

DIGITAL WE DAYS

2024



10 MBIT SINGLE PAIR ETHERNET OVER  
SHORT RANGE – MDI & PODL DESIGN

Simon Mark

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

# AGENDA

1. From Ethernet to SPE
2. Technical data
3. From automotive to industrial
4. 10BASE-T1s – in detail

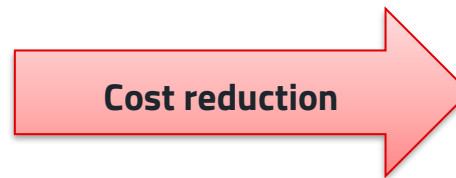
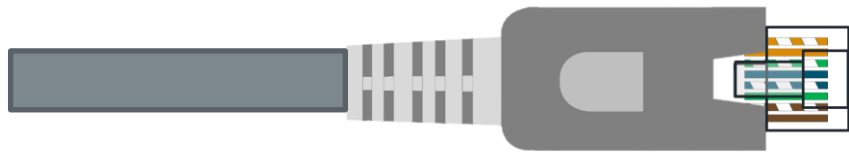


# 1. FROM ETHERNET TO SPE

## Multi Pair Ethernet

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

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



## Automotive Ethernet

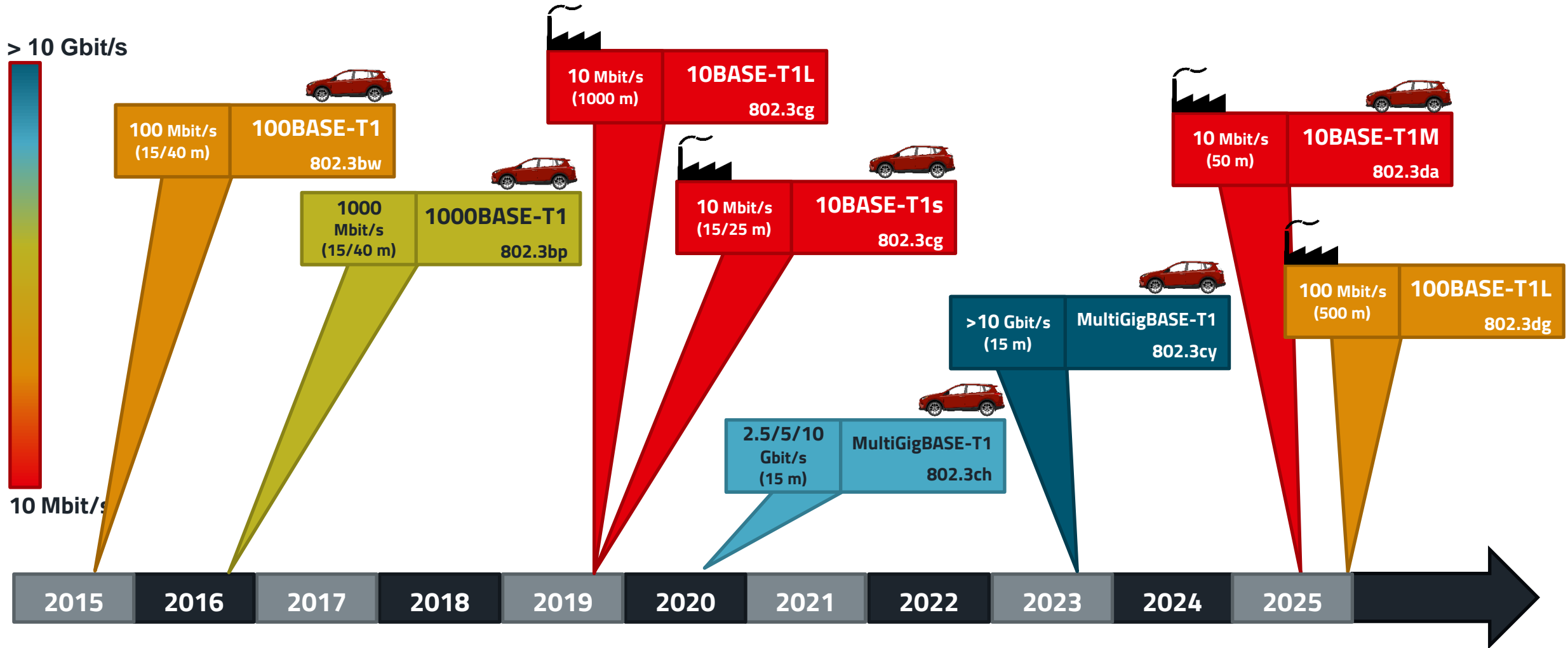
1- Pair: 100BASE-T1 (*IEEE 802.3bw*)

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



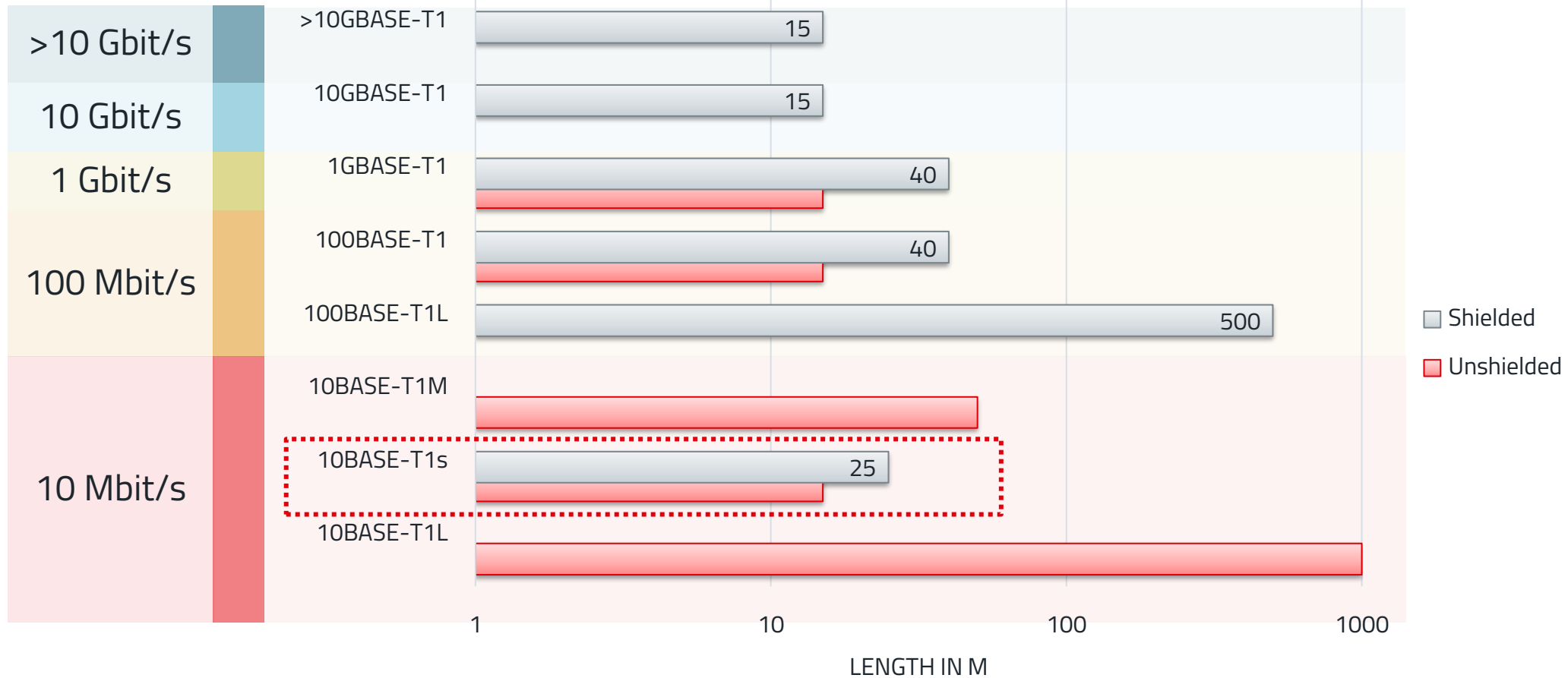
# 1. FROM ETHERNET TO SPE

## 1.1 Single Pair Ethernet History



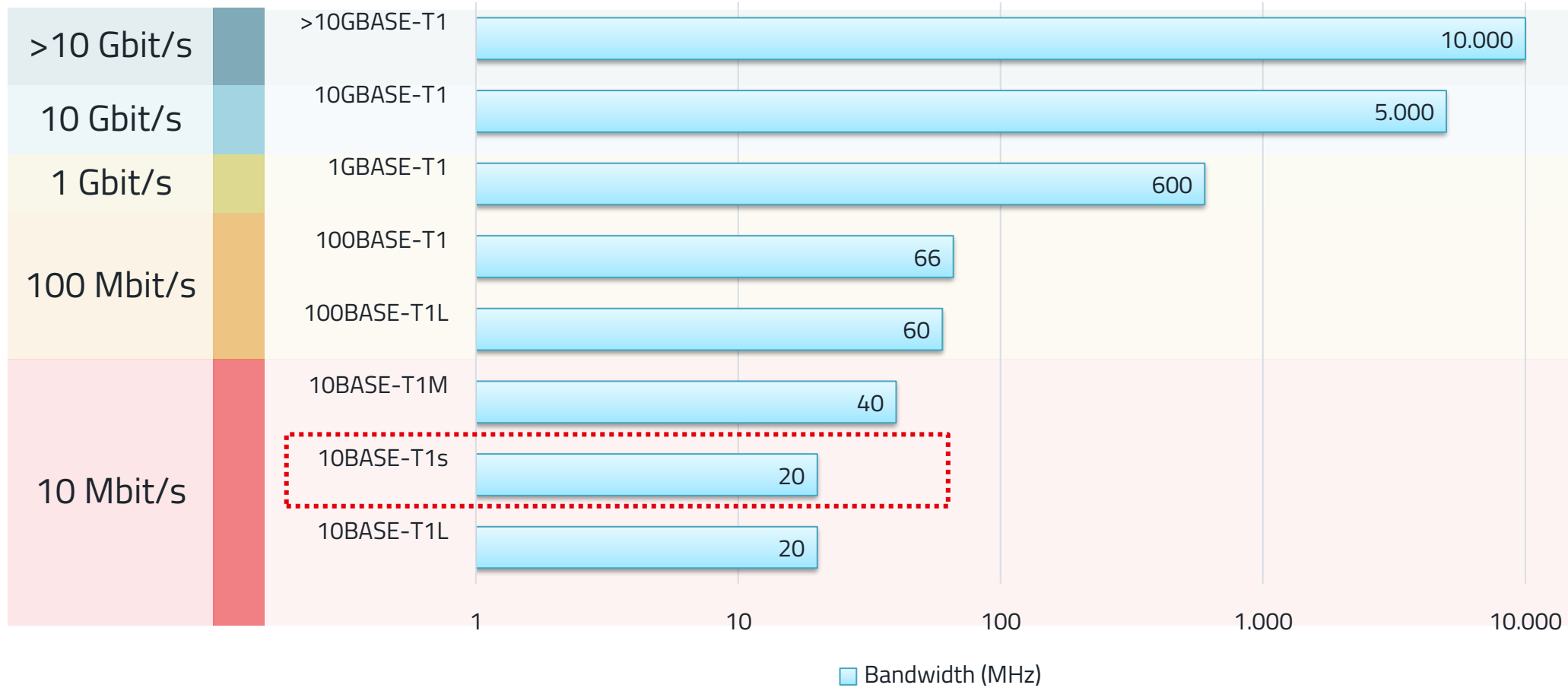
## 2. SPE – TECHNICAL DATA

### 2.1 Wiring length



## 2. SPE – TECHNICAL DATA

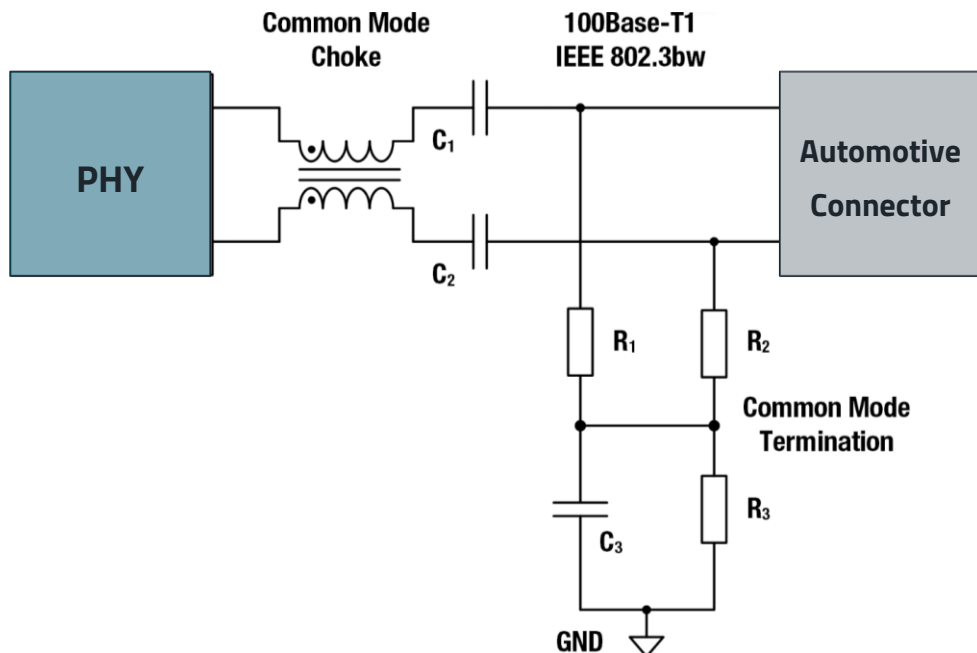
### 2.2 Bandwidth



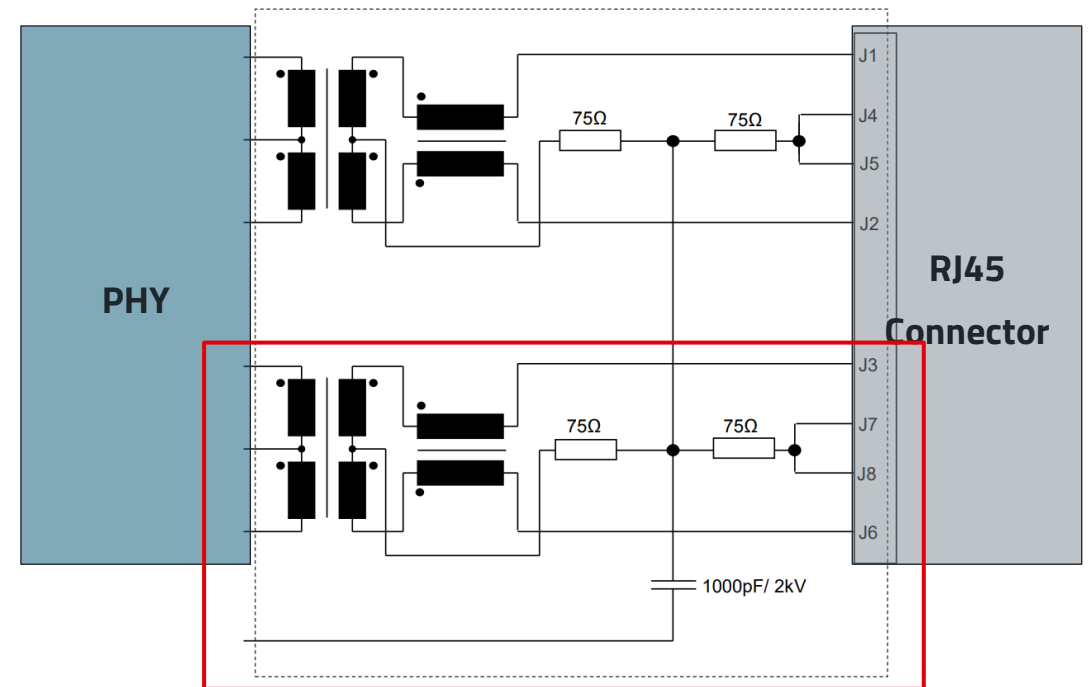
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.1 MDI circuits in comparison

### Automotive 10/100/1000BASE-T1



### Industrial Multi Pair Ethernet 100BASE-TX



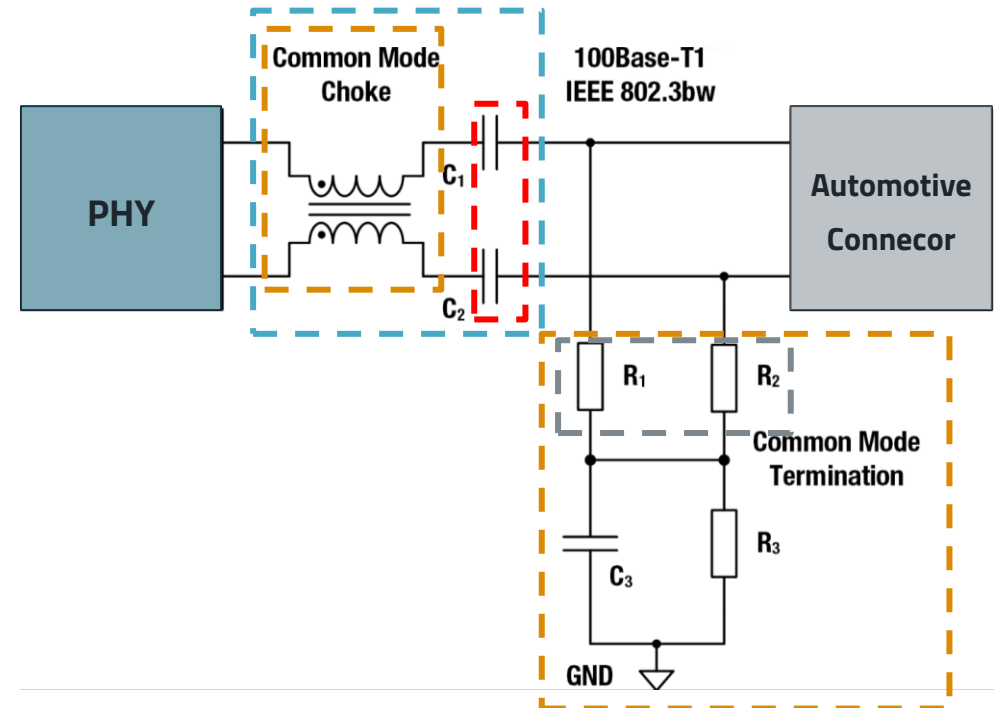
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.2 Design requirements - Automotive

### Automotive Requirements

<b>Isolation</b>	<b>60 V</b>
<b>CM Attenuation</b>	✓
<b>Return Loss</b>	✓
<b>Mode Conversion</b>	✓
<b>Cheap &amp; small</b>	✓

### Circuit





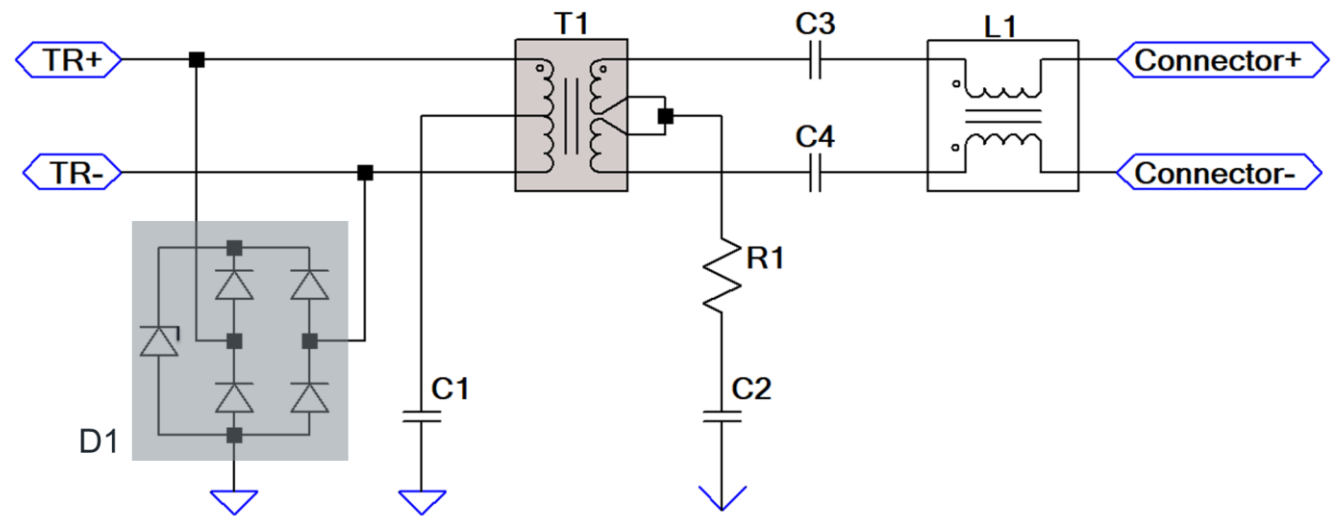
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

Isolation
Isolation DC
CM Attenuation
Return Loss
Mode Conversion
ESD Protection

### Circuit



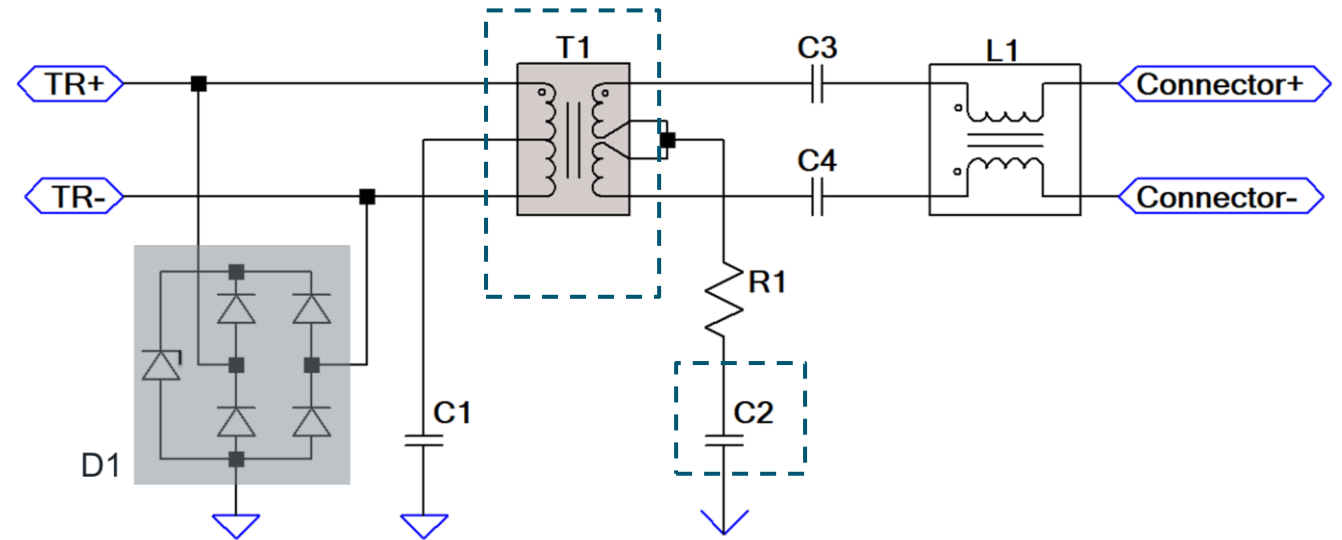
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

<b>Isolation</b>	<b>1500 V</b>
Isolation DC	
CM Dämpfung	
Return Loss	
Moden Umwandlung	
ESD Schutz	

### Circuit



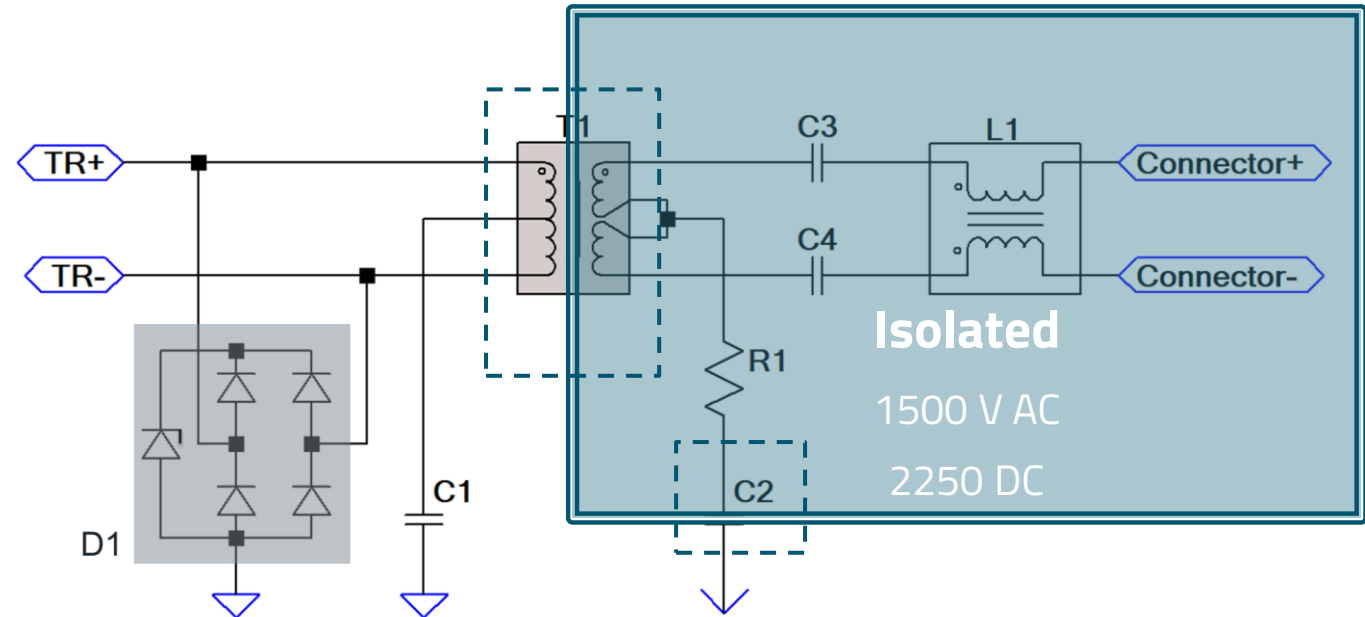
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

<b>Isolation</b>	<b>1500 V</b>
Isolation DC	
CM Attenuation	
Return Loss	
Mode Conversion	
ESD Protection	

### Circuit



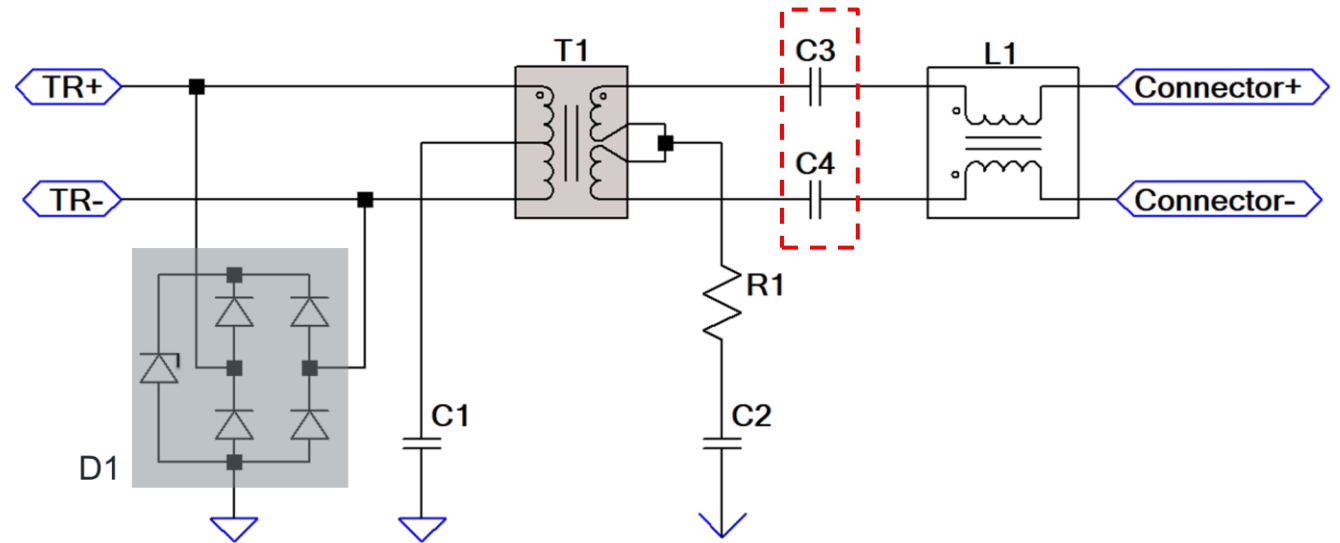
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

Isolation	1500 V
<b>Isolation DC</b>	<b>60 V</b>
CM Attenuation	
Return Loss	
Mode Conversion	
ESD Protection	

### Circuit



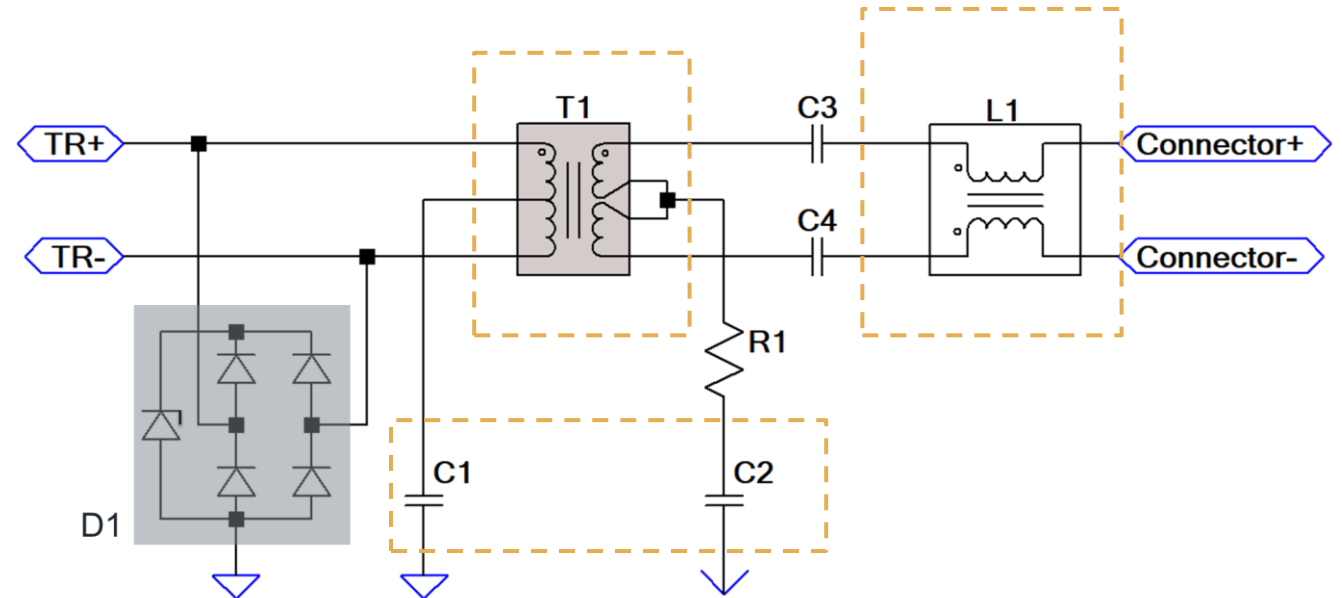
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

Isolation	1500 V
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<b>CM Attenuation</b>	✓
Return Loss	
Mode Conversion	
ESD Protection	

### Circuit



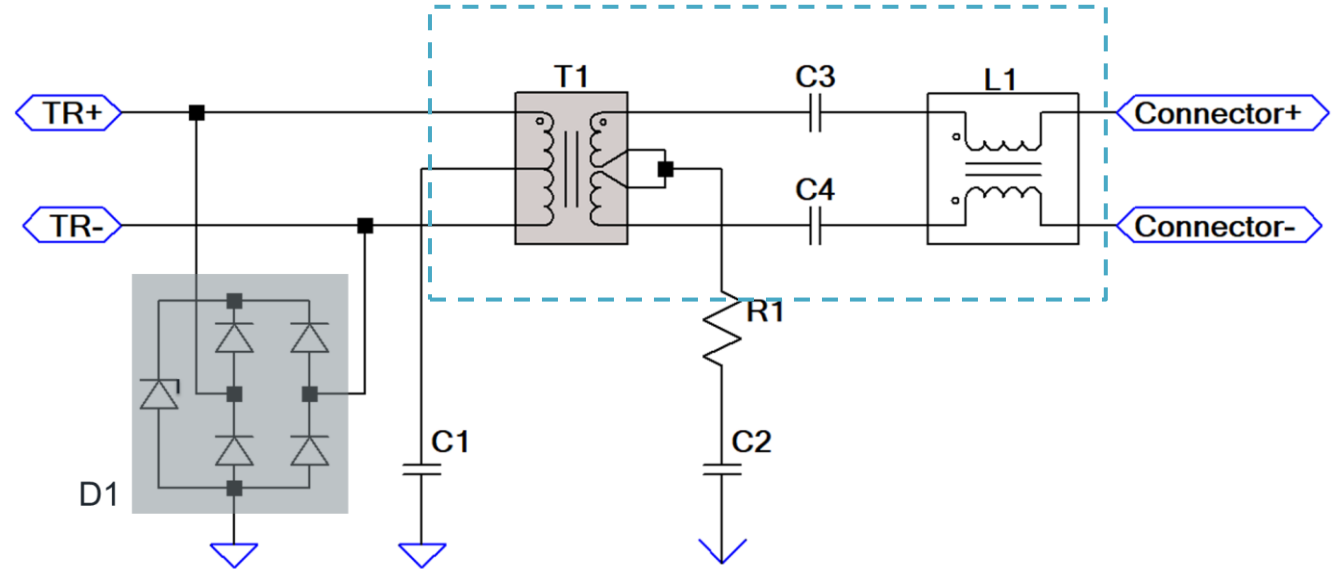
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

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CM Attenuation	✓
Return Loss	✓
Mode Conversion	
ESD Protection	

### Circuit



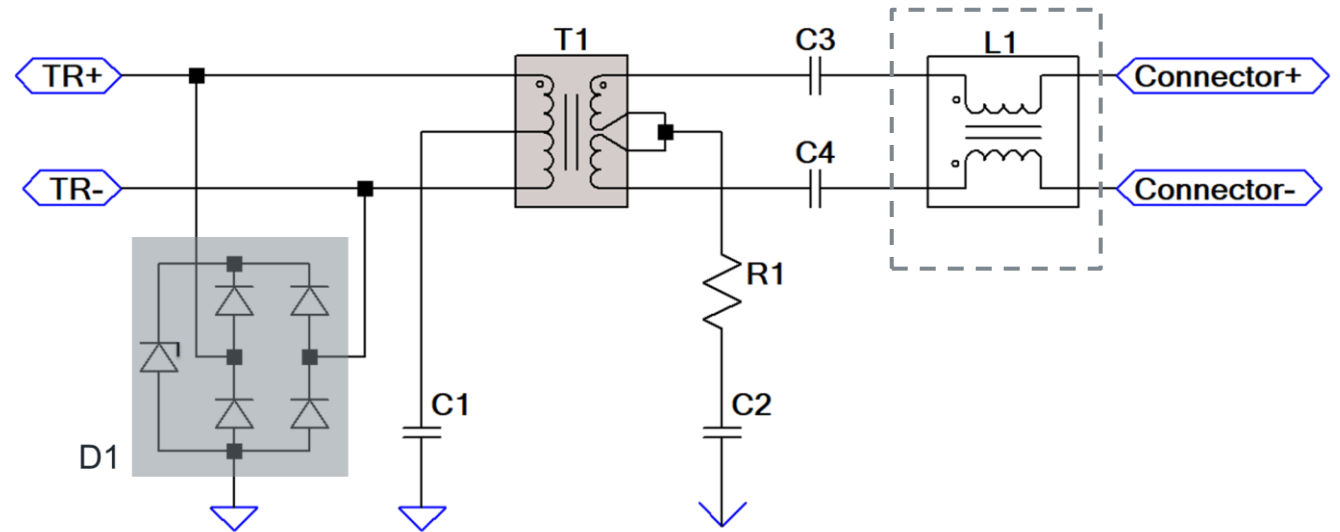
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

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

### Circuit



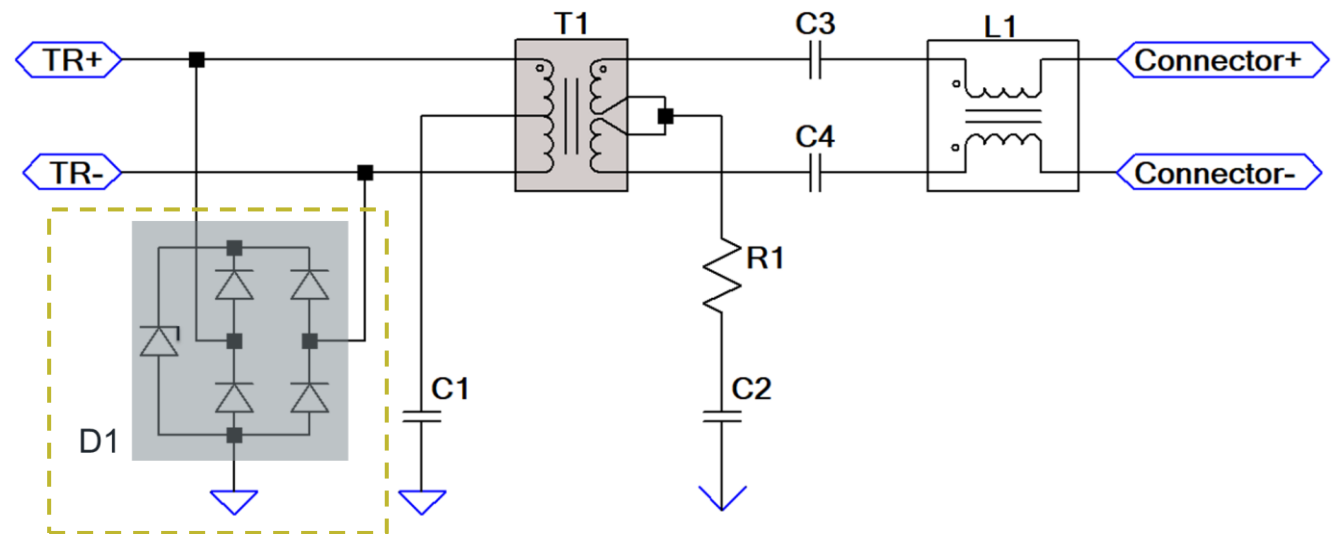
# 3. FROM AUTOMOTIVE TO INDUSTRIAL

## 3.3 Design requirements - Industry

### Industry Requirements

Isolation	1500 V
Isolation DC	60 V
CM Dämpfung	✓
Return Loss	✓
Mode Conversion	✓
<b>ESD Protection</b>	✓

### Circuit





## 4. 10BASE-T1S IN DETAIL

10BASE-T1<sub>s</sub> and 10BASE-T1<sub>L</sub> - Summary and comparison

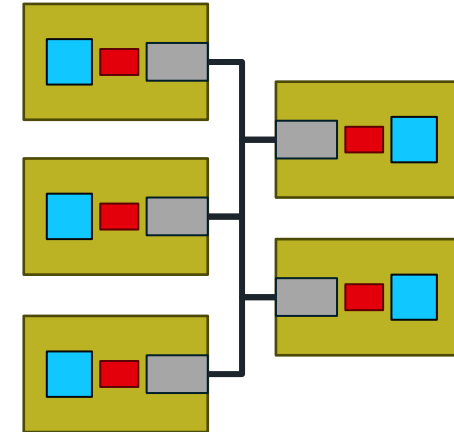
### 10BASE-T1<sub>L</sub>

- Data transmission: Full duplex
- System: Point to point
- Number of nodes: 2
- Length: up to over 1000 m



### 10BASE-T1<sub>s</sub>

- Data transmission : **Half duplex**
- System: Bus
- Number of nodes : 8-40
- Length : up to. 25 m



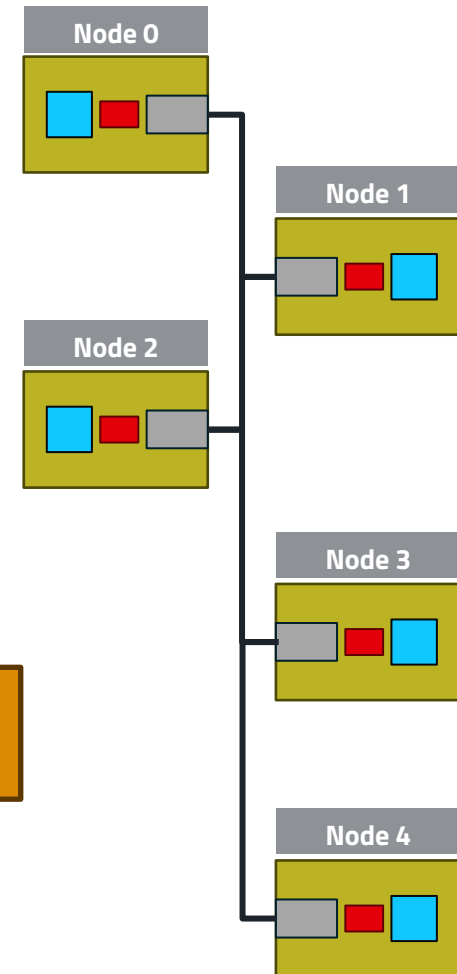
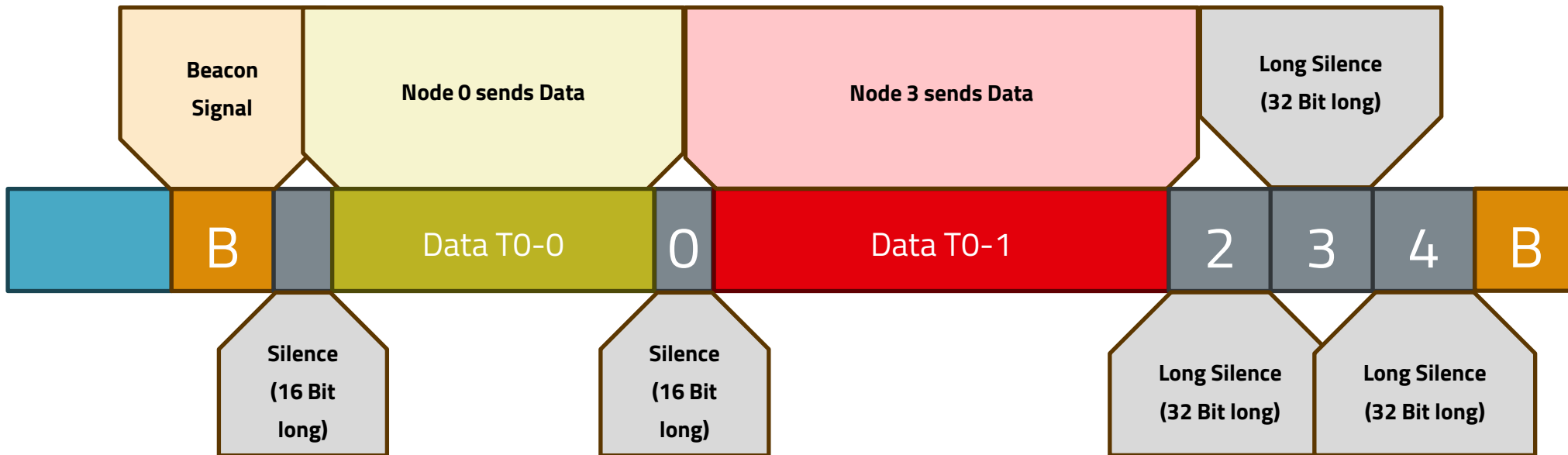
- Data transmission : **Half duplex / Full duplex**
- System: Point to Point
- Number of nodes : 2
- Length: 15 m



## 4. 10BASE-T1S IN DETAIL

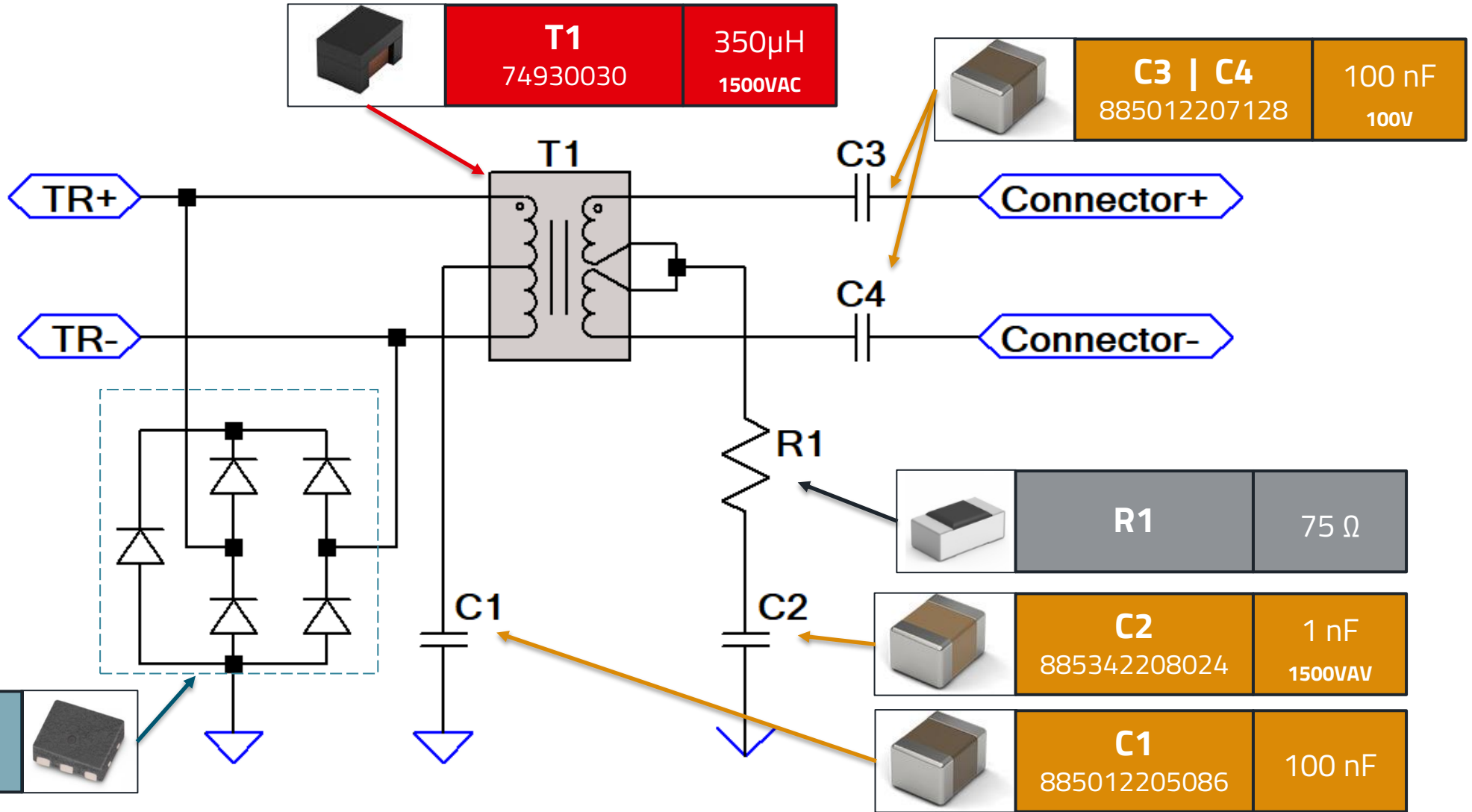
How it Works – PLCA (Physical Layer Collision Avoidance)

- Every Node has a specific Number
- Every Node has a specific Time so send Data
- In the Time a node is sending Data, all other Nodes are high impendant at the PHY



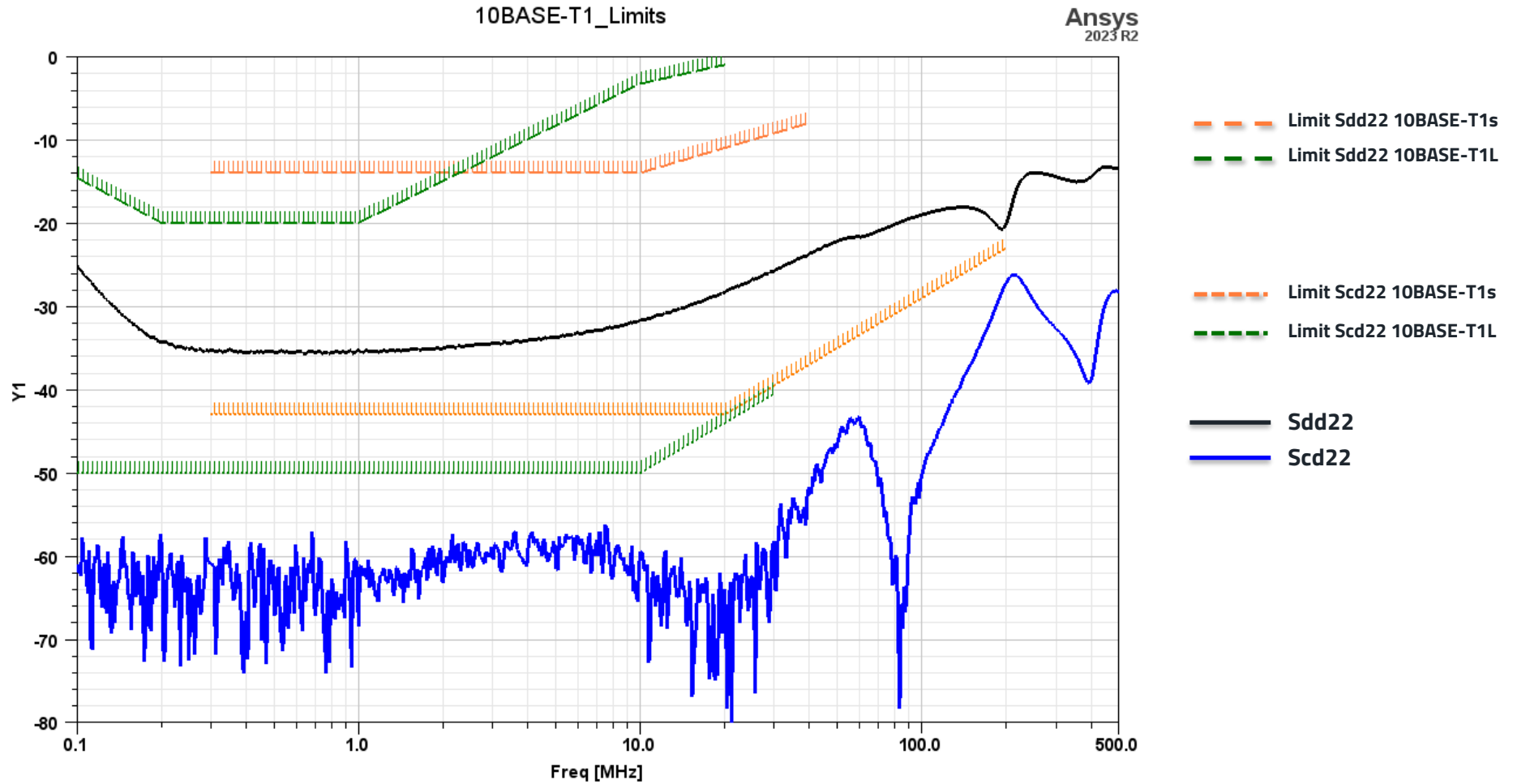
# 4. 10BASE-T1S IN DETAIL

## Circuit Design



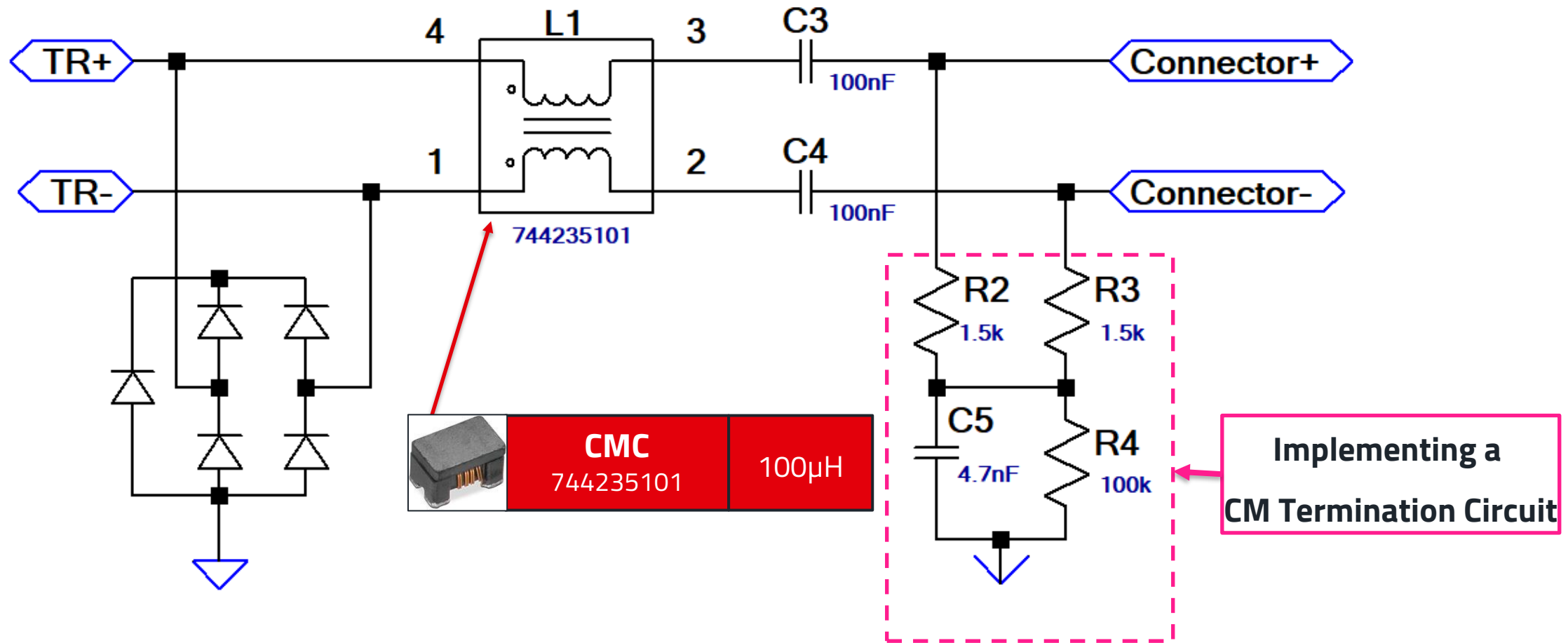
# 4. 10BASE-T1S IN DETAIL

Limits according IEEE 802.3cg



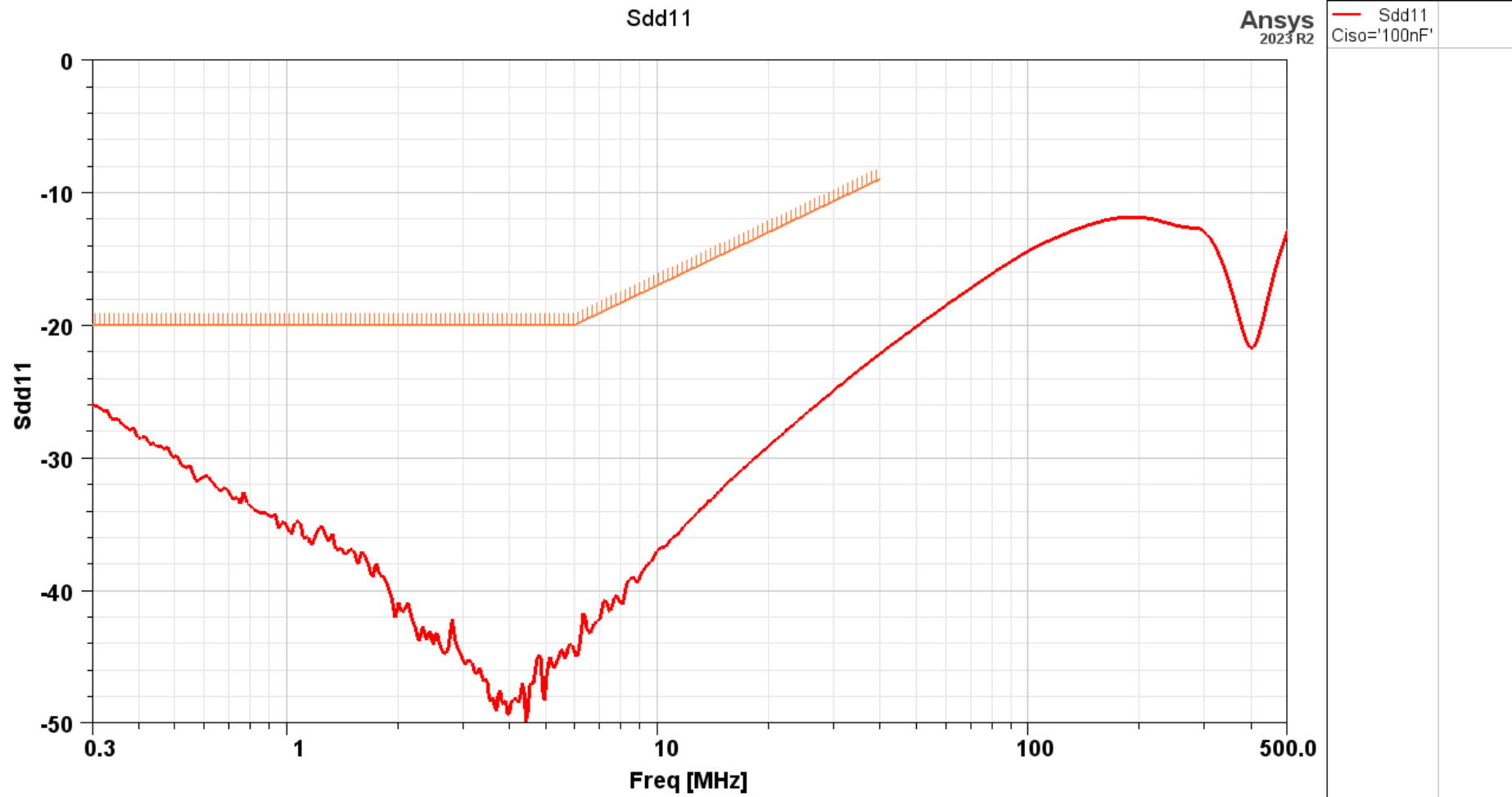
## 4. 10BASE-T1S IN DETAIL

Circuit Design with CMC to archive OPEN Alliance limits



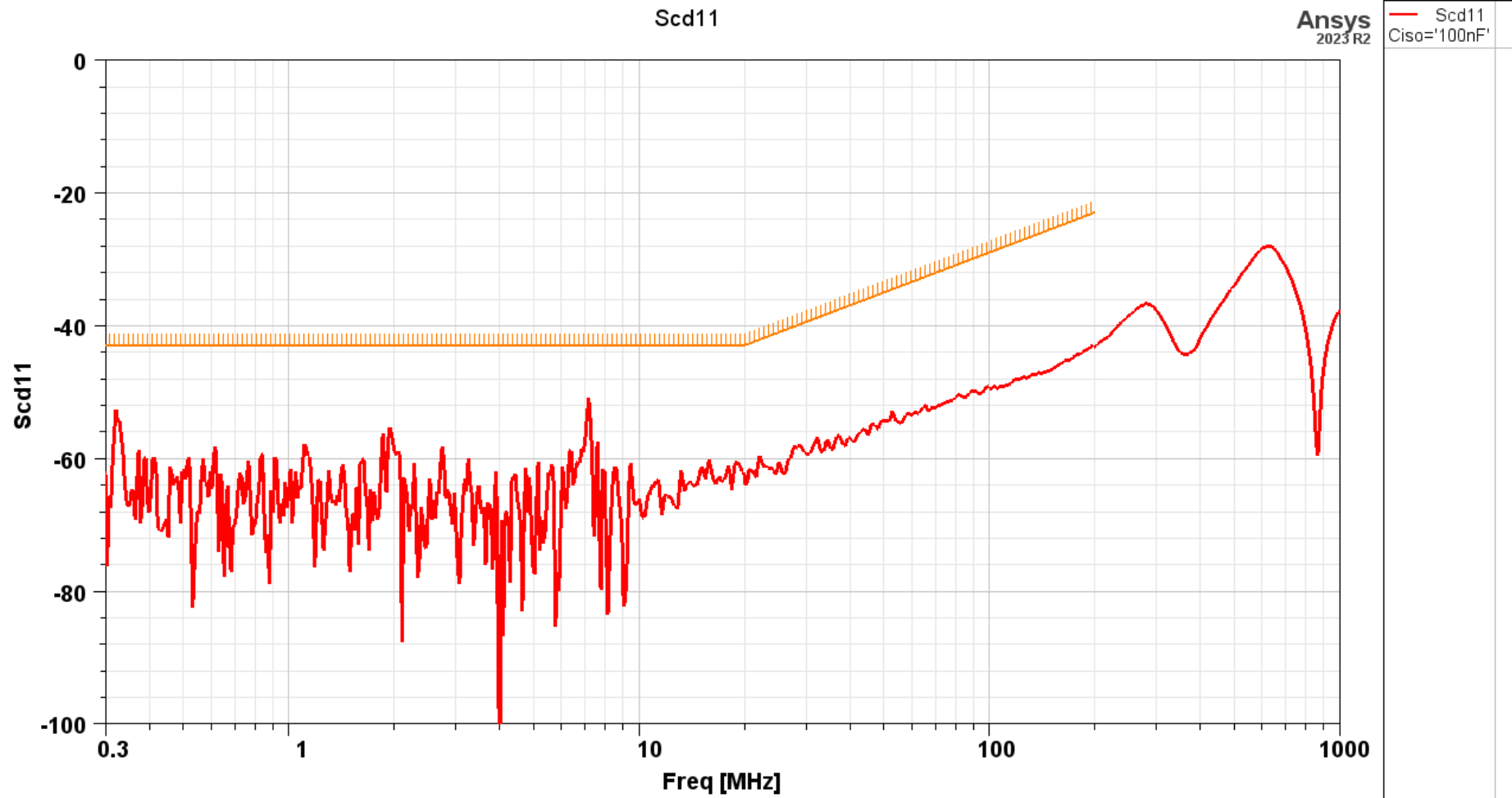
# 4. 10BASE-T1S IN DETAIL

## Return Loss



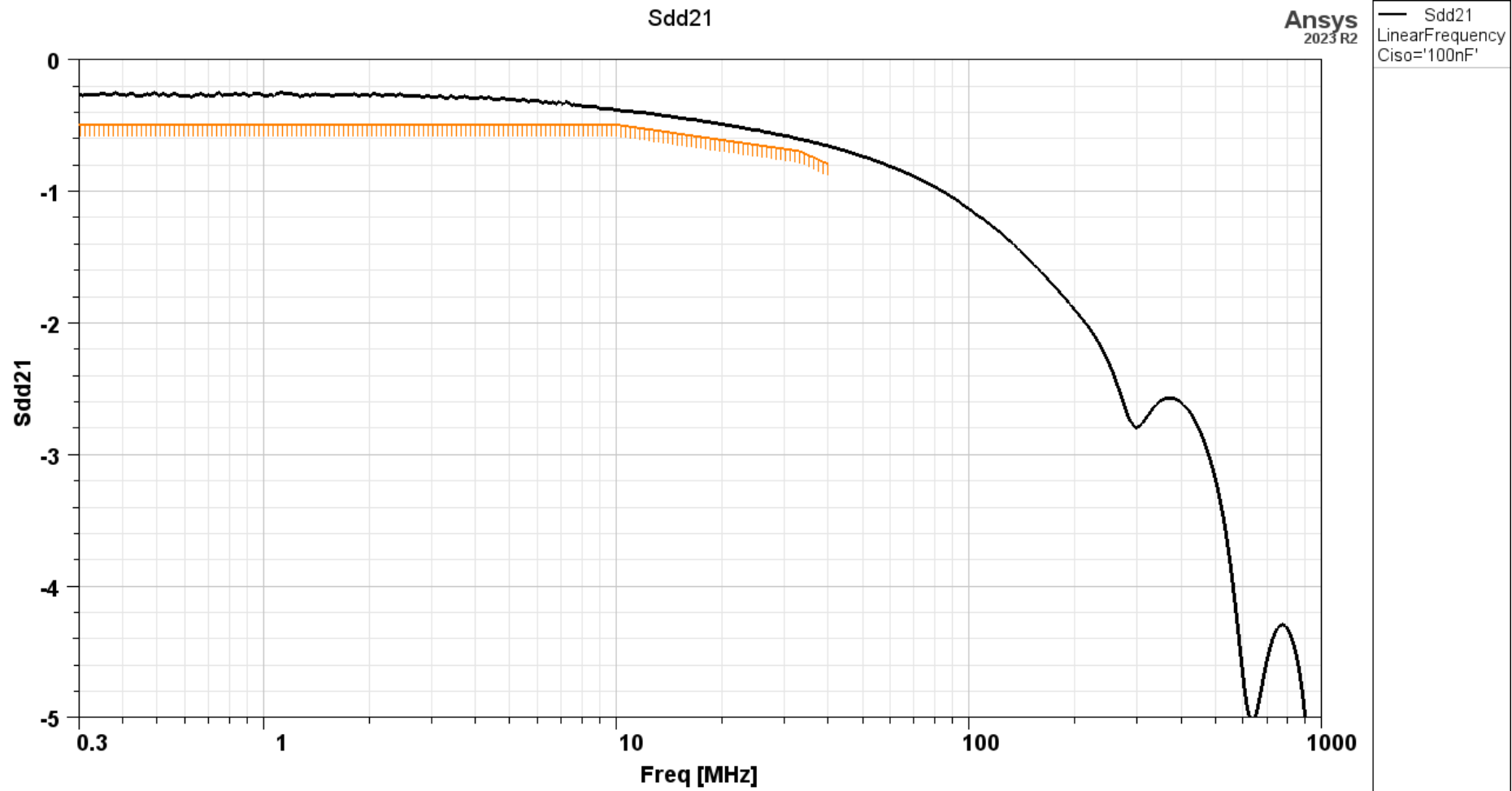
## 4. 10BASE-T1S IN DETAIL

### Return Loss



# 4. 10BASE-T1S IN DETAIL

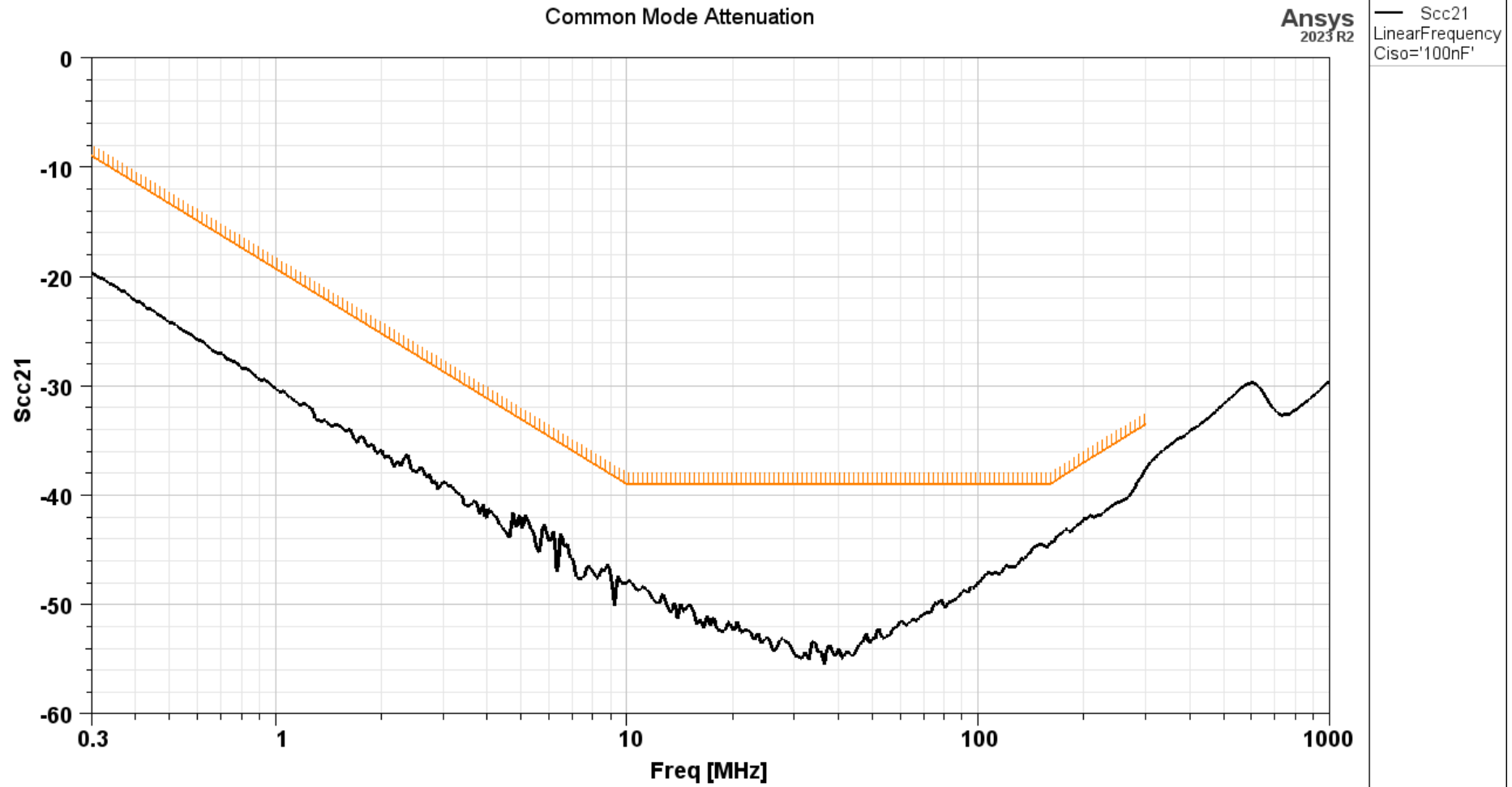
## Return Loss





# 4. 10BASE-T1S IN DETAIL

## Return Loss



## 4. 10BASE-T1S IN DETAIL

### Droop

#### Clause 146.5.4.2 (10BASE-T1L)

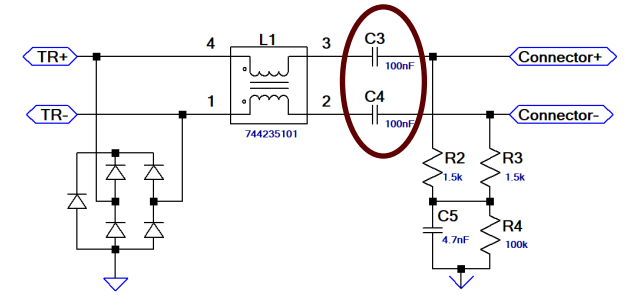
- While in test mode 2, the positive and negative droop of the transmitter should measure **below 10%**.
- This measurement is referenced to an **initial value** taken at **133.3 ns after the zero crossing** and a final value measured at **800 ns** after the zero crossing.

#### Clause 147.5.4.2 (10BASE-T1s)

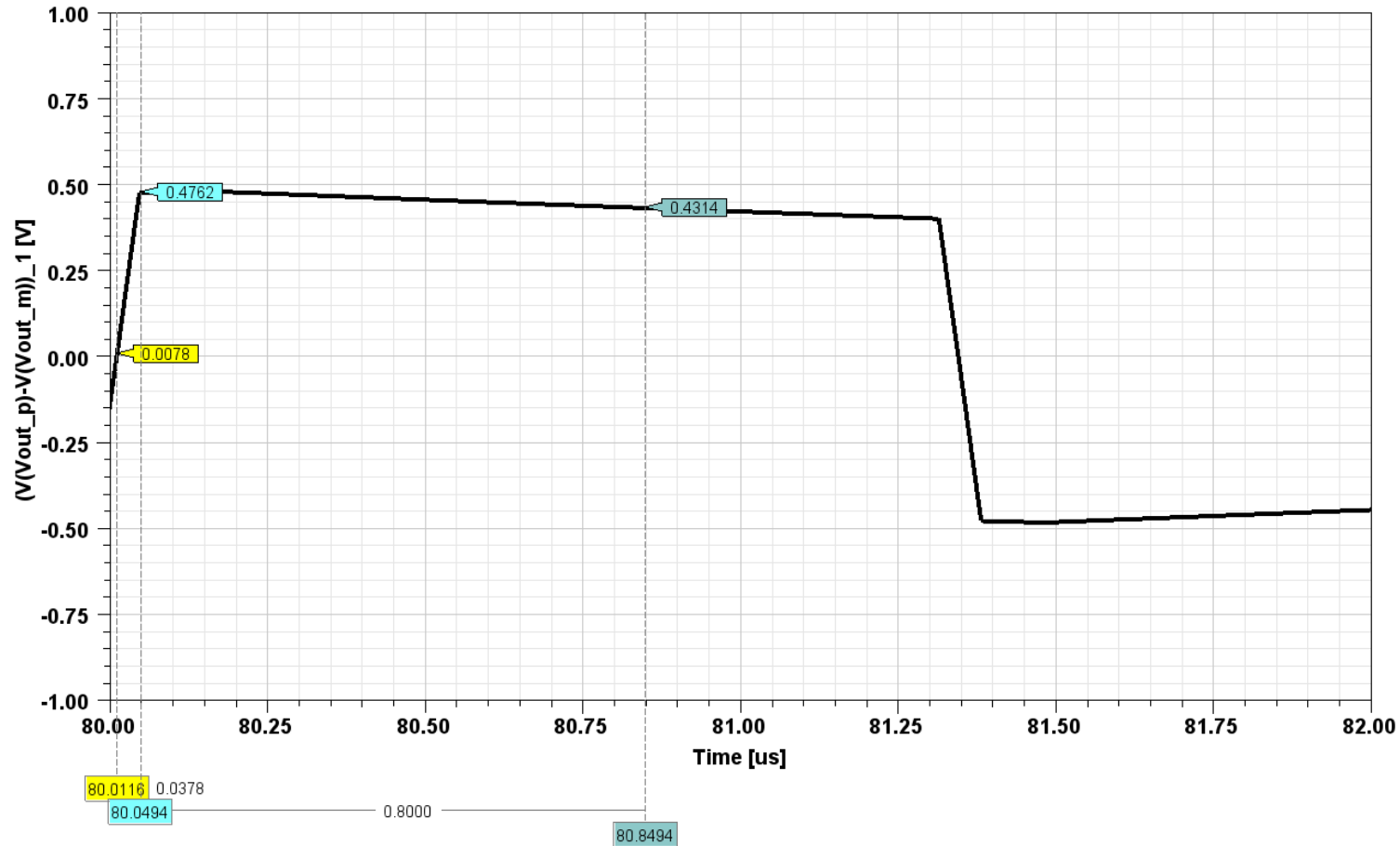
- While in test mode 2, the positive and negative droop of the transmitter should measure **below 30%**.
- This measurement is referenced to an **initial peak value** taken **after the zero crossing** and the value **800 ns** after the initial peak value.

# 4. 10BASE-T1S IN DETAIL

Drooptest with different capacitors



Droop 10BASE-T1s



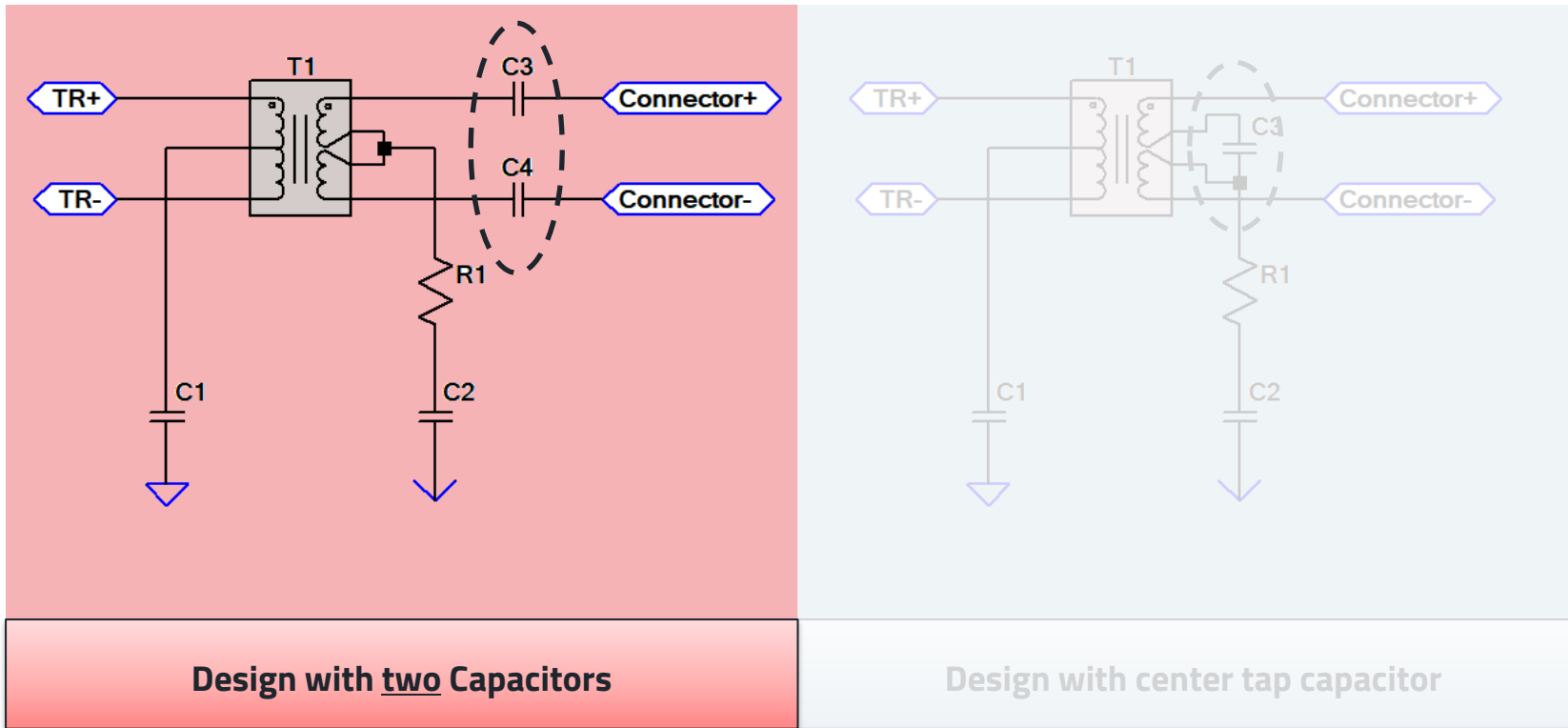
**@ 100nF: Droop = 13 %**  
**@ 220nF: Droop = 9,4 %**  
**@ 470nF: Droop = 7,8 %**

**10BASE-T1s**  
**Capacitor:**  
100 nF  
220 nF  
470 nF

**10BASE-T1L**  
**Capacitor:**  
470 nF

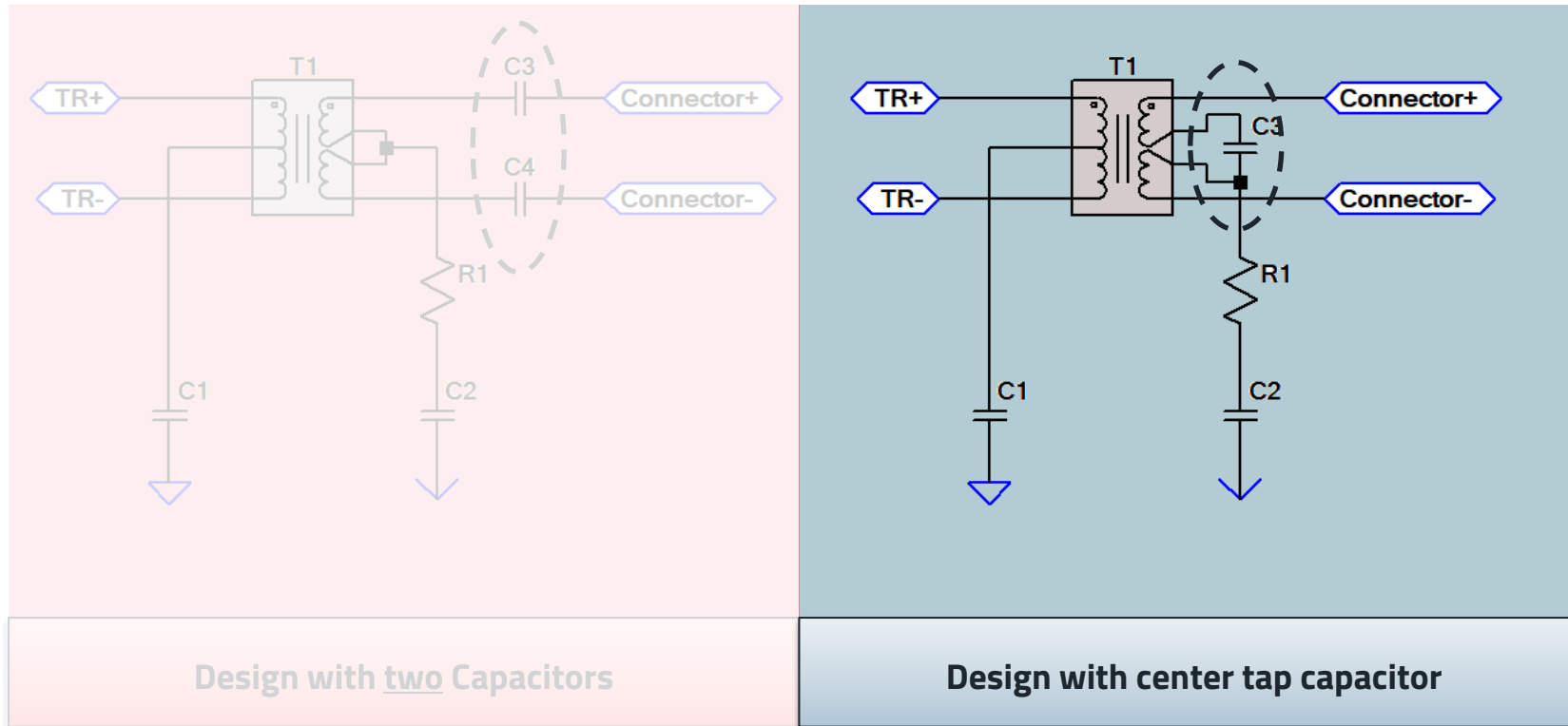
## 4. 10BASE-T1S IN DETAIL

SPE Circuit – DC isolation capacitor



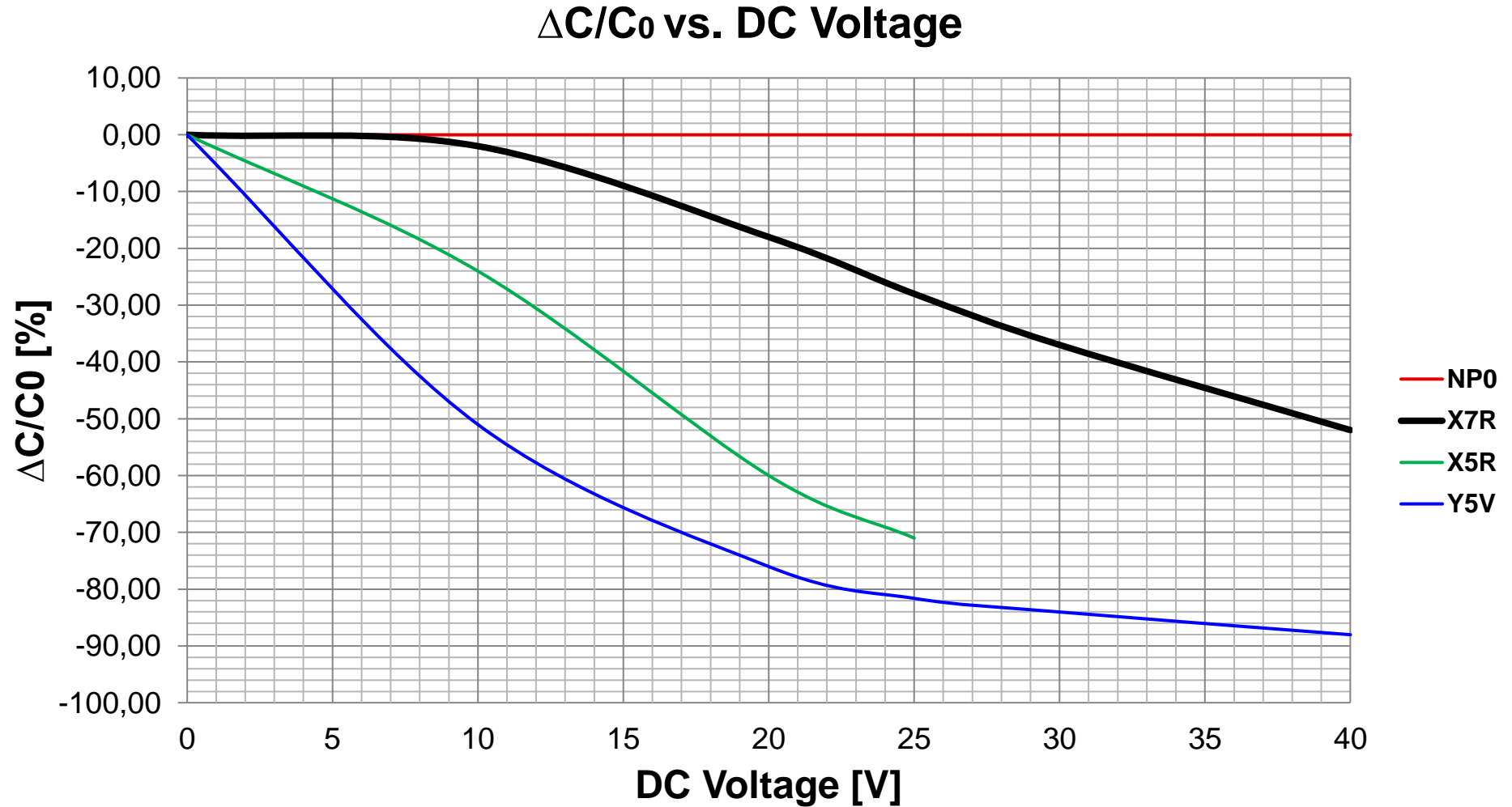
## 4. 10BASE-T1S IN DETAIL

SPE Circuit – DC isolation capacitor



## 4. 10BASE-T1S IN DETAIL

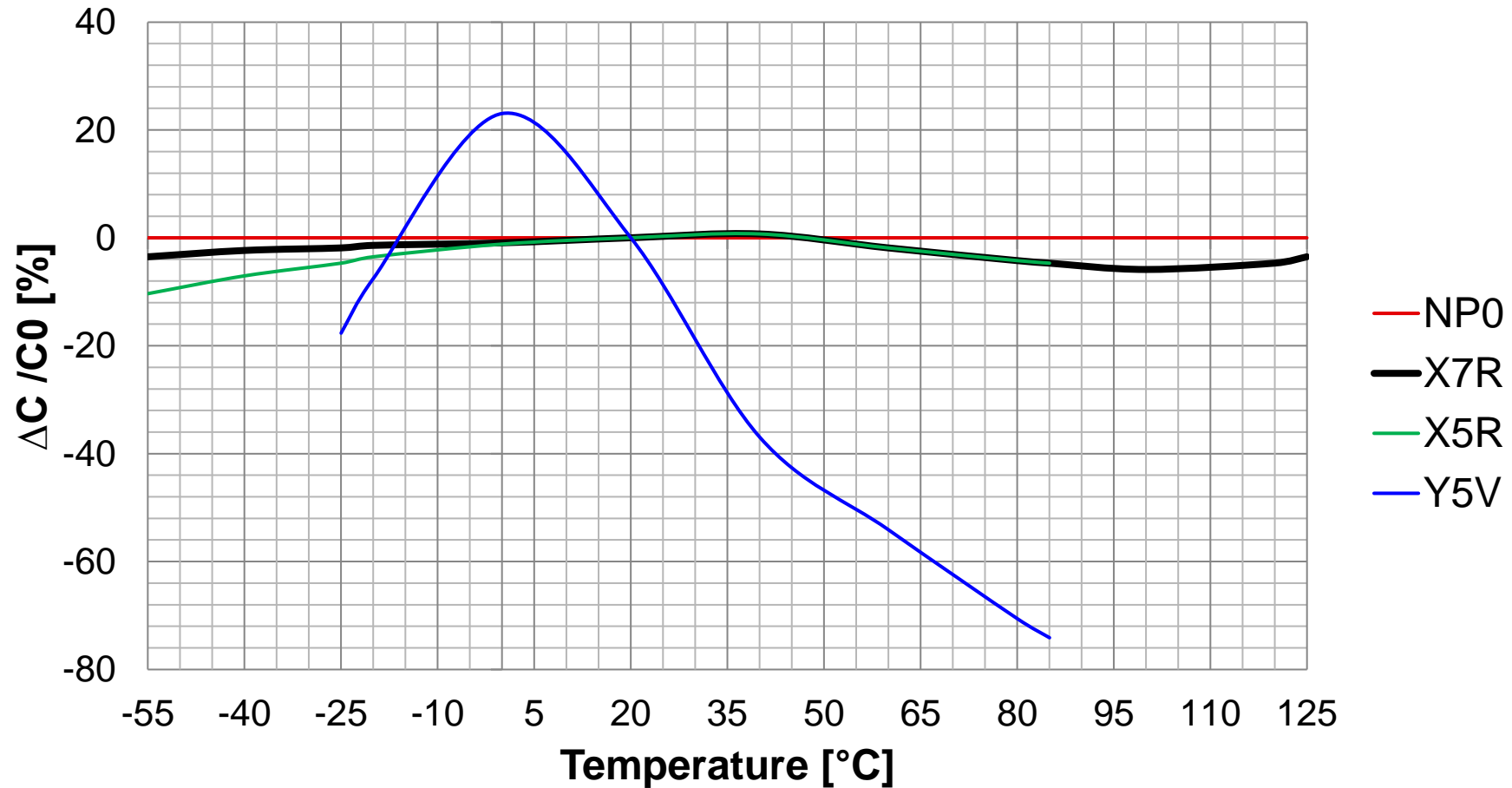
DC Isolation Capacitors – Saturation



## 4. 10BASE-T1S IN DETAIL

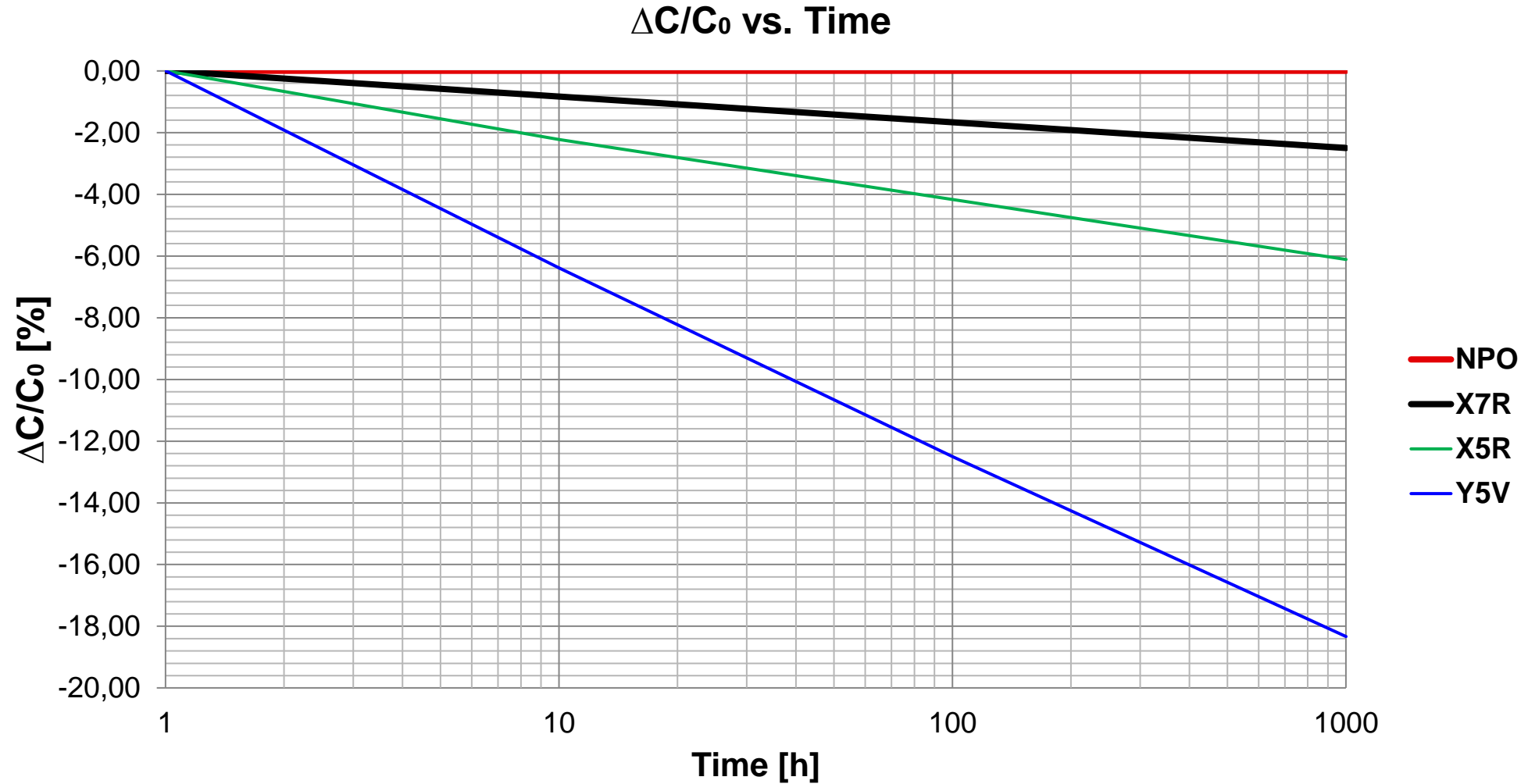
DC Isolation Capacitors – Temperature behaviour

### $\Delta C/C_0$ vs. Temperature



## 4. 10BASE-T1S IN DETAIL

DC Isolation Capacitors – Aging





## 4. 10BASE-T1S IN DETAIL

### DC Isolation Capacitor – Calculation Example

- Capacitor for 10BASE-T1L (885012207130 | 885012207128):
  - C: **470 nF** ±10% | **100 nF** ±10%
  - Nennspannung: 100 V | 100 V
  - Typ: X7R | X7R
- DC Saturation: 58 V both → 24 V per Capacitor
  - C<sub>470nF</sub>** → **-38 %**
  - C<sub>100nF</sub>** → **-5 %**
- Environment Temperature ca. **65 °C**
  - C<sub>470nF</sub>** → **-1.84 %**
  - C<sub>100nF</sub>** → **-3.8 %**
- Aging after 1000 h → **-2 %**
  - C<sub>470nF</sub>** → **-2 %**
  - C<sub>100nF</sub>** → **-2 %**

470 nF (100 V)

100 nF (100 V)

291 nF

95 nF

286 nF

92 nF

280 nF

89 nF

**Droop = 9.34 %**

**Droop = 17 %**

# 4. 10BASE-T1S IN DETAIL

## DC Isolation Capacitor – Redexpert Tool

**WÜRTH ELEKTRONIK** **REDEXPERT** Multilayer Ceramic Chip Capacitors (MLCCs) 100 / 1221 items

Order Code	Spec	Series	Description	Size	Ce...	C	Tole...	V <sub>R</sub>	R <sub>iso</sub>	DF	Q	T <sub>min</sub>	T <sub>max</sub>	TCC	Length	Width	Height	Technic
885012207128		WCAP-CSGP	General Purpose	0805	X7R	100 nF	±10 %	100 V	> 1.00 GΩ	2.5 %		-55.0°C	125°C	±15%	2.00 mm	1.25 mm	1.25 mm	X7R080
885012207130		WCAP-CSGP	General Purpose	0805	X7R	470 nF	±10 %	100 V	> 200 MΩ	10 %		-55.0°C	125°C	±15%	2.00 mm	1.25 mm	1.25 mm	X7R080
885012208001		WCAP-CSGP	General Purpose	1206	X7R	2.20 μF	±10 %	6.30 V	> 50.0 MΩ	10 %		-55.0°C	125°C	±15%	3.20 mm	1.60 mm	1.15 mm	X7R120
885012208002		WCAP-CSGP	General Purpose	1206	X7R	4.70 μF	±10 %	6.30 V	> 20.0 MΩ	10 %		-55.0°C	125°C	±15%	3.20 mm	1.60 mm	1.60 mm	X7R120
885012208003		WCAP-CSGP	General Purpose	1206	X7R	10.0 μF	±10 %	6.30 V	> 5.00 MΩ	10 %		-55.0°C	125°C	±15%	3.20 mm	1.60 mm	1.60 mm	X7R120

885012207128 × WCAP-CSGP · X7R · 0805 100 nF · 100 V

885012207130 × WCAP-CSGP · X7R · 0805 470 nF · 100 V

Click and type or drop an Order Code here

ADD MORE

Show Panel: Z vs. F ESR vs. F ΔC vs. V<sub>DC-Bias</sub> C vs. V<sub>DC-Bias</sub> ΔC vs. V<sub>AC</sub> C vs. T ΔT vs. I<sub>avg</sub>(F)

### Capacitance change / DC-Bias Voltage

DC-bias Voltage (V)	100 nF Change (%)	470 nF Change (%)
0	0	0
20	0	-5
40	-10	-25
60	-35	-55
80	-60	-70
100	-80	-75

### Capacitance / DC-Bias Voltage

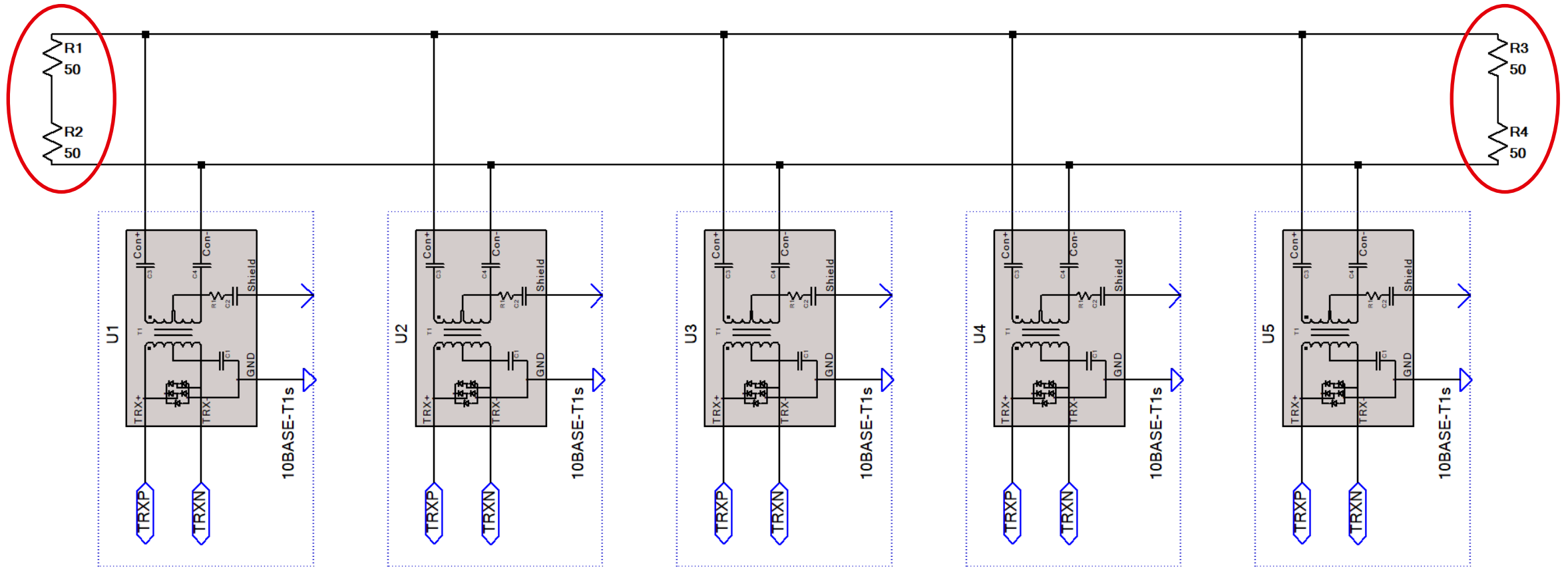
DC-bias Voltage (V)	100 nF (nF)	470 nF (nF)
0	100	470
20	100	350
40	80	200
60	60	120
80	50	80
100	50	60

### Capacitance Change / Temperature

Temperature (°C)	100 nF Change (%)	470 nF Change (%)
-55	-10	-10
-35	-5	-5
-15	-2	-2
5	0	0
25	0	0
45	0	0
65	-2	-2
85	-5	-5
105	-8	-8
125	-10	-10

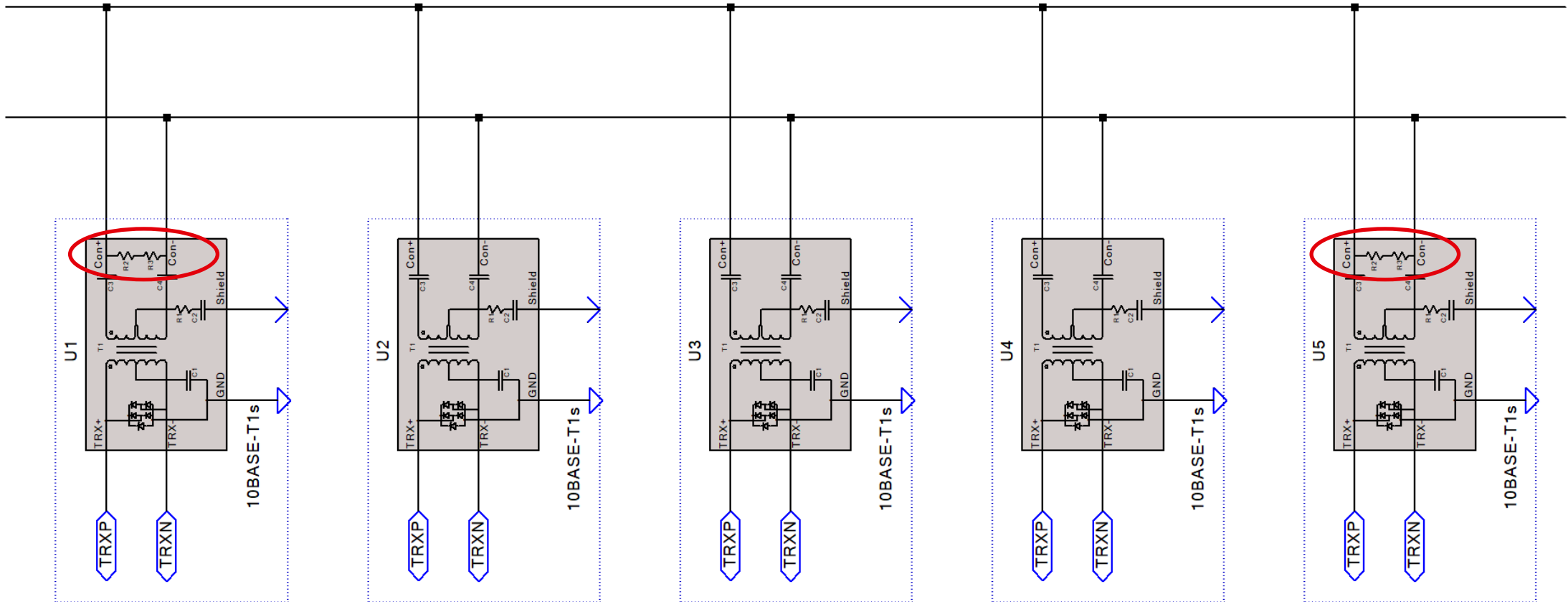
# 4. 10BASE-T1S IN DETAIL

## Termination on Bus Line for 10BASE-T1s



# 4. 10BASE-T1S IN DETAIL

## Termination at MDI for 10BASE-T1s



## 4. 10BASE-T1S 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*

# Questions

& Answers



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

[digital-we-days@we-online.com](mailto:digital-we-days@we-online.com)  
[Simon.Mark@we-online.com](mailto:Simon.Mark@we-online.com)