

DIGITAL WE DAYS

2024



ELECTROSTATIC DISCHARGE

Christian Koch

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Electrostatic Discharge

- Driven by Ionization of materials (e.g. rubbing/friction)
- Discharge between materials
- Discharge by contact due to human
- Can lead to main failure of electronics



ESD Voltage

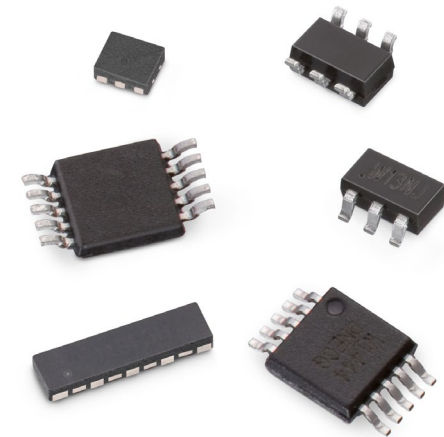
Typical electric potentials due to triboelectric effect!

ESD Source	Created charge at...	
	...10-20% Room humidity	...65-90% Room humidity
Walking across a carpet	35.000V	1.500V
Walking on vinyl floor	12.000V	250V
Opening vinyl envelope	7.000V	600V
Picking up polyethylene bag	20.000V	1.200V
Sitting on upholstered chair	18.000V	1.500V

Protective measures

- External (work environment):
 - Avoidance or rather reduction of electrostatic charging
 - Special floor cover, clothes, shoes
 - Controlled potential equalization (grounding bracelet)
 - ESD protective package for sensitive components and modules

- Internal (device level):
 - Protective circuit at interfaces
 - Protective circuit at sensitive integrated circuits

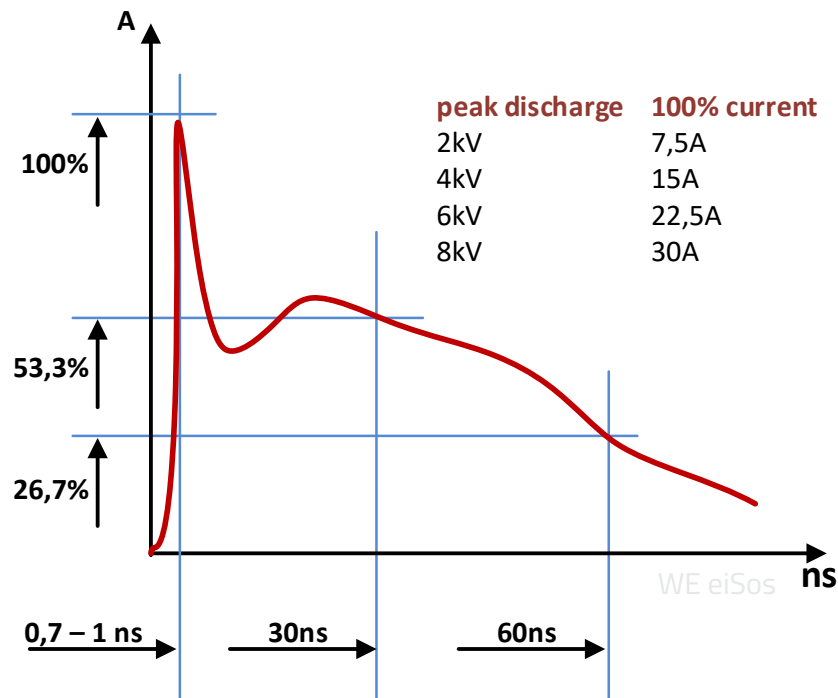


IEC 61000-4-2 ESD

Basic Standard

- Testing a device's immunity against electrostatic discharge is described in the standard **EN 61000-4-2**.
- The discharge occurs via a **conductive contact** with the device or via an **air gap**.
- The standard defines the **discharge current waveform** from the generator into a 50 Ω calibration load.

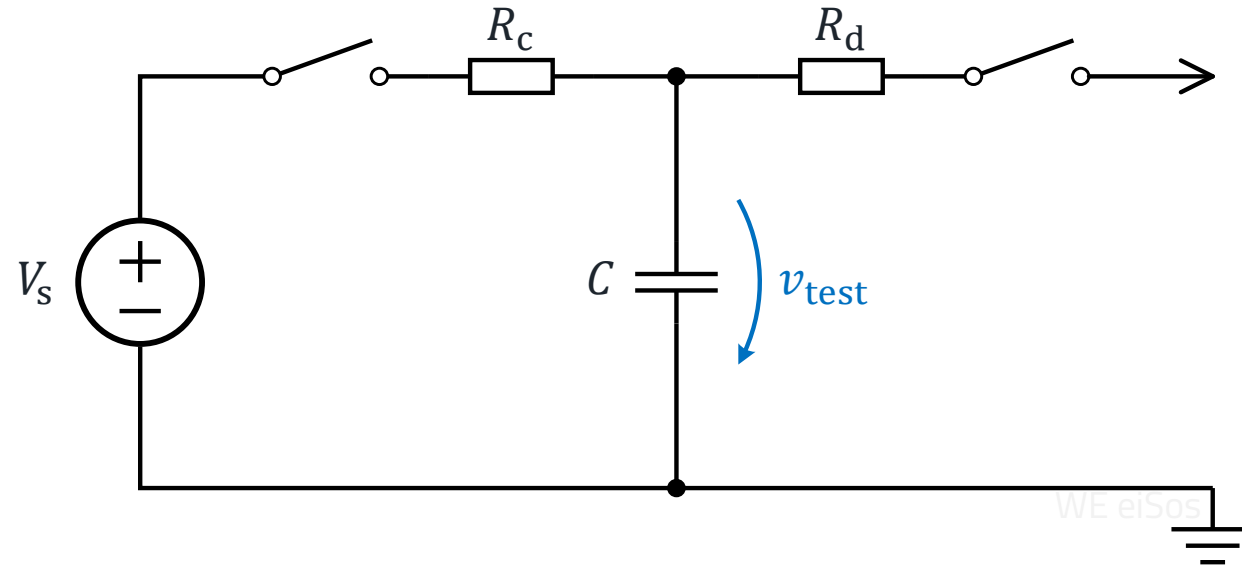
EN 61000-4-2 current waveshape



Severity level	Contact discharge	Air discharge
1	2 kV	2 kV
2	4 kV	4 kV
3	6 kV	8 kV
4	8 kV	15 kV
X	Special	Special

Test generator

- Equivalent circuit of the test generator:

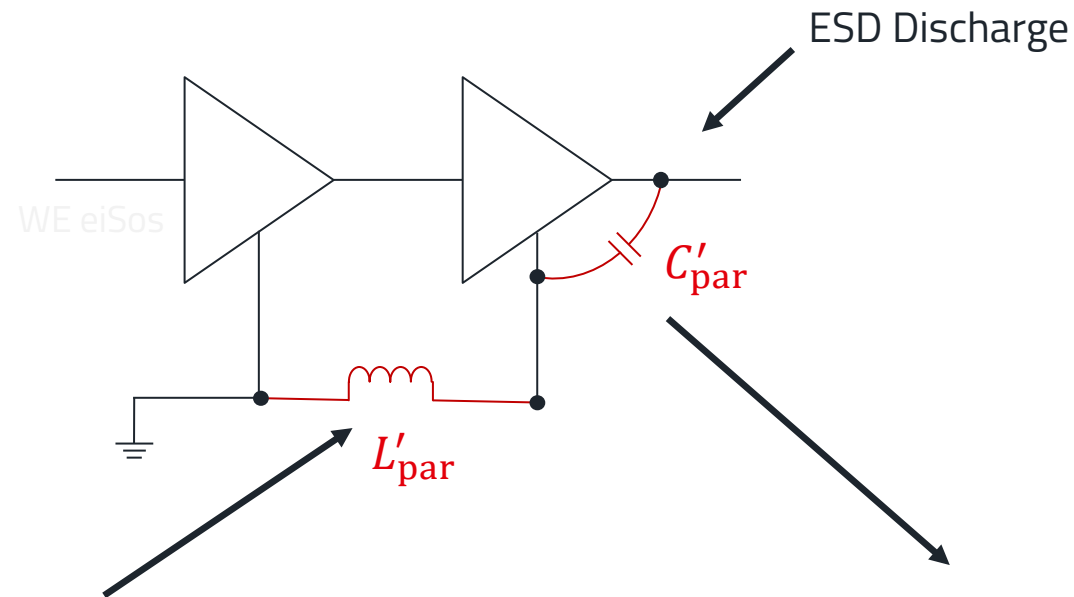


- The storage capacitance $C = 150\text{pF}$ together with the discharge resistance $R_d = 330\Omega$ emulates the electrical behavior of a human (HBM = human body model).
- v_{test} = Test voltage

Transient Noise sources

Electrostatic Discharge

- Parasitic parameters in digital circuitry cause high voltages and currents.
- Magnitude:
 - $C'_{\text{par}} = 5\text{pF/cm}$
 - $L'_{\text{par}} = 10\text{nH/cm}$



$$v_L = L_{\text{par}} \cdot \frac{di_{\text{ESD}}}{dt} = 10\text{nH} \cdot \frac{10\text{A}}{1\text{ns}} = 100\text{V}$$

$$i_C = C_{\text{par}} \cdot \frac{dv_{\text{ESD}}}{dt} = 5\text{pF} \cdot \frac{2000\text{V}}{1\text{ns}} = 10\text{A}$$

Protective Components against ESD

WE-VE ESD Suppressor



0402/0603/0805

WE-TVS Diode – Standard/High/Super-Speed



DFN-1210-6L



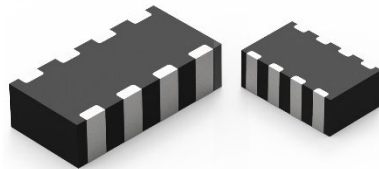
DFN-1610-2L

WE-TVSP Power TVS Diode



DO-214
AC/AA/AB

WE-VEA ESD Suppressor-Array



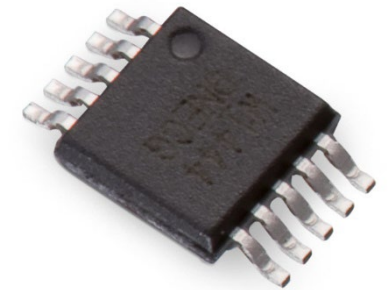
0508/0612



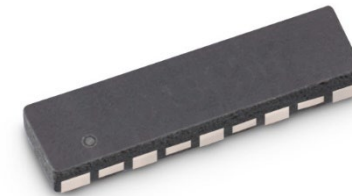
SC70-6L



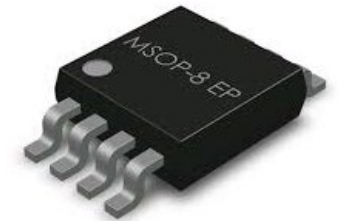
SOT-23-6L



MSOP-10L



DFN-3810-9L

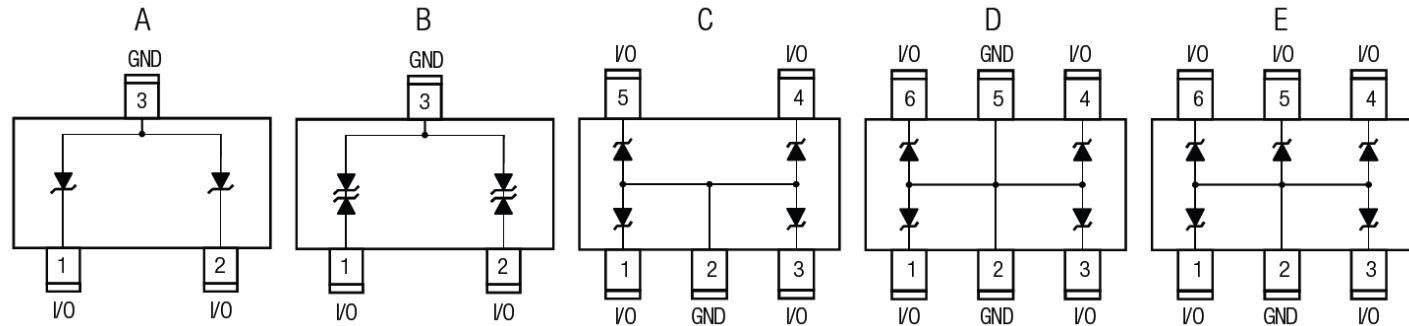
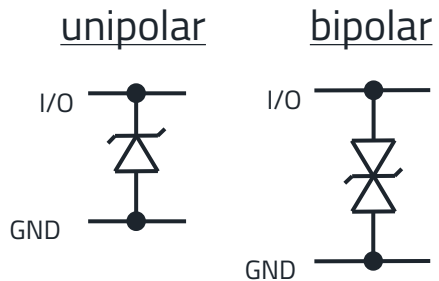
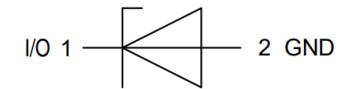
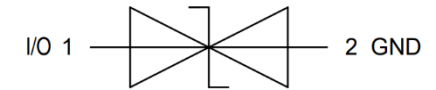
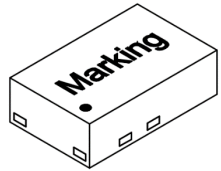
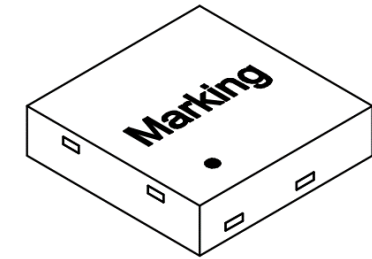
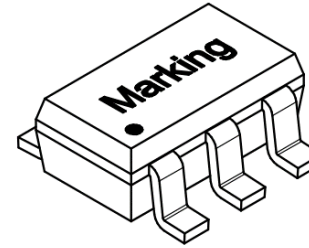
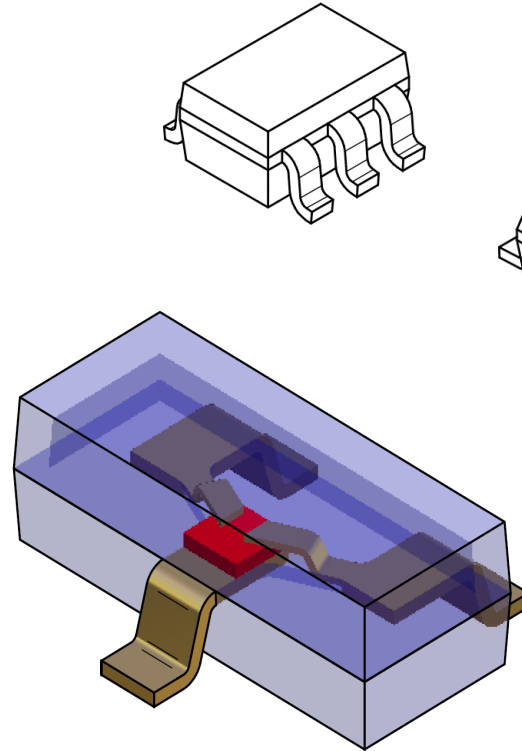


MSOP-8L

WE-TVS Standard Series

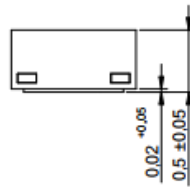
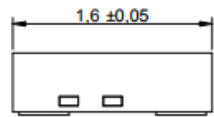
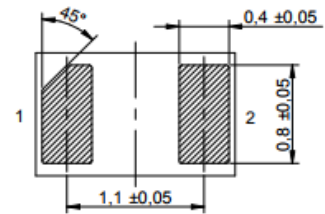
- Materials:
 - ESD-Suppressor: Zinc oxide
 - TVS-Diode: Silicon

- Diode-types:

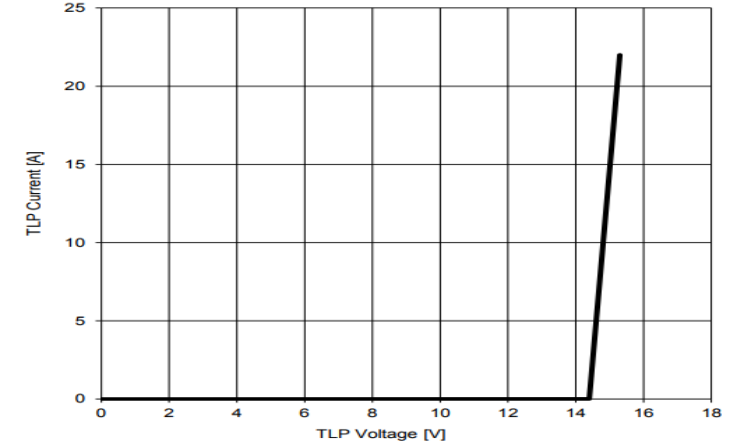


WE-TVS Standard Series

DFN1610-2L highly compact TVS diode for DC-Applications



Transmission Line Pulsing (TLP) Measurement:



- All
- SOT23-3L
- SOT23-6L
- SC70-5L
- SC70-6L
- DFN1610-2L
- DFN2020-2L

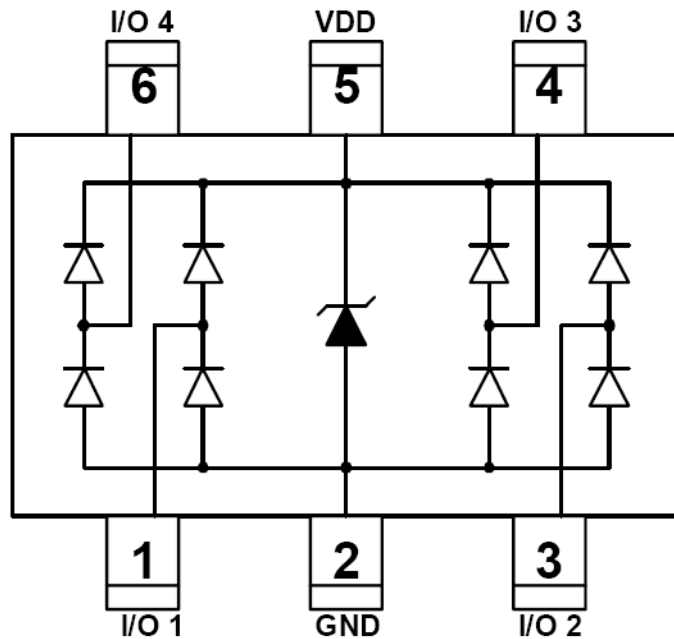
Order Code	Data-sheet	Simulation	Downloads	Channels	Polarity	V _{Ch max.} (V)	V _{BR min.} (V)	C _{Ch typ.} (pF)	I _{Peak} (A)	V _{ESD Air} (kV)	V _{ESD Contact} (kV)
824045817	SPEC		6 FILES	1	Unidirectional	7	7.8	830	60	30	30
824045812	SPEC		6 FILES	1	Unidirectional	12	13.3	440	38	30	30
824045810	SPEC		6 FILES	1	Unidirectional	20	22.8	240	24	30	30
824031815	SPEC		6 FILES	1	Unidirectional	5	6	250	80	30	30
824032813	SPEC		6 FILES	1	Bidirectional	3.3	4	280	180	30	30
824032815	SPEC		6 FILES	1	Bidirectional	5	6	140	100	30	30



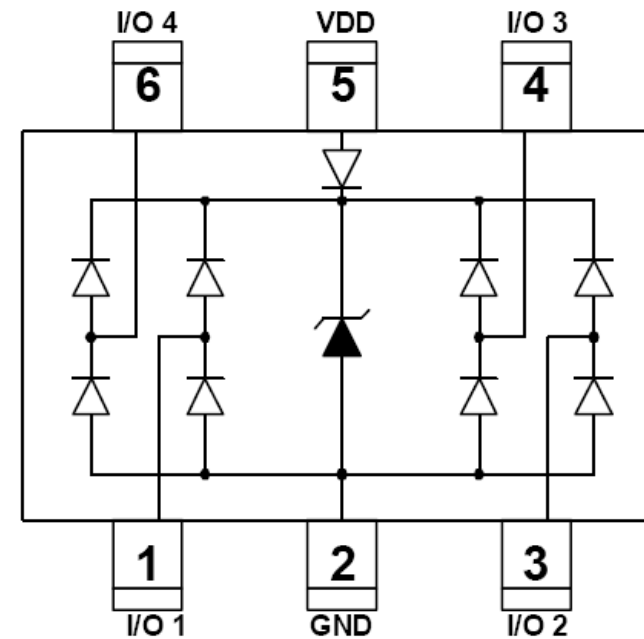
WE-TVS High/Super Speed Series

Internal circuitry

WE-TVS: 824 015

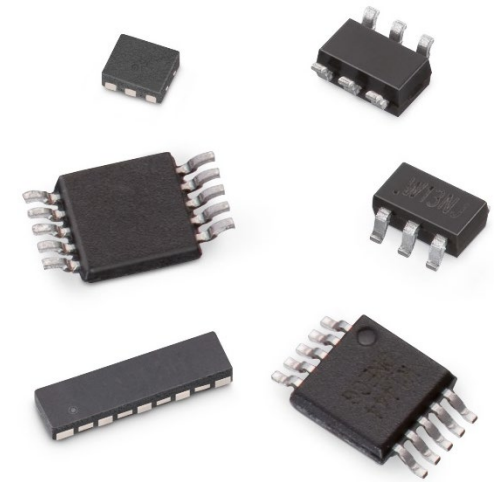


WE-TVS: 824 014



WE-TVS Super Speed Series

- Super Speed data lines
- HDMI 1.3/1.4/2.0, DVI
- DisplayPort
- USB 3.1 Gen 1 (5Gb/s)
- SATA and eSATA
- GBit LAN
- Thunderbolt
- LVDS
- ESD protection in accordance with EN 61000-4-2
 - 8 kV contact discharge
 - 15 kV air discharge



- All
- SOT23-6L
- MSOP-10L
- MSOP-8L
- DFN3810-9L
- DFN1210-6L

Order Code	Data-sheet	Simulation	Downloads	Channels	Polarity	V _{Ch max.} (V)	V _{BR min.} (V)	C _{Ch typ.} (pF)	I _{Peak} (A)	V _{ESD Air} (kV)	V _{ESD Contact} (kV)	Application
824012823	SPEC		6 FILES	2	Unidirectional	3.3	4.5	0.18	3	15	8	USB 3.1 Gen1&2 (5Gb/s, 10Gb/s), USB
824014	SPEC		6 FILES	4+1	Unidirectional	5	6	0.55	4	16	10	HDMI 1.3, DVI & DisplayPort
82401444	SPEC		6 FILES	4+1	Unidirectional	5	6	0.55	5	16	10	HDMI 1.3, DVI & DisplayPort
82401646	SPEC		6 FILES	6+1	Unidirectional	5	6	–	–	15	8	USB 3.0, HDMI 1.4
824014883	SPEC		6 FILES	8	Unidirectional	3.3	4.5	0.5	5	15	12	USB 3.1 Gen1 (5Gb/s), USB 3.1 Type C,
824014885	SPEC		6 FILES	8	Unidirectional	5	6	0.5	5	15	15	USB 3.1 Gen1 (5Gb/s), USB 3.1 Type C,

TVS diode selection

TVS Diode Selection

1. Operating voltage:

- Choosing the suitable operating voltage for the interface

Properties	Test conditions		Value			Unit
			min.	typ.	max.	
Channel Operating Voltage	I/O to GND	V_{Ch}			5	V
(Reverse) Breakdown Voltage	$I_{BR}=1mA$; I/O to GND	V_{BR}	6		9	V
Channel (Reverse) Leakage Current	$V_{I/O}=V_{DC}$; $V_{GND}=0V$	$I_{Ch Leak}$			1	μA
Forward Voltage	$I_F=15mA$; GND to I/O	V_F		0.9	1.2	V
(Channel) Input Capacitance	$V_{GND}=0V$ $V_{I/O}=2.5V$, $f=1MHz$, I/O to GND	C_{Ch}		0.5	0.65	pF
Channel to Channel Input Capacitance	$V_{GND}=0V$ $V_{I/O}=2.5V$, $f=1MHz$, between I/O pins	C_{Cross}		0.03	0.08	pF
Channel ESD Clamping Voltage	IEC 61000-4-2 +8kV (TLP=16A) Contact Mode, I/O to GND	$V_{Ch Clamp ESD}$		10.5		V

TVS diode selection

TVS Diode Selection

2. Capacitance:

- The capacitances C_{ch} and C_x have an impact on the **signal integrity**. They are voltage-dependent.

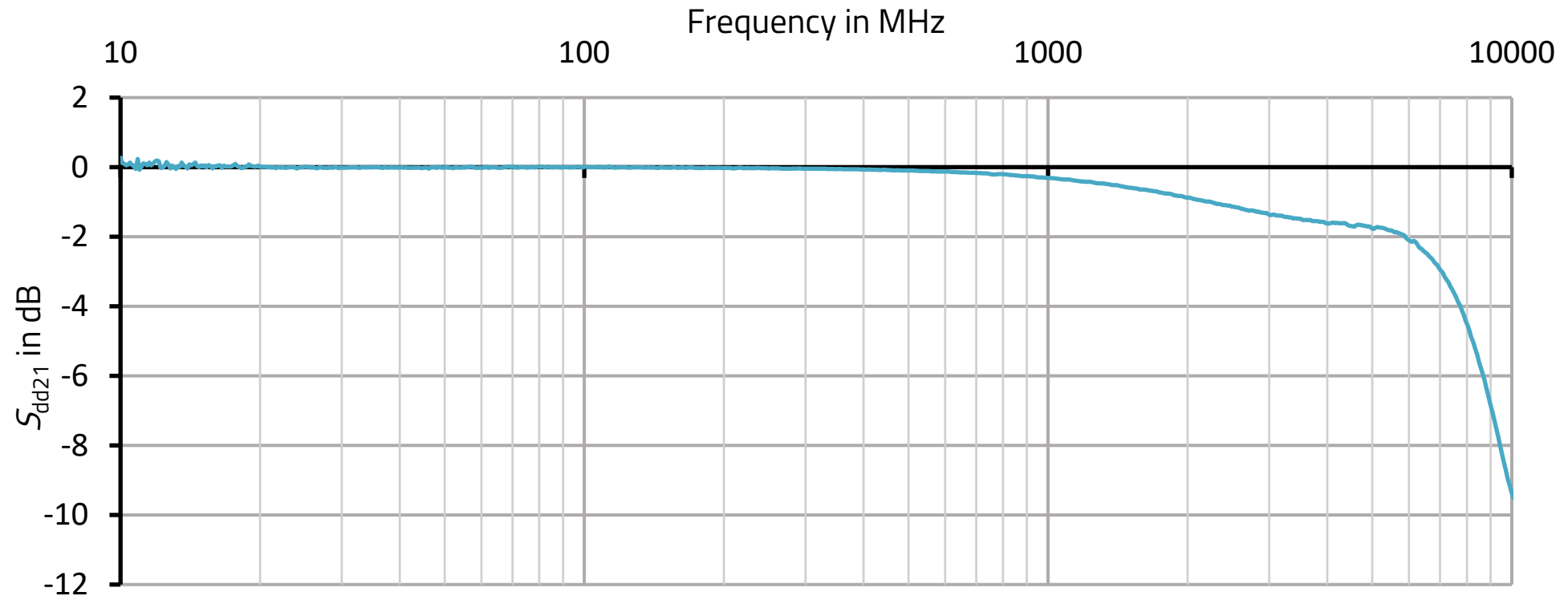
Properties	Test conditions		Value			Unit
			min.	typ.	max.	
Channel Operating Voltage	I/O to GND	V_{Ch}			5	V
(Reverse) Breakdown Voltage	$I_{BR}=1mA$; I/O to GND	V_{BR}	6		9	V
Channel (Reverse) Leakage Current	$V_{I/O}=V_{DC}$; $V_{GND}=0V$	$I_{Ch Leak}$			1	μA
Forward Voltage	$I_F=15mA$; GND to I/O	V_F		0.9	1.2	V
(Channel) Input Capacitance	$V_{GND}=0V$ $V_{I/O}=2.5V$, $f=1MHz$, I/O to GND	C_{Ch}		0.5	0.65	pF
Channel to Channel Input Capacitance	$V_{GND}=0V$ $V_{I/O}=2.5V$, $f=1MHz$, between I/O pins	C_{Cross}		0.03	0.08	pF
Channel ESD Clamping Voltage	IEC 61000-4-2 +8kV (TLP=16A) Contact Mode, I/O to GND	$V_{Ch Clamp ESD}$		10.5		V

TVS diode selection

TVS Diode Selection

3. Insertion loss:

- The insertion loss is related to the **scattering parameter** S_{dd21} (presented as amplification).



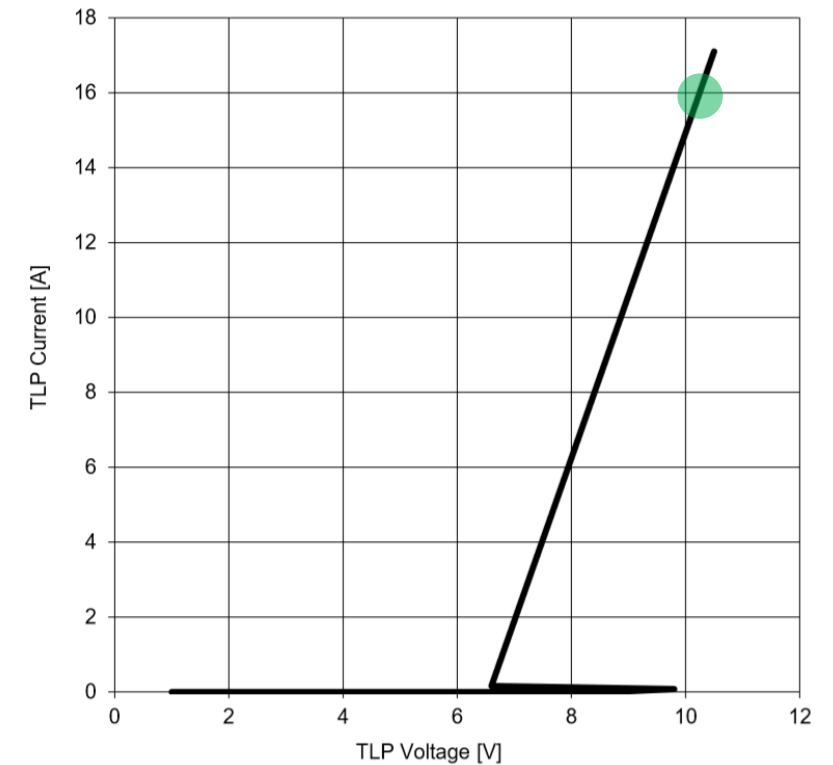
TVS diode selection

TVS Diode Selection

4. Clamping voltage:

- The clamping voltage is determined by the **transmission line pulsing (TLP)** method.

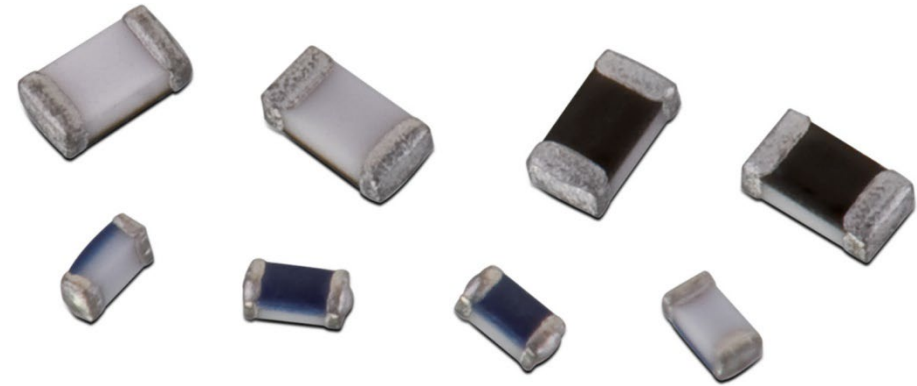
Properties	Test conditions		Value			Unit
			min.	typ.	max.	
Channel Operating Voltage	I/O to GND	V_{Ch}			5	V
(Reverse) Breakdown Voltage	$I_{BR}=1mA$; I/O to GND	V_{BR}	6		9	V
Channel (Reverse) Leakage Current	$V_{I/O}=V_{DC}$; $V_{GND}=0V$	$I_{Ch Leak}$			1	μA
Forward Voltage	$I_F=15mA$; GND to I/O	V_F		0.9	1.2	V
(Channel) Input Capacitance	$V_{GND}=0V$ $V_{I/O}=2.5V$, $f=1MHz$, I/O to GND	C_{Ch}		0.5	0.65	pF
Channel to Channel Input Capacitance	$V_{GND}=0V$ $V_{I/O}=2.5V$, $f=1MHz$, between I/O pins	C_{Cross}		0.03	0.08	pF
Channel ESD Clamping Voltage	IEC 61000-4-2 +8kV (TLP=16A) Contact Mode, I/O to GND	$V_{Ch Clamp ESD}$		10.5		V



WE-VE ULC

Ultra Low Capacitance 0,2pF

- USB 2.0, HDMI, DVI, Firewire, Antennas
- ESD protection in accordance with EN 61000-4-2:
 - 8 kV contact discharge
 - 15 kV air discharge



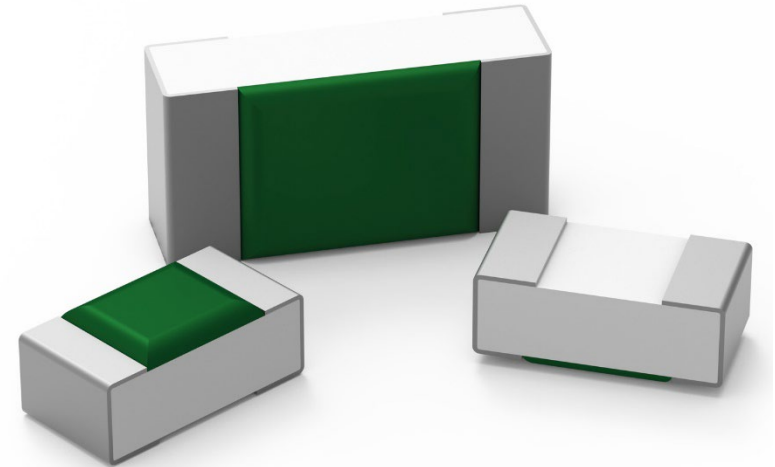
- All
- 0402
- 0603

Order Code	Data-sheet	Simulation	Downloads	V _{DC} (V)	I _{Leak} (μA)	V _{Ch Clamp ESD min.} (V)	V _{Trig ESD} (V)	V _{ESD Air} (kV)	Size
82307050029	SPEC		6 FILES	5	0.05	17	100	15	0402
82306050029	SPEC		6 FILES	5	0.01	30	150	15	0603
82306120029	SPEC		6 FILES	12	0.01	30	150	15	0603

WE-VE femtoF

0,05pF

- data lines, bus systems or semiconductors
- ESD protection in accordance with EN 61000-4-2:
 - 8 kV contact discharge
 - 15 kV air discharge



All 0402 0603





Order Code	Data-sheet	Downloads	V _{DC} (V)	C _{Ch typ.} (pF)	Size	V _{ESD Air} (kV)	V _{ESD Contact} (kV)	Design Kit
8231606A	SPEC	6 FILES	6	0.05	0603	15	8	–
8231706A	SPEC	6 FILES	6	0.05	0402	15	8	823999
8231614A	SPEC	6 FILES	14	0.05	0603	15	8	–
8231714A	SPEC	6 FILES	14	0.05	0402	15	8	–
8231626A	SPEC	6 FILES	26	0.05	0603	15	8	–
8231726A	SPEC	6 FILES	26	0.05	0402	15	8	–

WE-VE ESD Suppressor

- data lines, bus systems or semiconductors
- ESD protection in accordance with EN 61000-4-2:
 - 8 kV contact discharge
 - 15 kV air discharge

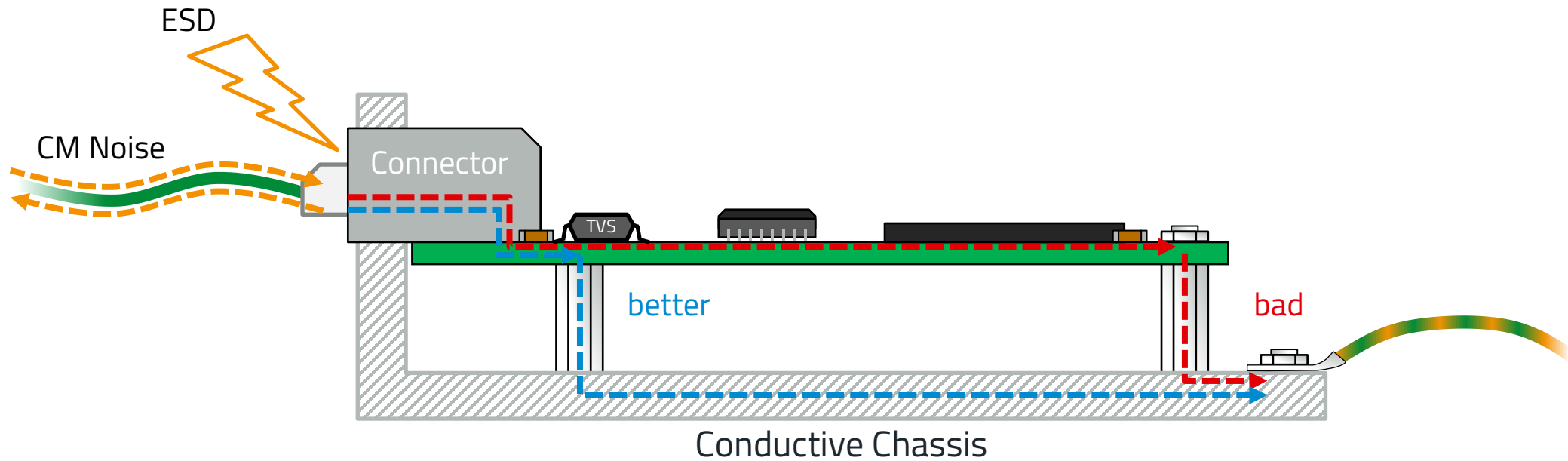


All
0402
0603
0805

Order Code	Data-sheet	Simulation	Downloads	V _{DC} (V)	I _{Leak} (μA)	V _{Clamp typ.} (V)	V _{ESD Air} (kV)	C _{Ch min.} (pF)	Size	Application	Design Kit
82356050101	SPEC		6 FILES	5	1	55	15	100	0603	RS-485, Sensors	823999
82356050050	SPEC		6 FILES	5	1	75	15	5	0603	USB 1.1 USB 2.0	823999
82356120100	SPEC		6 FILES	12	1	60	15	10	0603	USB 1.1 RS-232 LAN 10 Mbit	823999
82356240030	SPEC		6 FILES	24	1	180	15	3	0603	USB 2.0 LAN 100 Mbit	823999

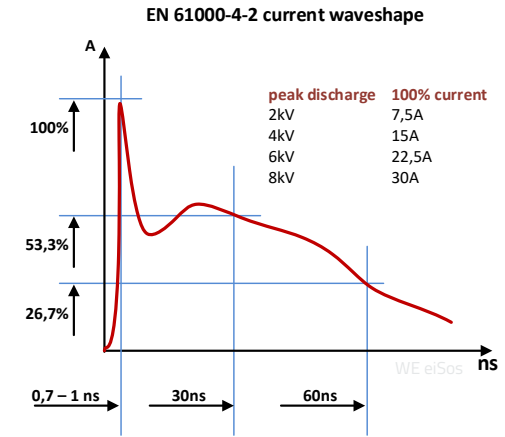
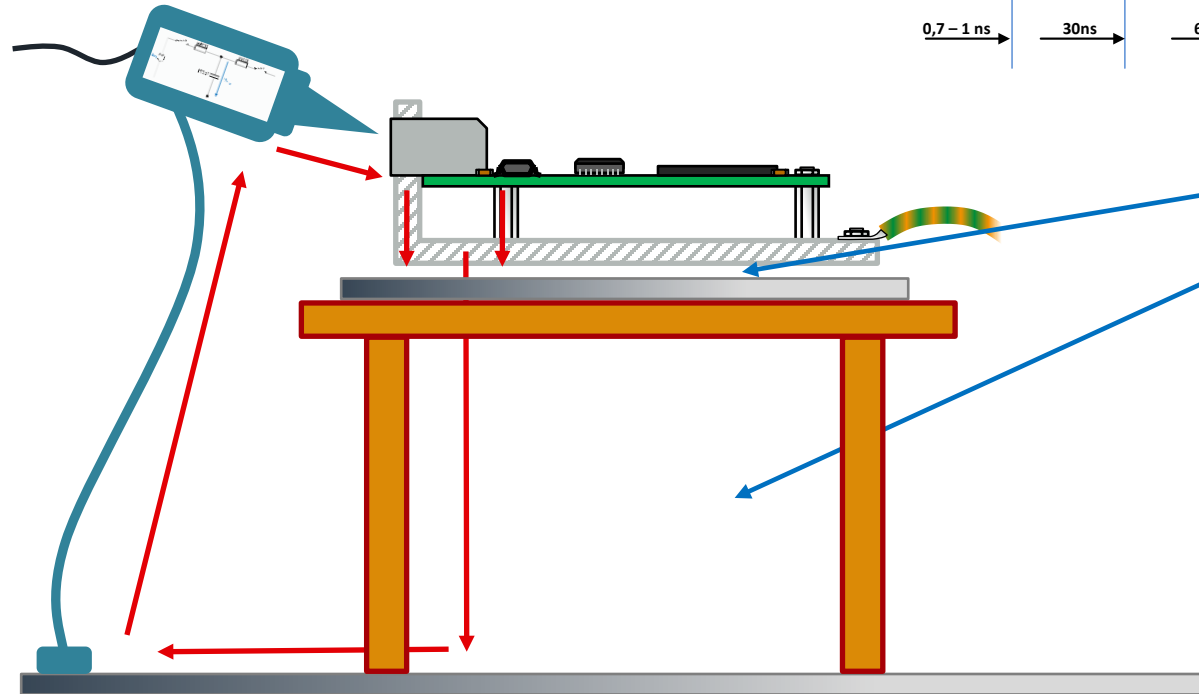
ESD Noise Path

- Grounding studs have to be placed so that disturbances don't affect the electronic parts
- Reference ground for ESD (and common mode noise) is earth potential (PE)



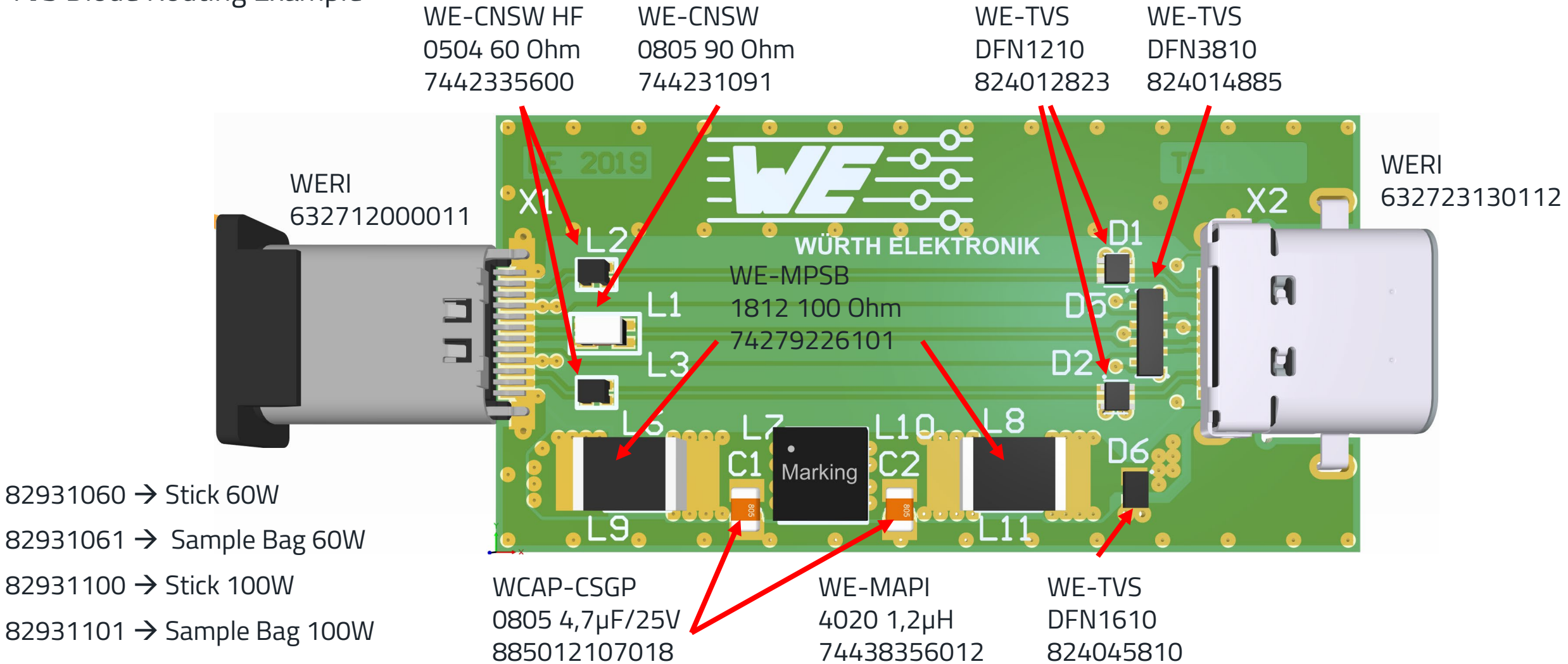
ESD-Test Setup

According to EN 61000-4-2



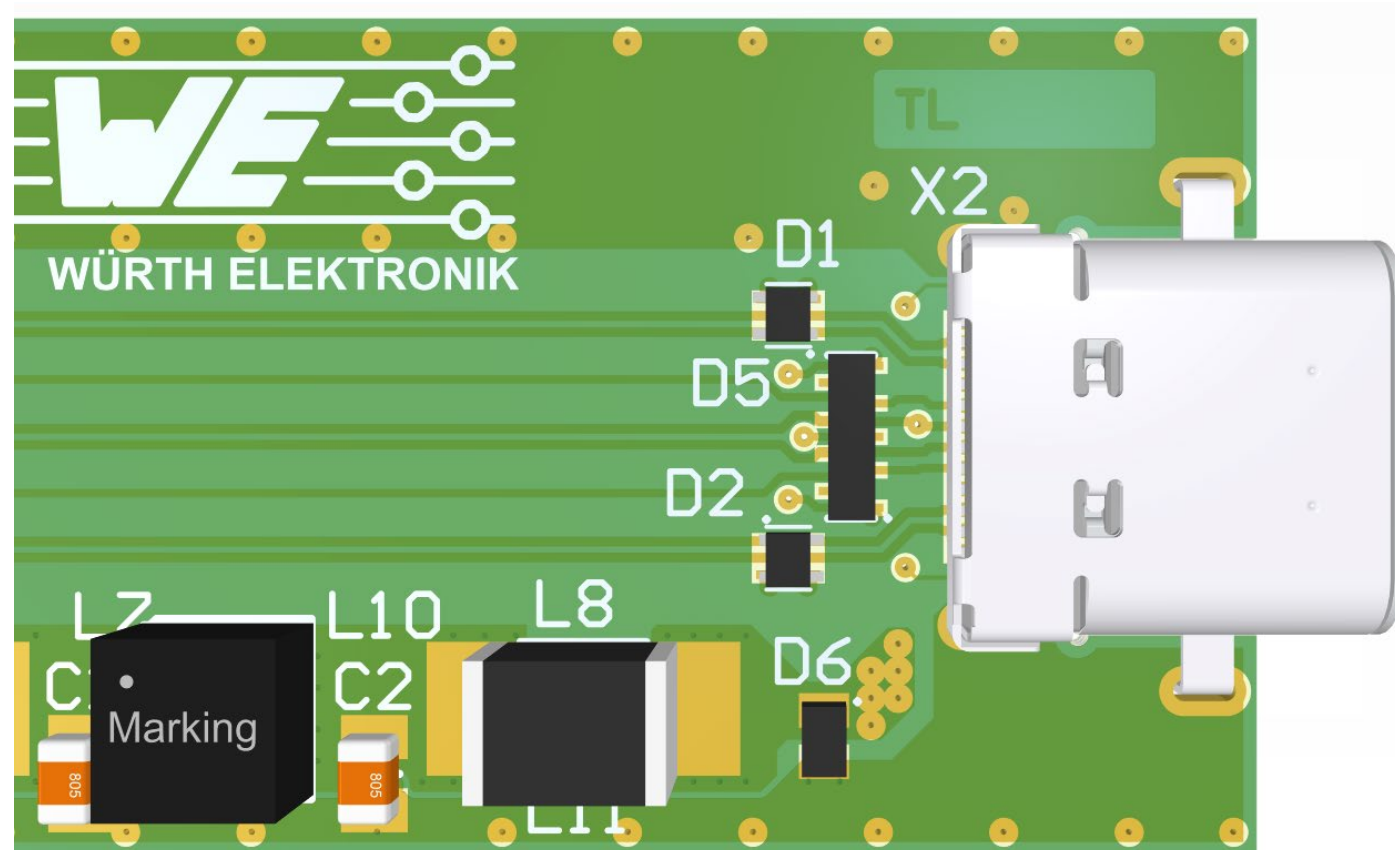
USB 3.1 Type-C Filterboard

TVS Diode Routing Example



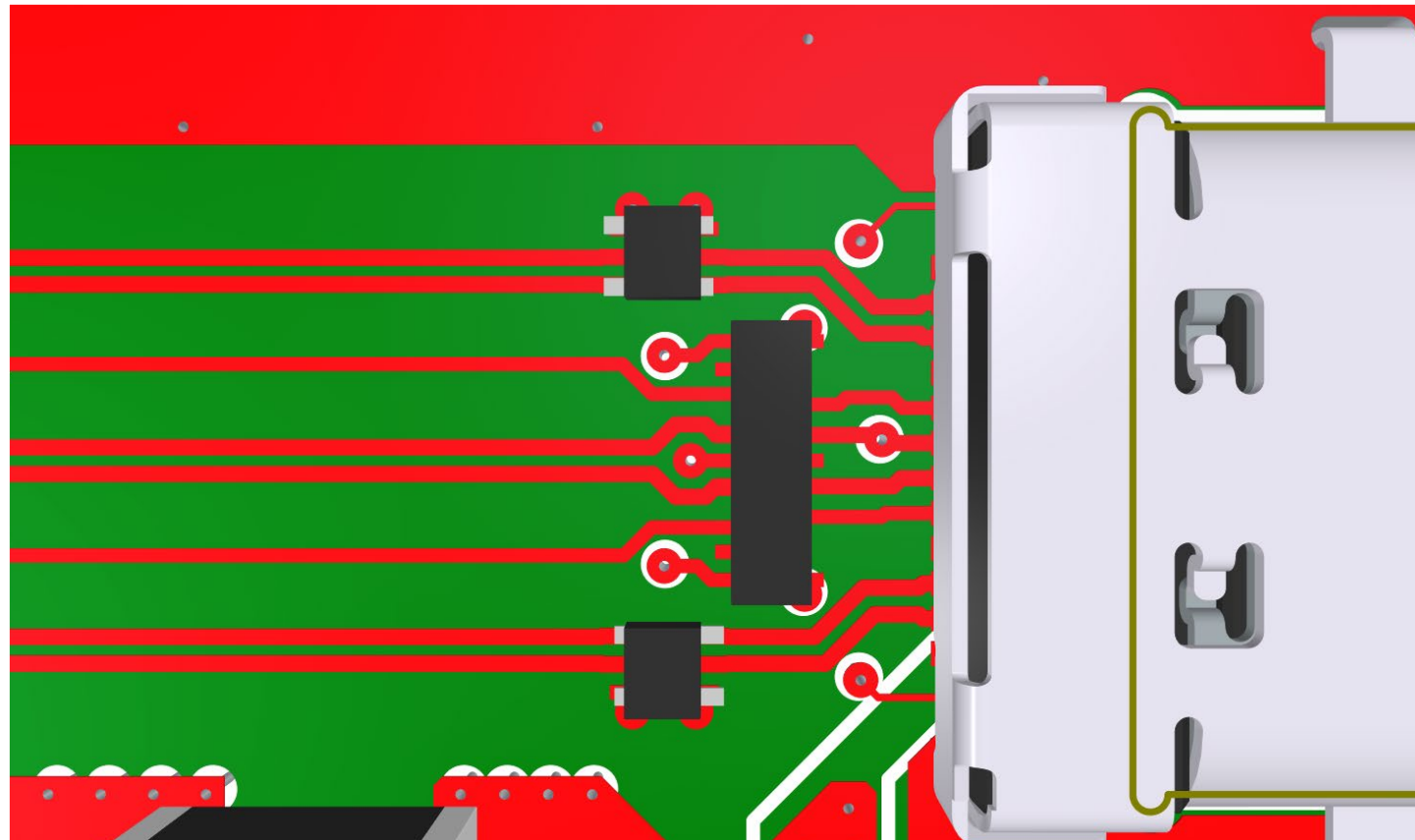
USB 3.1 Type-C Filterboard

TVS Diode Routing Example



USB 3.1 Type-C Filterboard

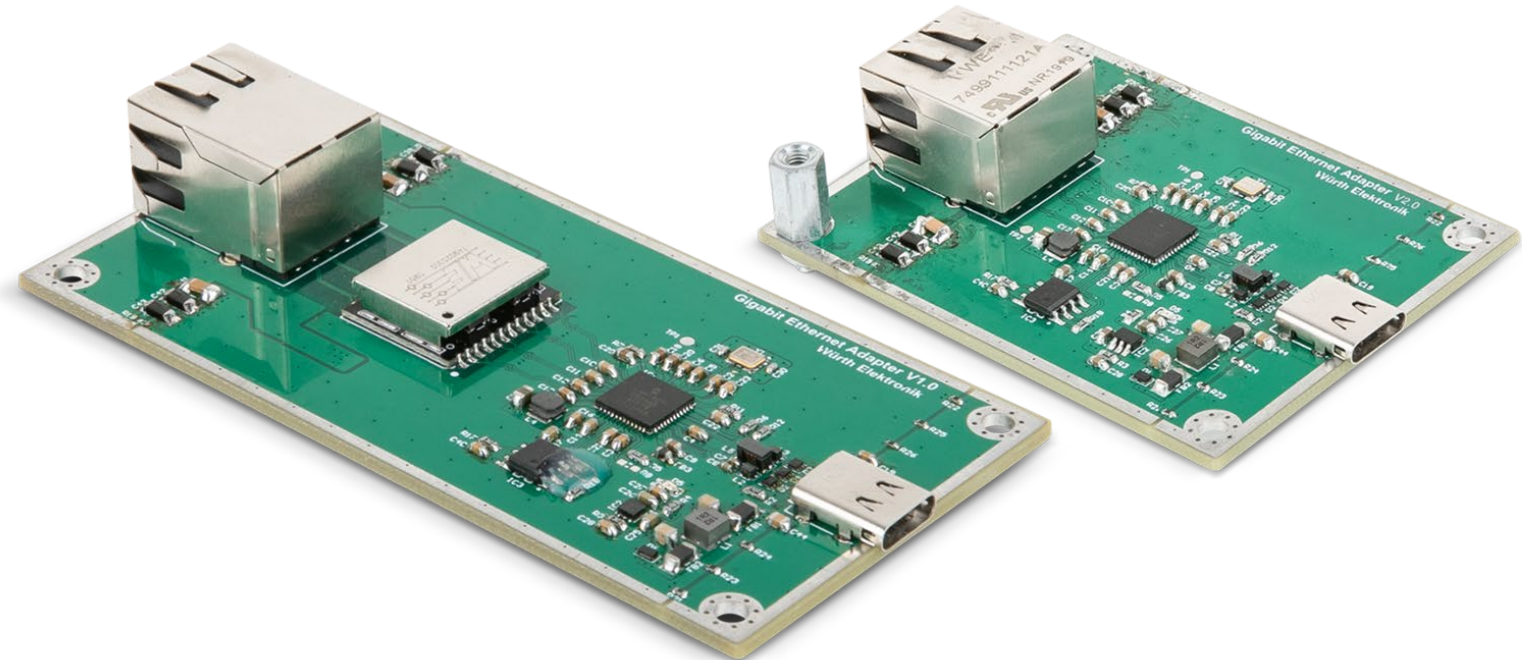
TVS Diode Routing Example



RD016/ANP116: Gigabit-Ethernet Front End

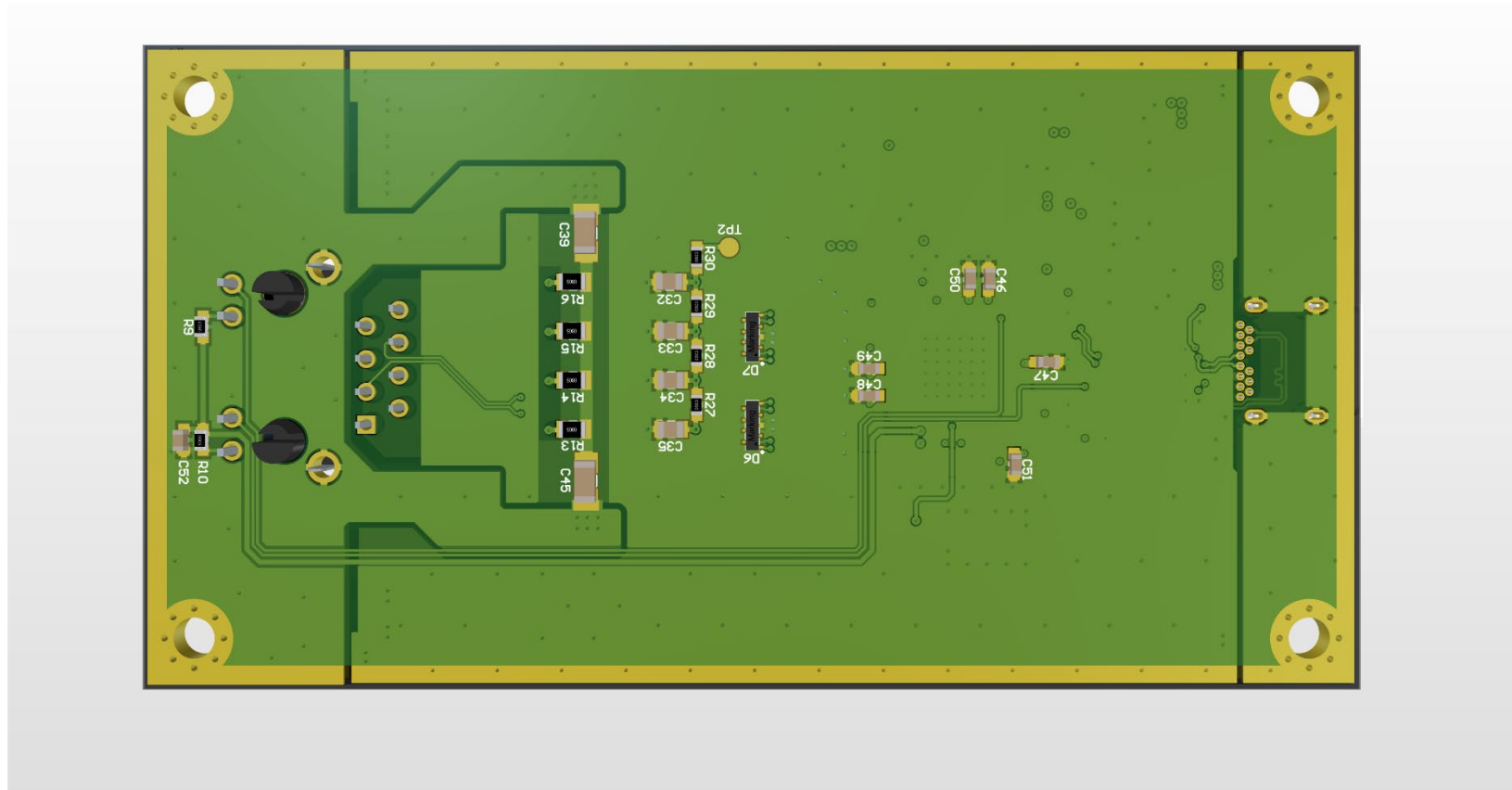
TVS Diode Routing Example

- Gigabit-Ethernet Front End
 - USB-Type C (USB 3.1)
 - 1 Gigabit RJ45/Ethernet-Interface
- Design templates
 - Discrete components
 - Integrated design
- Layout-reference in [RD016](#)
- EMC-evaluation in [ANP116](#)



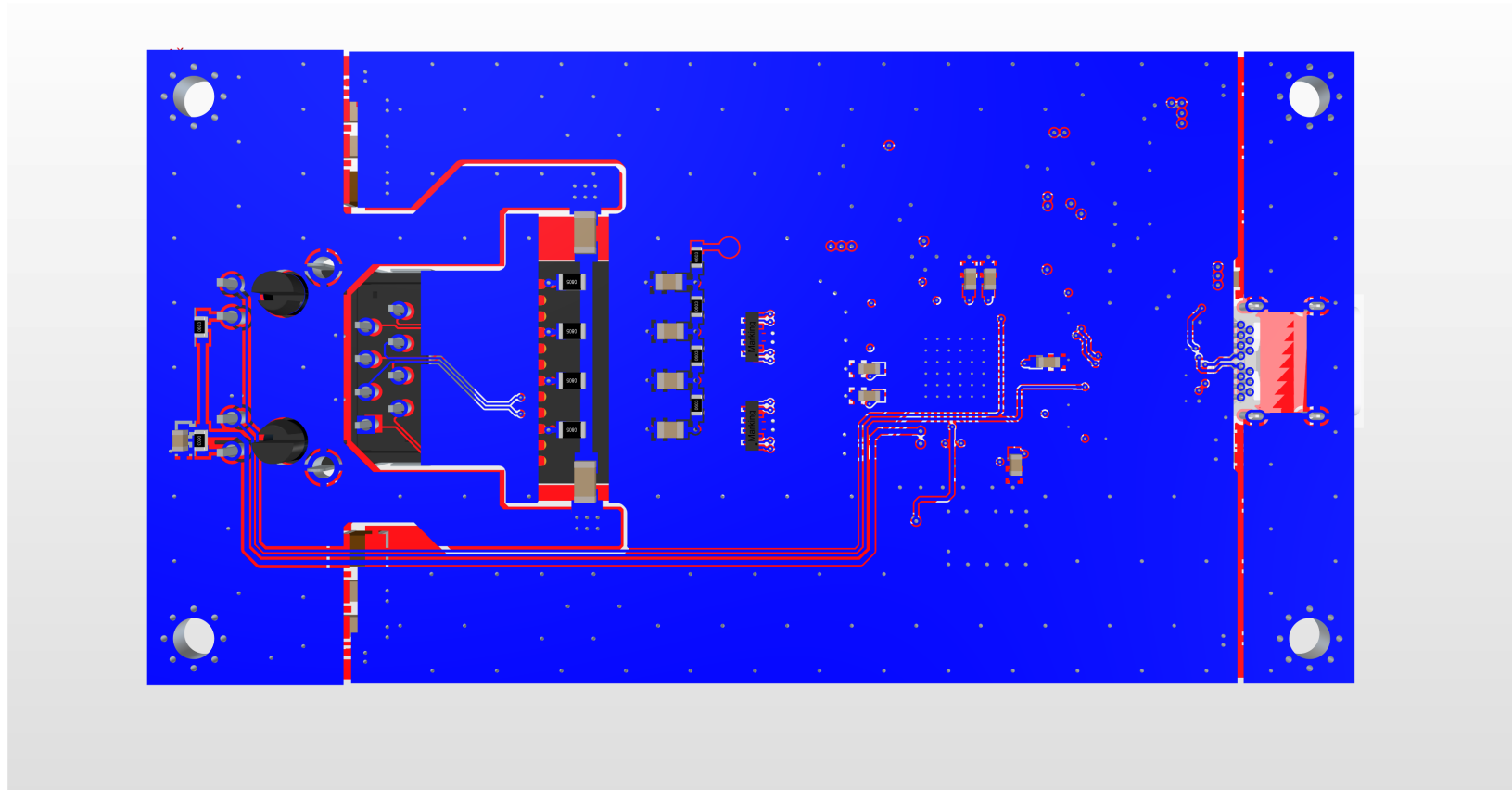
RD016/ANP116: Gigabit-Ethernet Front End

TVS Diode Routing Example



RD016/ANP116: Gigabit-Ethernet Front End

TVS Diode Routing Example



Questions

& Answers



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

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Christian.Koch@we-online.de