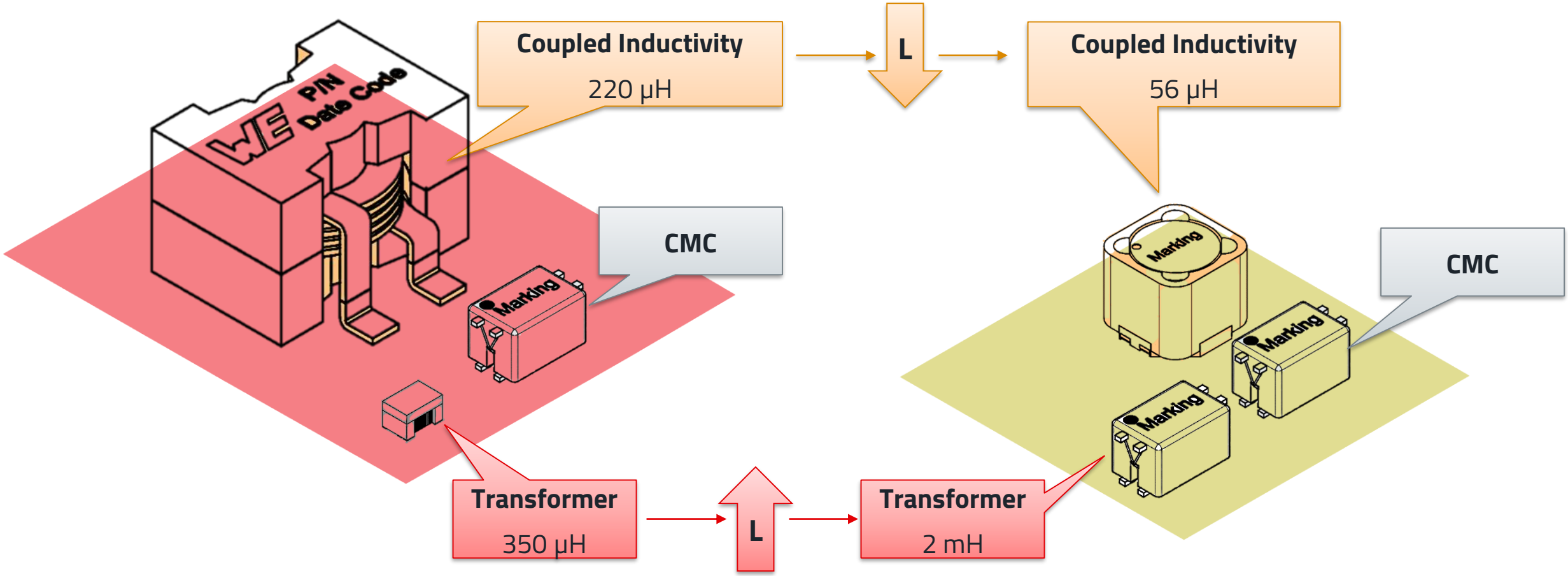
5.5 SPOE Power classes

Class	0	1	2	3	4	5	6	7	8	9
U	5,5…18V	5,5…18V	14…18V	14…18V	12…36V	12…36V	26…36V	26…36V	48…60V	48…60V
I	0,1A	0,22A	0,25A	0,47A	0,1A	0,34A	0,21A	0,46A	0,73A	1,3A
P	0,5W	1W	3W	5W	1W	3W	5W	10W	30W	50W

Class	10	11	12	13	14	15
U	20…30V	20…30V	20…30V	50…58V	50…58V	50…58V
I	0,092A	0,24A	0,632A	0,231A	0,6A	1,579A
P	1,32W	3,2W	8,4W	7,7W	20W	52W

5. FROM POE TO SPOE

5.6 Selection of components for high currents (1.6A)

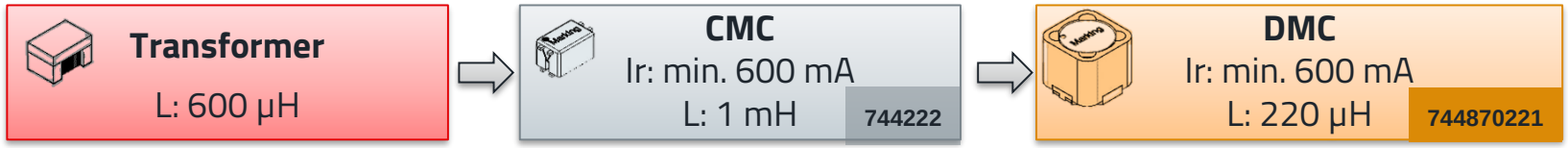


5. FROM POE TO SPOE

5.7 Design for power class 14

Selection of power class:

Class	14
U	50…58V
I	0,6A
P	20W

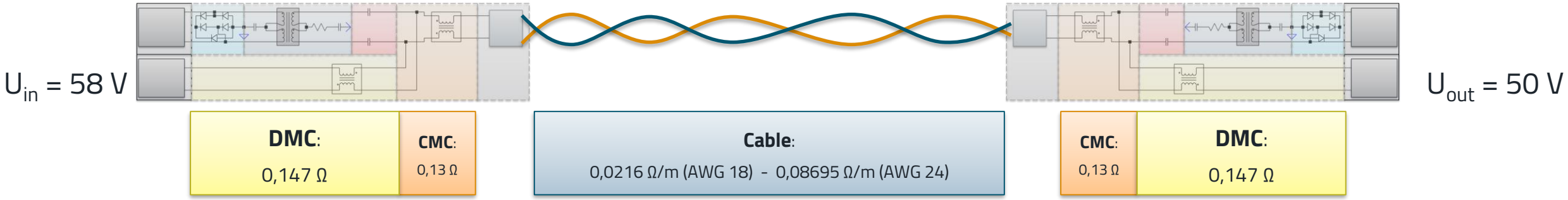


5. FROM POE TO SPOE

5.8 Cable length @ SPoE class 14

- Depending on
  - MDI components
  - Cable diameter
  - Power class (voltage and current)

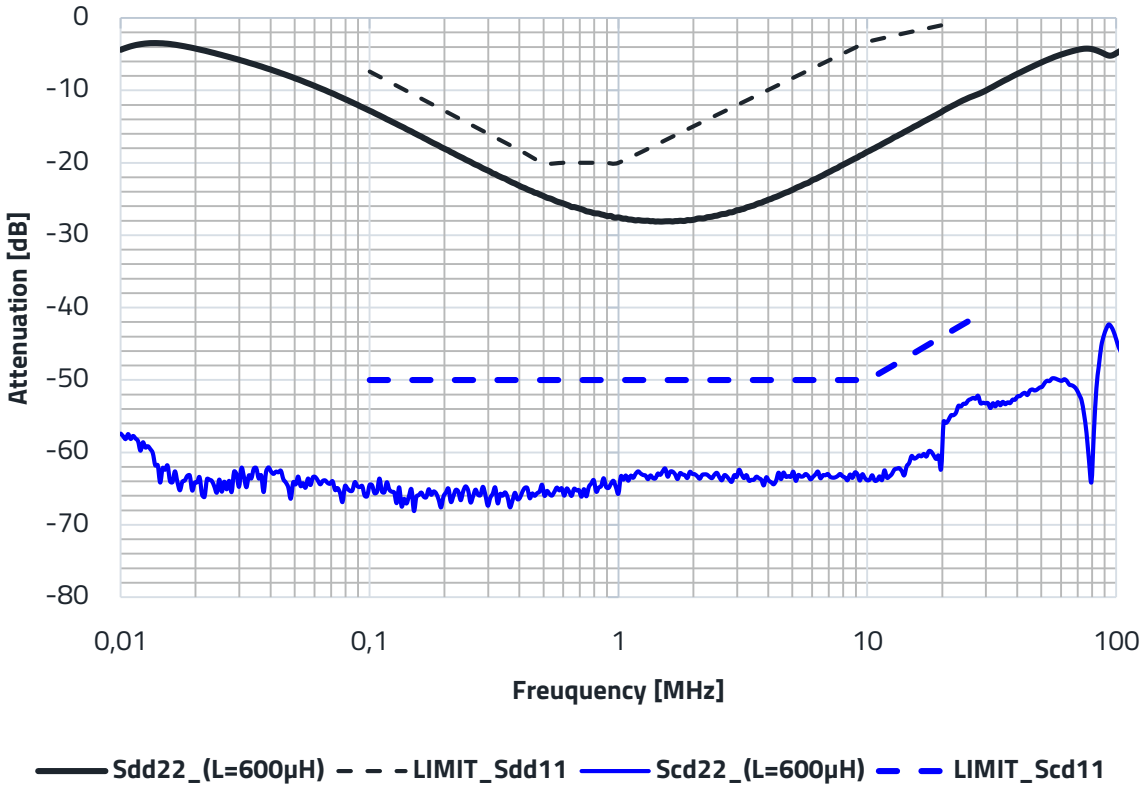
Cable type	Cable length [m]
AWG18	230
AWG19	183
AWG20	145
AWG21	115
AWG22	91
AWG23	72
AWG24	57



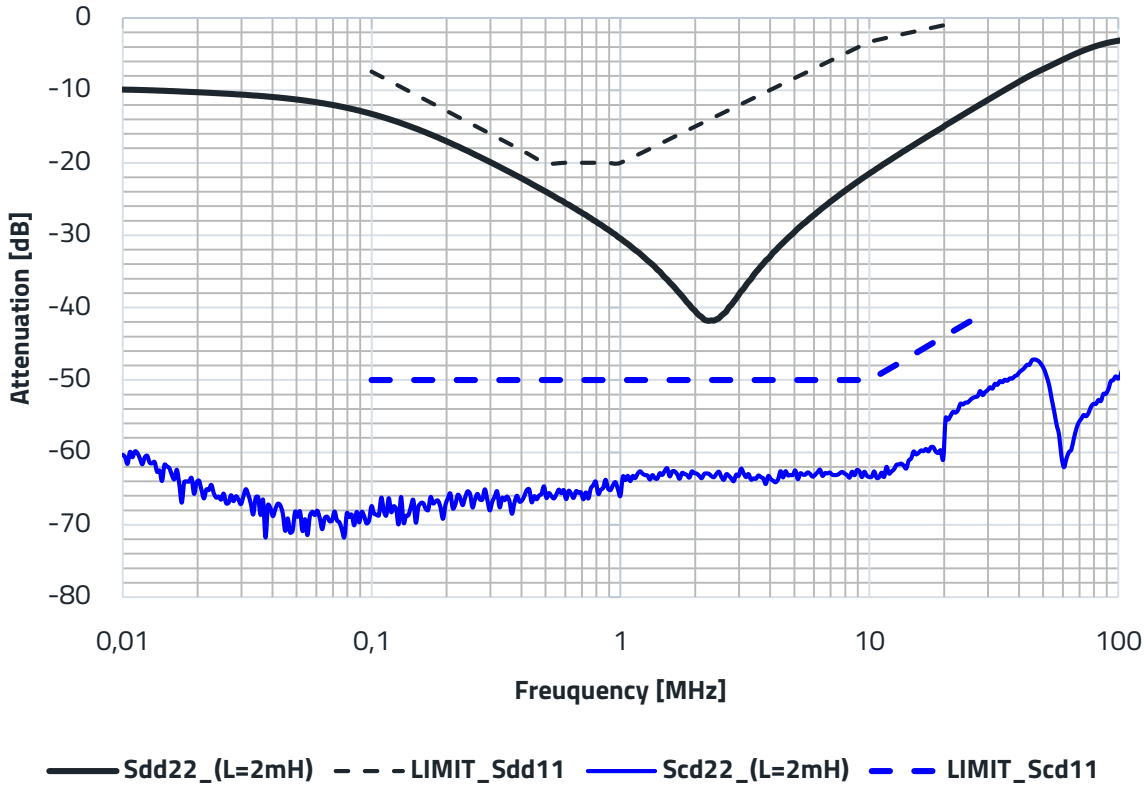
5. VON POE ZU SPOE

5.9 Design of Power Class 14 - Simulation Results

600 µH Transformer

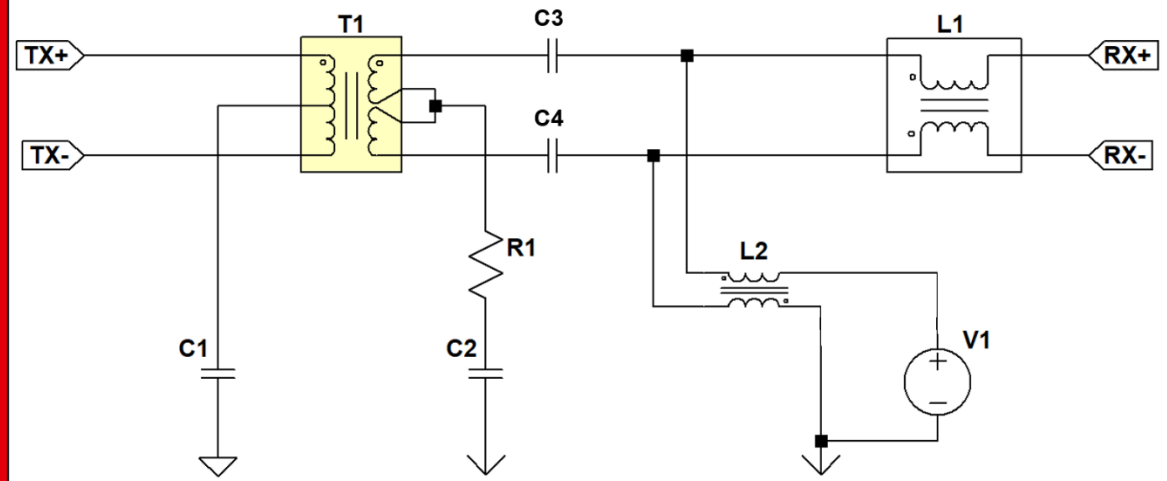


2000 µH Transformer



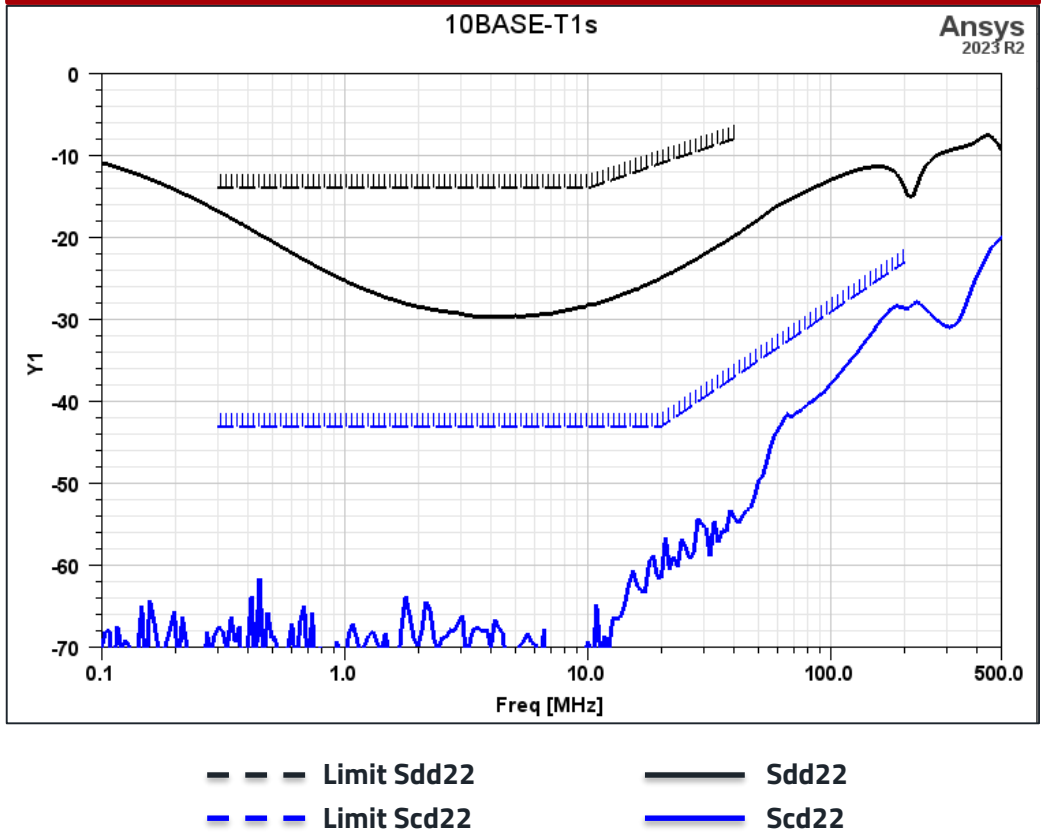
10BASE-T1S & PODL

Circuit



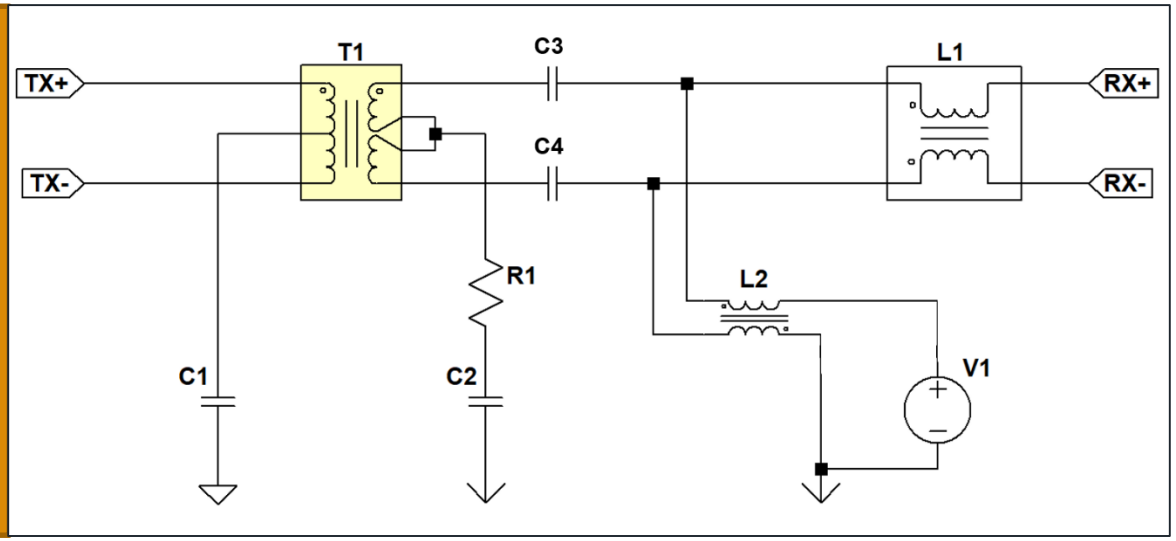
Name	Value	Isolation	Size	Current Rating	Article number
C1	100 nF	50 V	0402		885012205086
C2	1 nF	2 kV	1206		885342208024
C3, C4	100 nF	100 V	0603		885012206120
T1	350 µH	1500 V	1812		74930030
L1	10 µH	80 V	9.2 x 6 x 5 mm	1600 mA	744226
L2	47 µH	500 V (AC)	6 x 6 x 4mm	0.6 A (both) (0.9 A single)	7448844470
R1	100 Ω		0603		

Limits



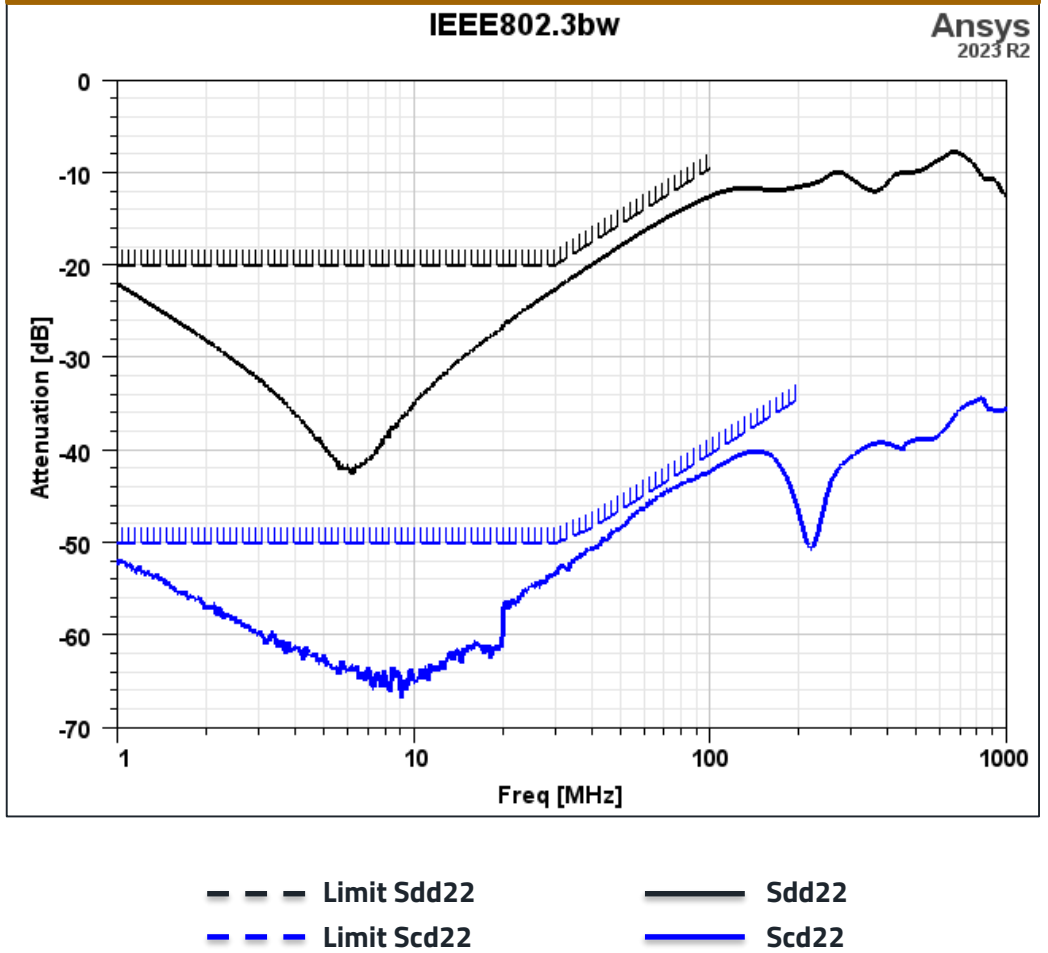
100BASE-T1 & PODL

Circuit



Name	Value	Isolation	Size	Current Rating	Article number
C1	100 nF	50 V	0402		885012205086
C2	1 nF	2 kV	1206		885342208024
C3, C4	100 nF	100 V	0603		885012206120
T1	350 µH	1500 V	1812		74930120
L1	10 µH	80 V	9.2 x 6 x 5 mm	1600 mA	744226
L2	47 µH	1500 V	5030	0.49 A (both) (0.7 A single)	7448841470
R1	100 Ω		0603		

Limits



5. FROM POE TO SPOE

SPoE Controller

PSE Controller

- Company: Analog Devices
- Name: LTC4296-1
- **5 Port** Controller
- Supported Voltage: **6 V- 60 V**
- Supported power classes: 10 -15 (**1,3 W – 52 W**)
- Eval - Kit available

PD Controller

- Company : Analog Devices
- Name: LTC9111
- PD Controller
- Supported Voltage: **2,3 V- 60 V**
- Supported power classes: 10 -15 (**1,3 W – 52 W**)
- Eval - Kit available

Questions

& Answers

We are here for you now!
Ask us directly via our chat or via E-Mail.

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