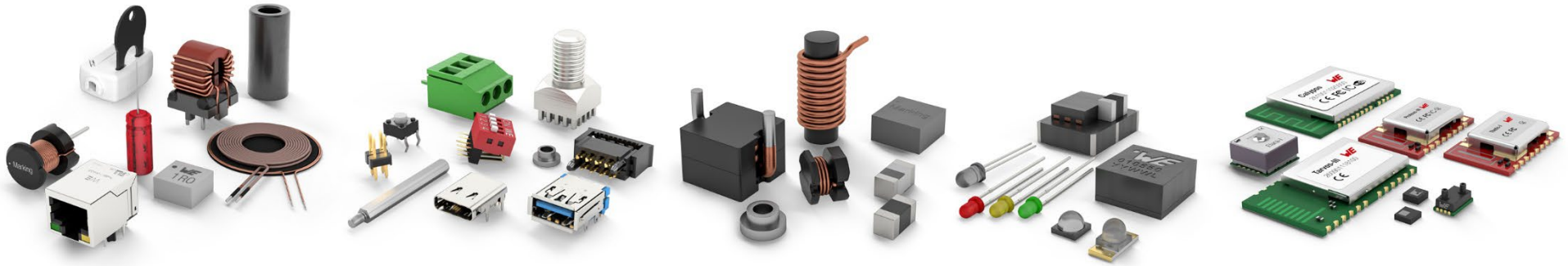

OVERVOLTAGE PROTECTION FOR SAFE OPERATION - TRANSIENT PROTECTION FOR NON-ISOLATED DC/DC POWER MODULES

Timur Uludag Senior Technical Marketing Manager

INTRODUCTION AND THEORETICAL BACKGROUND

Transients – Root Cause

What is a “transient”?

“Transient over voltages can be defined as short-term deviations from a nominal voltage value, which exceeds the permissible tolerance range of the nominal voltage in an electrical system.”

INTRODUCTION AND THEORETICAL BACKGROUND

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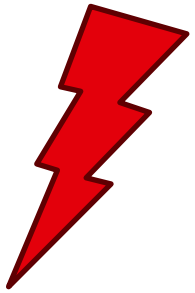
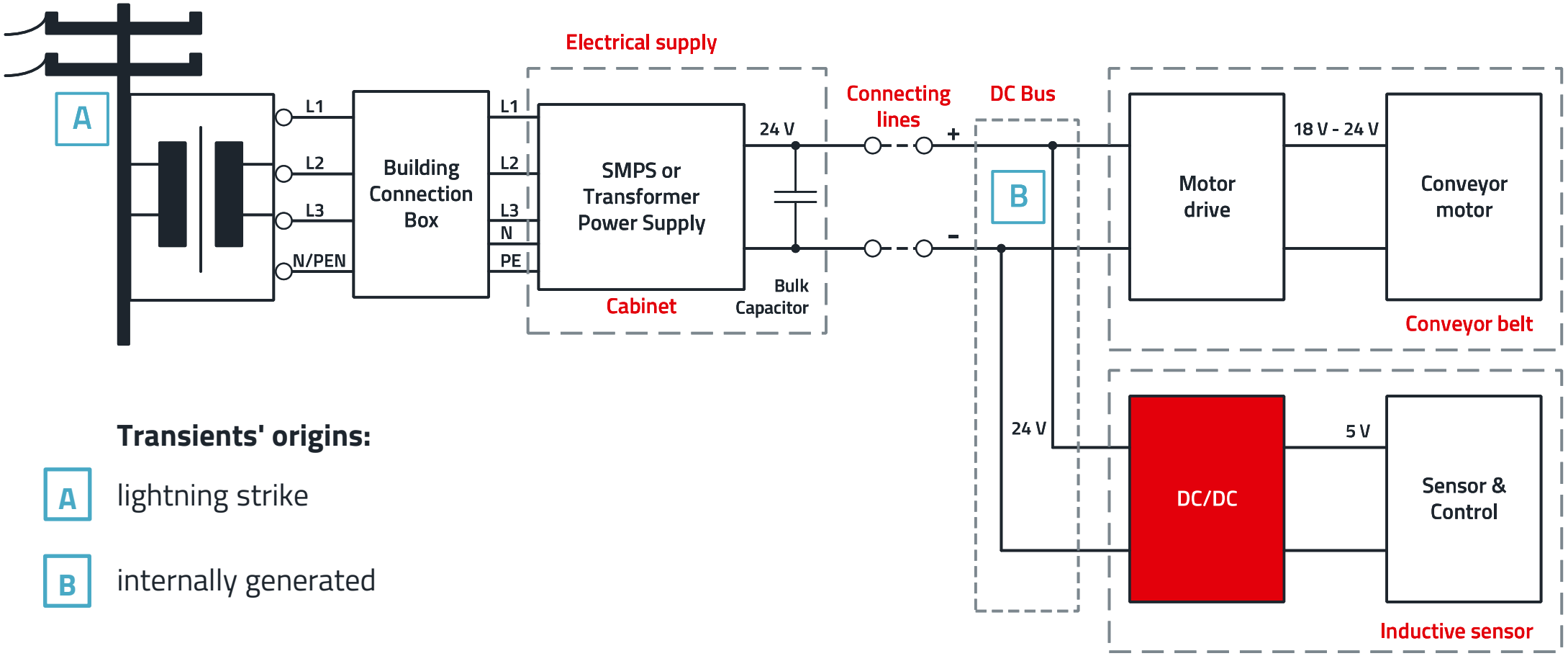
Effects?

“The effects of the transient over voltages are mostly destructive.”



INTRODUCTION AND THEORETICAL BACKGROUND

Typical industrial environments for DC/DC power modules



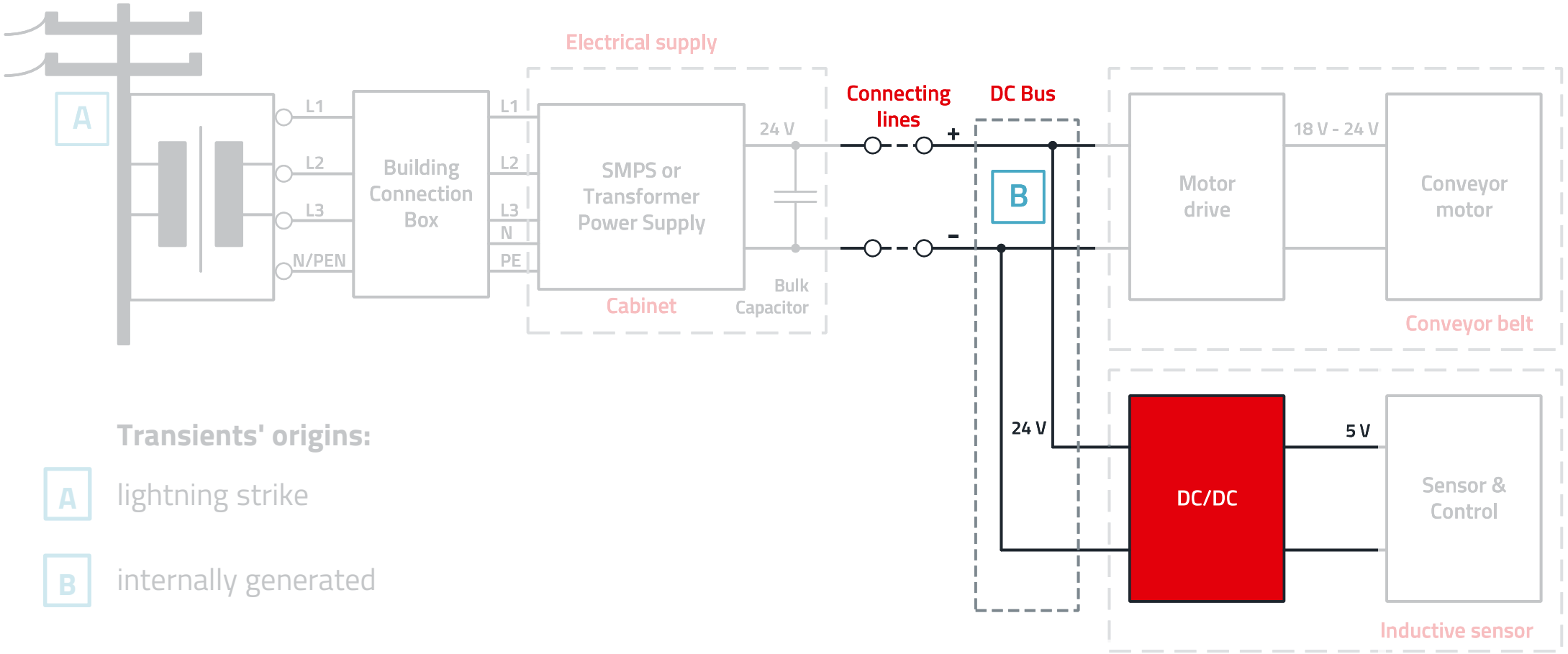
Transients' origins:

A lightning strike

B internally generated

INTRODUCTION AND THEORETICAL BACKGROUND

Typical industrial environments for DC/DC power modules



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A lightning strike

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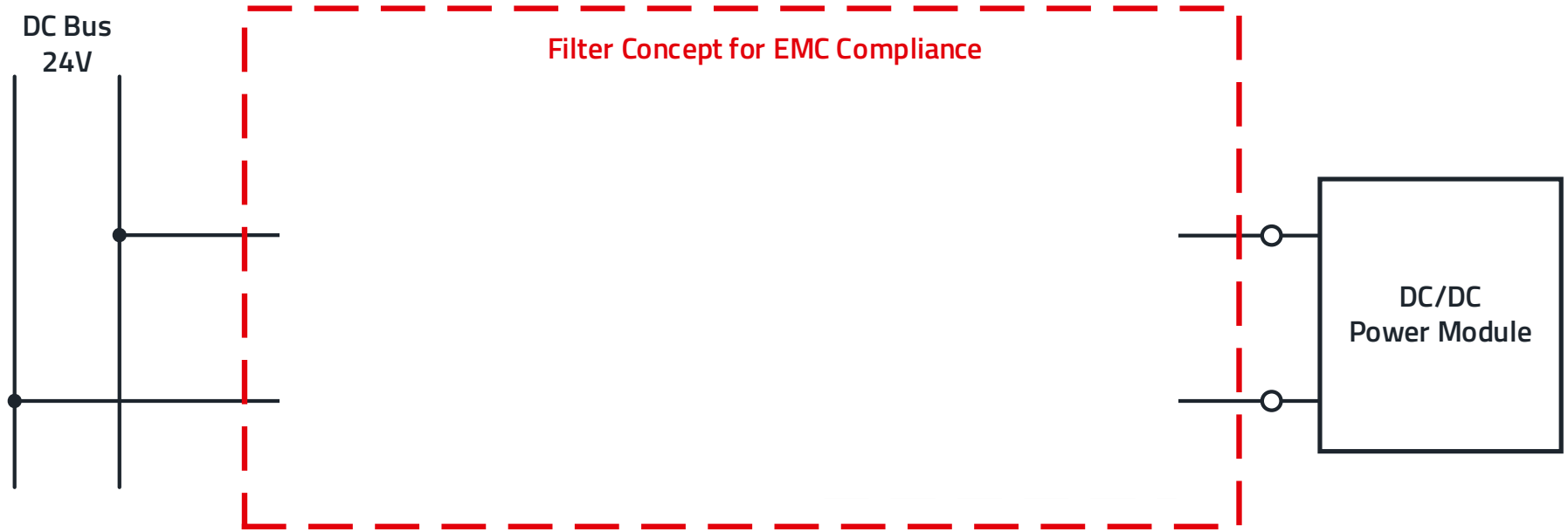
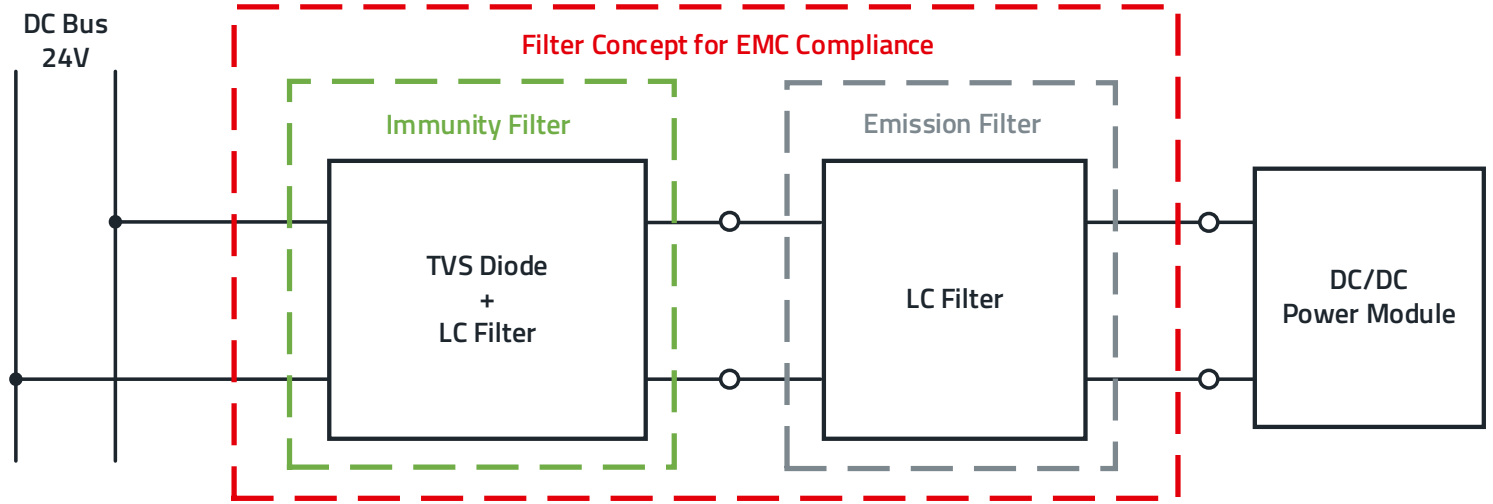
INTRODUCTION AND THEORETICAL BACKGROUND

EMC Filter Concept for DC/DC Power Modules



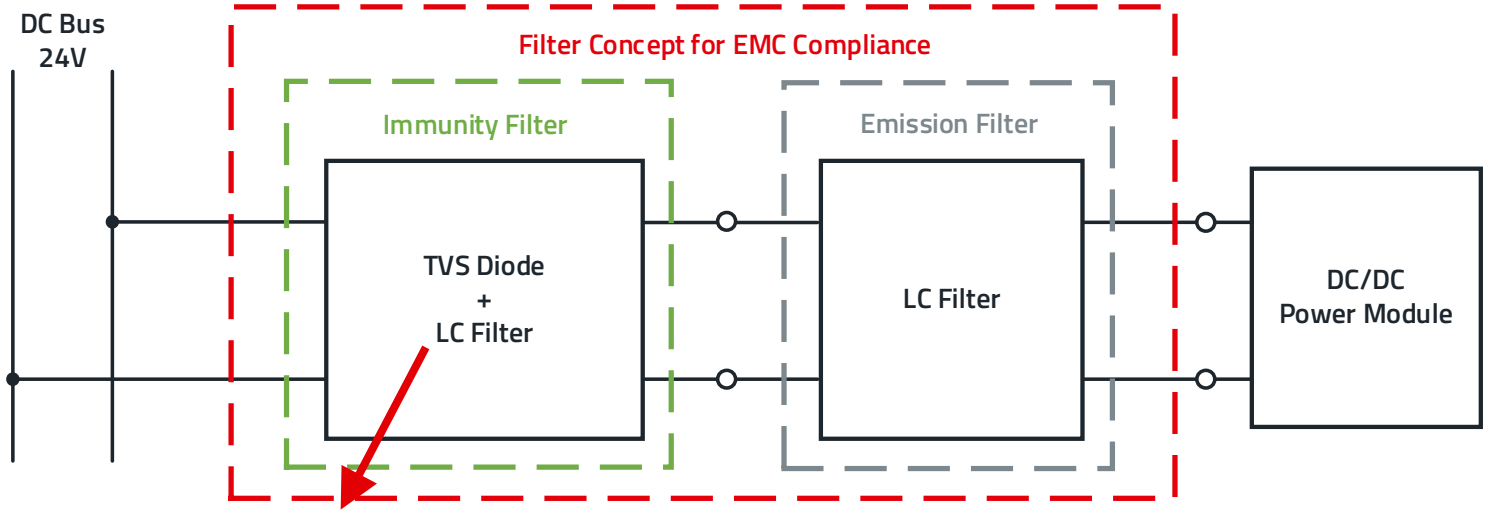
INTRODUCTION AND THEORETICAL BACKGROUND

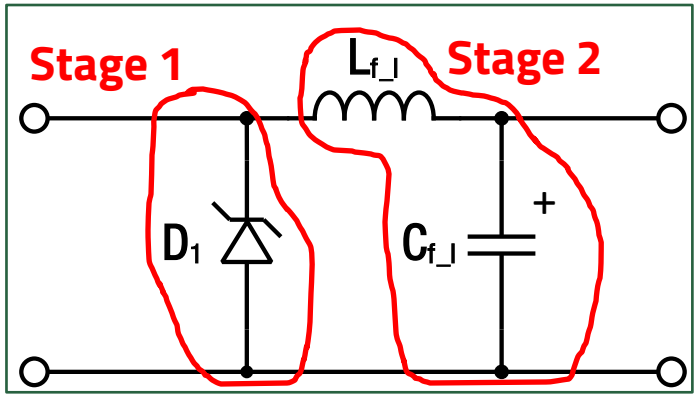
EMC Filter Concept for DC/DC Power Modules



INTRODUCTION AND THEORETICAL BACKGROUND

EMC Filter Concept for DC/DC Power Modules

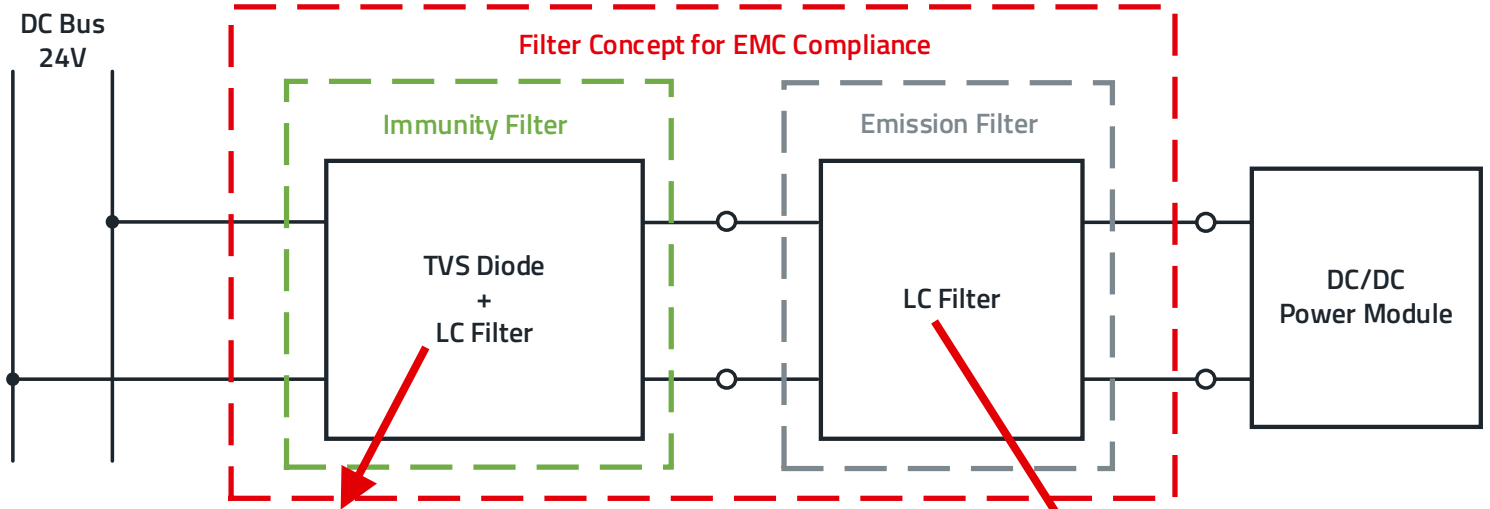


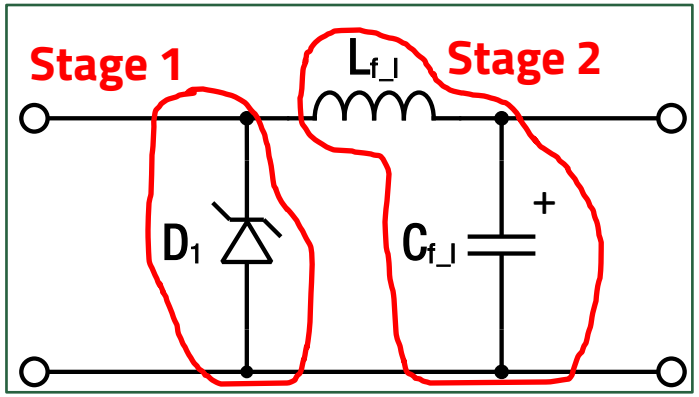


→ 2 stage concept for transient suppression

INTRODUCTION AND THEORETICAL BACKGROUND

EMC Filter Concept for DC/DC Power Modules





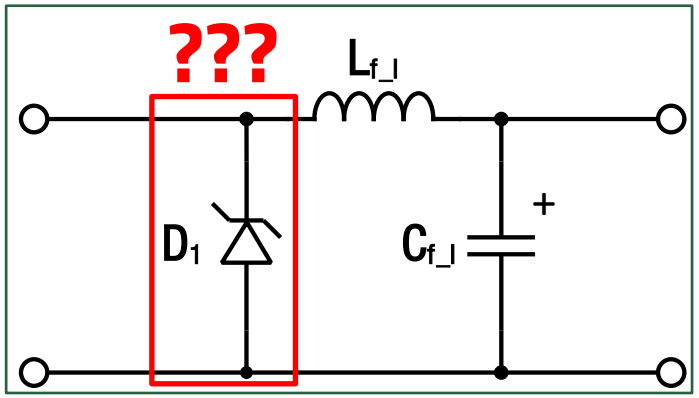
→ 2 stage concept for transient suppression

Emission Filter
→ LC Filter for emission reduction

→ ANS018 | EMI Filter Design for Non-Isolated DC/DC Converters

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage One - Required Parameters for Calculation



Parameters:

- V_{DC}: supply voltage for the power module
- V_{BR}: voltage where 1 mA of current is flowing through the TVS diode
- I_{PEAK}: max. peak current flowing through the TVS diode @ V_{CLAMP_MAX}
- P_{DISS}: maximum dissipated power for the TVS diode
- V_{CLAMP_MAX}: voltage where the diode carries the I_{PEAK}

IMMUNITY FILTER DESIGN LIMITS

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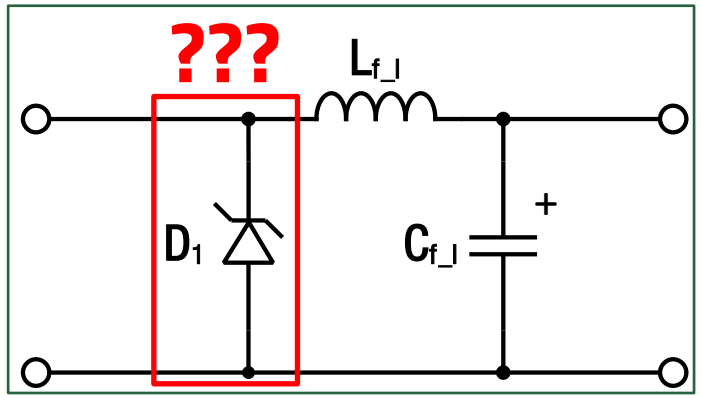

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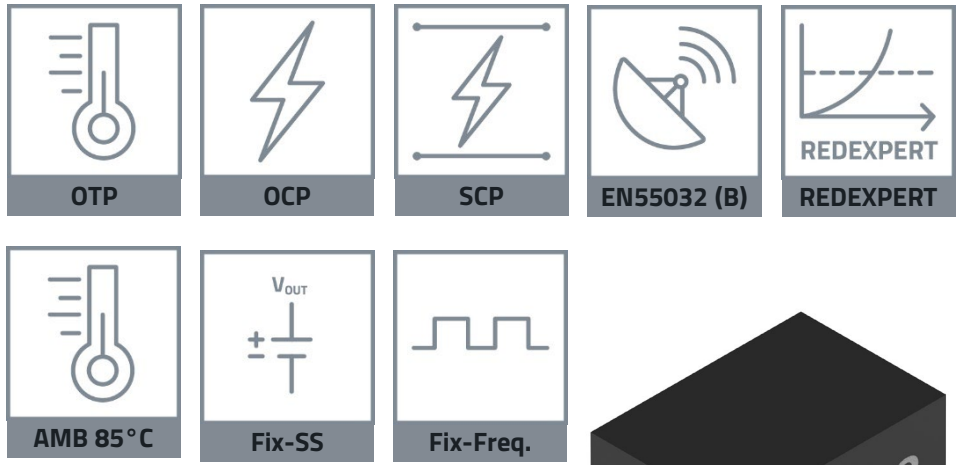
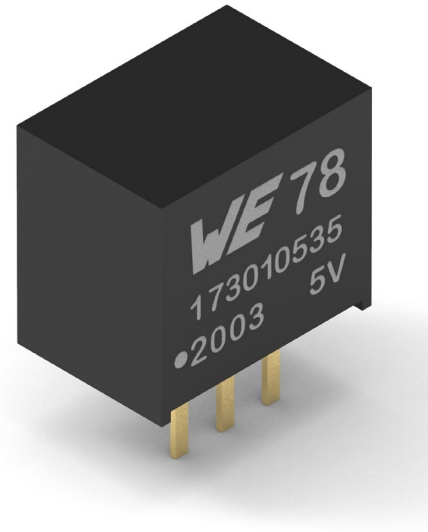
IMMUNITY FILTER DESIGN LIMITS

DC/DC Power Module

Description:

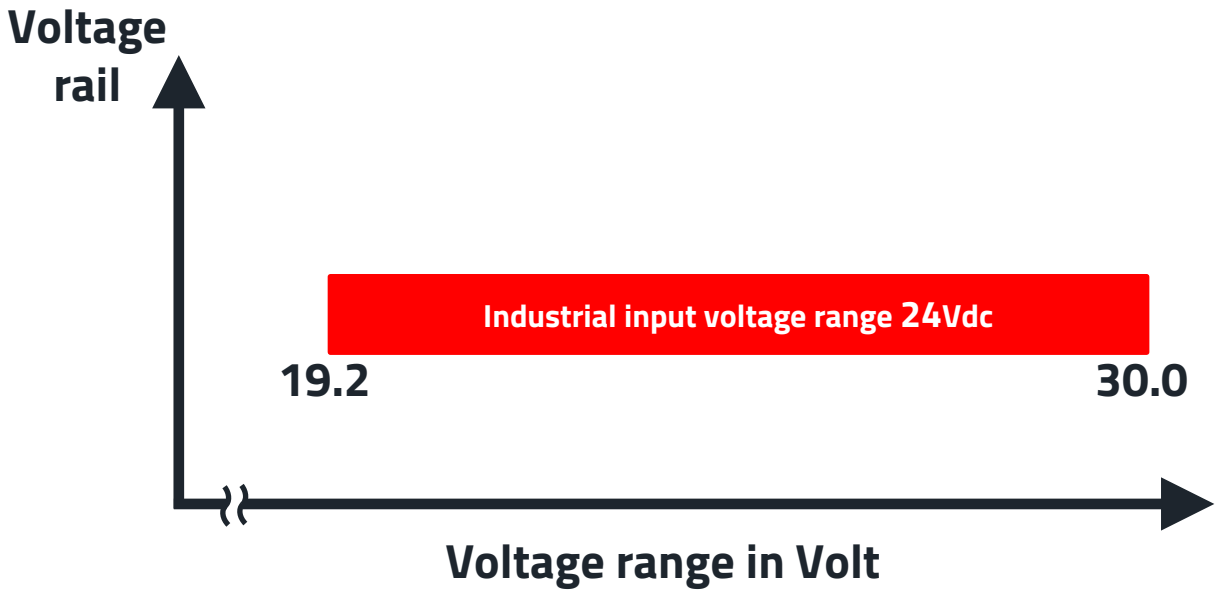
- V_{IN} = 8 to 36 V
- V_{OUT} = 5 V
- I_{OUT} = 1 A
- SIP-3 package
- Replacement for L78x Linear regulators (no cooling required)
- Ambient temperature 85°C
- Options
  - Fixed Soft Start
  - Fixed switching frequency
- EMI compliant (with additional input filter)





IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage One - Determination of V_{DC}



Determination of V_{DC}:

→ 30 Vdc

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage One - Selection of the TVS diode

Based on the available parts in the product portfolio of Würth Elektronik

Products

All | DO-214AC 400W Unidirectional | DO-214AC 400W Bidirectional | DO-214AA 600W Unidirectional | DO-214AA 600W Bidirectional | DO-214AB 1500W Unidirectional | DO-214AB 1500W Bidirectional | DO-214AB 3000W Unidirectional | DO-214AB 3000W Bidirectional

Order Code	Data-sheet	Downloads	Status	Technical Reference	V_{DC} (V)	V_{BR} (V)	I_{Peak} (A)	P_{Diss} (W)	$V_{Clamp\ max.}$ (V)
824550301	SPEC	7 FILES	Active	SMDJ30A	30	35.05	62	3000	48.4

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage One - Determination of V_{BR}

Datasheet screenshot “Electrical Properties” TVS diode 824550301:

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
DC Operating Voltage	V_{DC}		30	V	max.
(Reverse) Breakdown Voltage	V_{BR}	1 mA	35.05	V	±5%
Clamping Voltage	V_{Clamp}	I_{PEAK}	48.4	V	max.
(Reverse) Peak Pulse Current	I_{Peak}	10/1000 µs	62	A	max.
(Forward) Peak Pulse Current 1)	I_{Peak}		300	A	max.
Leakage Current	I_{Leak}	V_{DC}	2	µA	max.
Steady State Power Dissipation	P_{Diss}	T_A = 50 °C	6.5	W	max.
Power Dissipation 2)	P_{Diss}	10/1000 µs	3000	W	max.
Polarity	Unidirectional				

1) 8.3 ms single half-sine wave or equivalent square wave. Duty cycle = 4 pulses per minute
2) Mounted on 5.0 mm x 5.0 mm (0.03 mm thick) Copper Pads to each terminal

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage One - Determination of V_{CLAMP_MAX}

Datasheet screenshot “Electrical Properties” TVS diode 824550301:

Electrical Properties:

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DC Operating Voltage	V_{DC}		30	V	max.
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IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage One - Determination of V_{CLAMP_MAX} with Temperature Correction

Equation for temperature influence on V_{CLAMP_MAX} (Tj):

$$V_{CLAMP\_MAX}(T_j) = V_{CLAMP\_MAX}(25\,°C) \cdot \left(1 + \alpha T \cdot \left(T_j - 25\,°C\right)\right)$$

$$V_{CLAMP\_MAX}(25\,°C) = 48.4\ V$$

αT = temperature coefficient $(9.9 \cdot 10^{-4}\ \frac{1}{°C})$

Tj = junction temperature (55 °C)

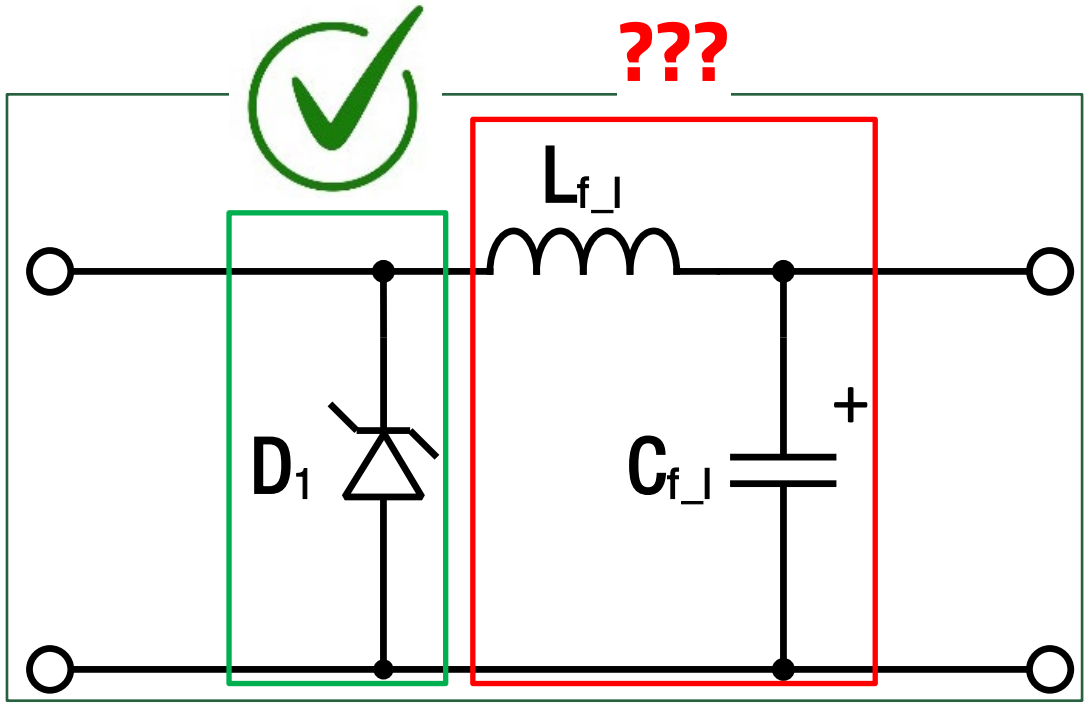
$$V_{CLAMP\_MAX}(55°C) = 48.4\,°C \cdot \left(1 + 9.9 \cdot 10^{-4}\ \frac{1}{°C} \cdot (55°C - 25\,°C)\right)$$

$$V_{CLAMP\_MAX}(55°C) = 49.84\ V$$

→ This value will be now the starting point for the dimensioning of the second stage of the immunity filter.

IMMUNITY FILTER DESIGN LIMITS

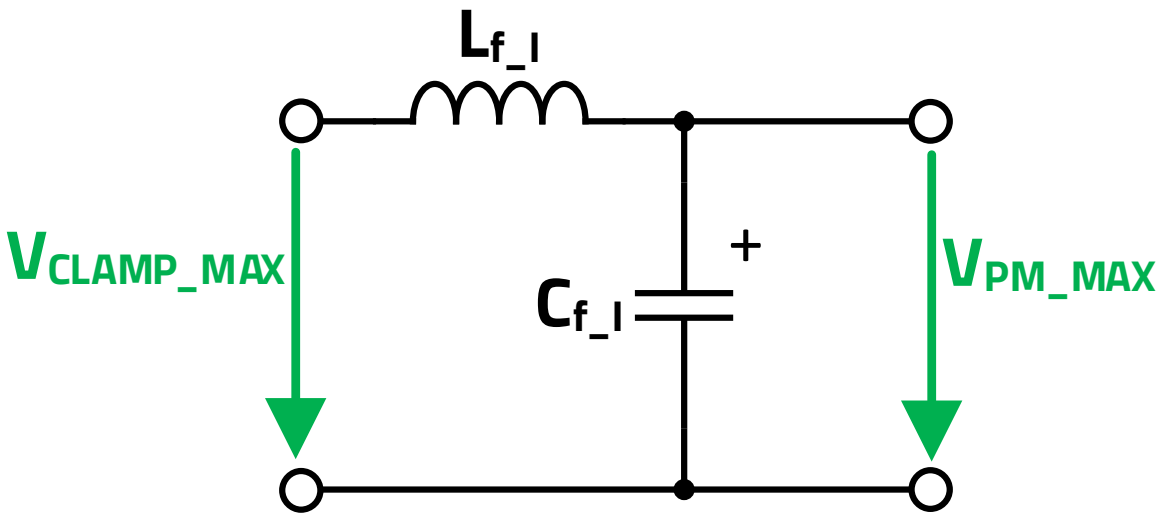
Immunity Filter Stage Two



IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – Required Damping

Immunity – LC – Filter:



Estimation of required filter attenuation:

$$G = 20 \cdot \log\left(\frac{V_{PM\_MAX}}{V_{CLAMP\_MAX}}\right)$$

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – Required Damping

Immunity – LC – Filter:

Table 5: Absolute maximum ratings.

SYMBOL	PARAMETER	LIMIT		UNIT
		MIN(1)	MAX(1)	
VIN	Input pin voltage	-0.3	44	V
VOUT	Output pin voltage	-0.3	25	V
$T_{storage}$	Assembled, non-operating storage temperature	-40	125	°C
V_{esd}	ESD Voltage (Human Body Model), according to EN61000-4-2 (4)	-4	4	kV

$$G = 20 \cdot \log\left(\frac{V_{PM\_MAX}}{V_{CLAMP\_MAX}}\right)$$

$V_{CLAMP\_MAX}(55°C) = 49.84\ V$

$V_{PM\_MAX} = 44\ V$

$$G = 20 \cdot \log\left(\frac{44\ V}{49.84\ V}\right)$$

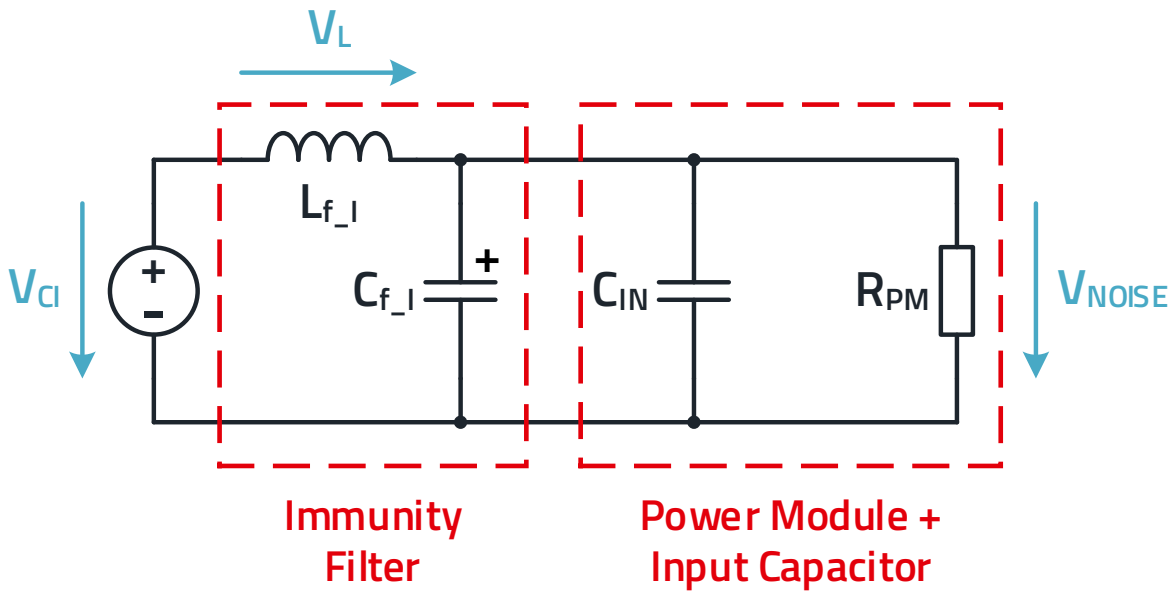
Required filter attenuation:

$$\mathbf{G = -1.08dB}$$

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – Equation

Immunity – LC – Filter + Power Module:



Estimation of required filter attenuation:

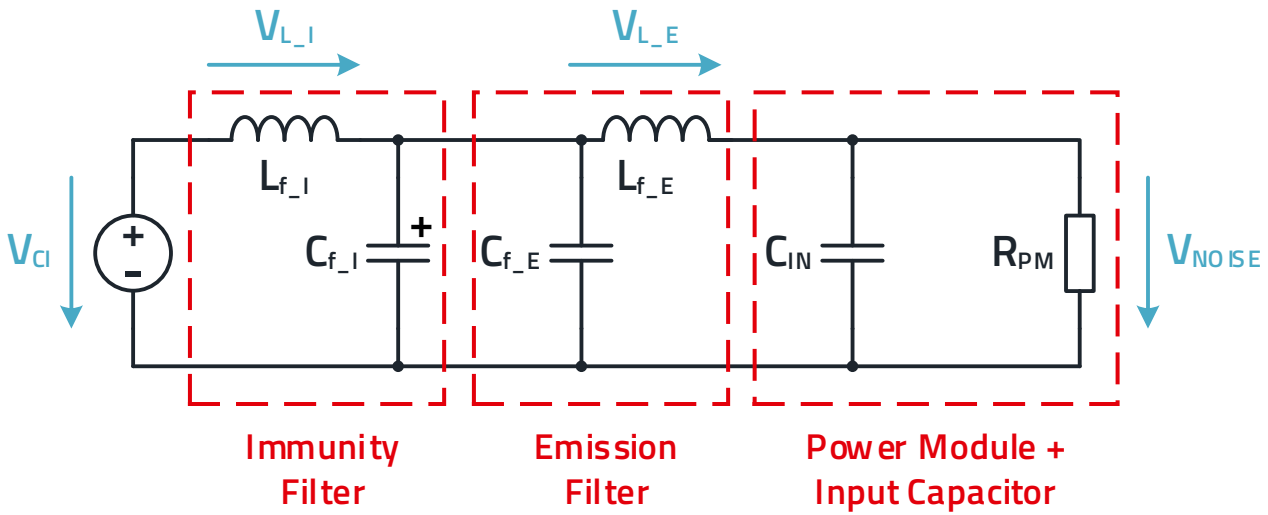
$$G = 20 \cdot \log\left(\left|\frac{V_{noise}}{V_{CI}}\right|\right)$$

$$\frac{V_{noise}}{V_{CI}} = \frac{\frac{1}{Y_{Cf\_I} + Y_{Cin} + Y_{RPM}}}{Z_{Lf} + \left(\frac{1}{Y_{Cf\_I} + Y_{Cin} + Y_{RPM}}\right)}$$

IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – Equation for C_{f_I}

Immunity – LC – Filter + LC-Emission Filter + Power Module:



With additional emission filter the equation is:

$$C_{f\_I} = \frac{1-\left(10^{\frac{G}{10}}-\left(\omega\frac{L_{f\_I}}{R_{PM}}\right)^2\right)^{\frac{1}{2}}}{\omega^2\cdot L_{f\_I}} - \left(C_{in}+C_{f\_E}\right)$$

Needed values:

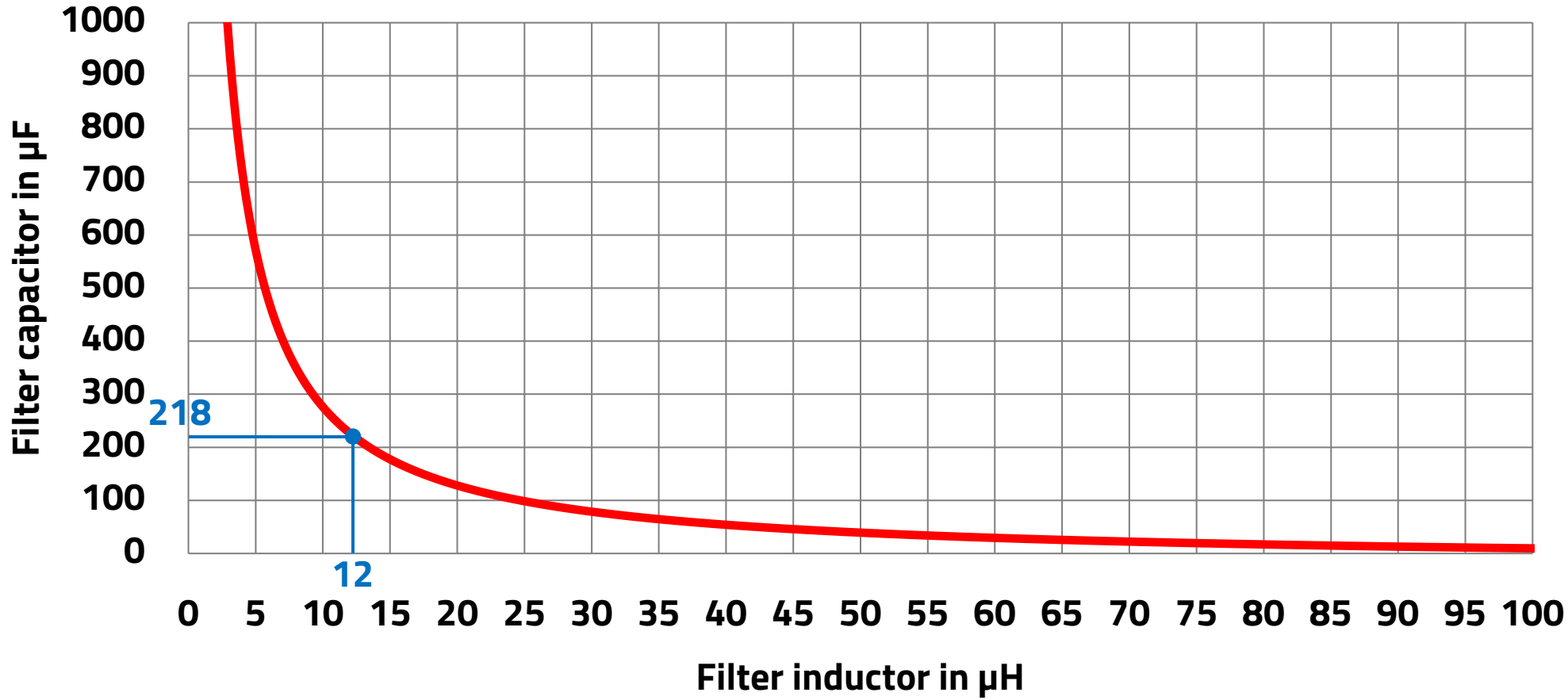
$G = -1.08\text{dB}$ $\quad L_{f\_I} = 12\mu\text{H}$ $\quad R_{PM} = 101\Omega$

$\omega = 1\text{kHz}$ $\quad C_{in} = 2\text{x}4.7\mu\text{F}$ $\quad C_{f\_E} = 2\text{x}4.7\mu\text{F}$

$$C_{f\_I} = \frac{1-\left(10^{\frac{-1.08\text{dB}}{10}}-\left(1\text{kHz}\cdot\frac{12\mu\text{H}}{101\Omega}\right)^2\right)^{\frac{1}{2}}}{1\text{kHz}^2\cdot 12\mu\text{H}} - (2\cdot 4.7\mu\text{F}+2\cdot 4.7\mu\text{F}) = 218\mu\text{F}$$

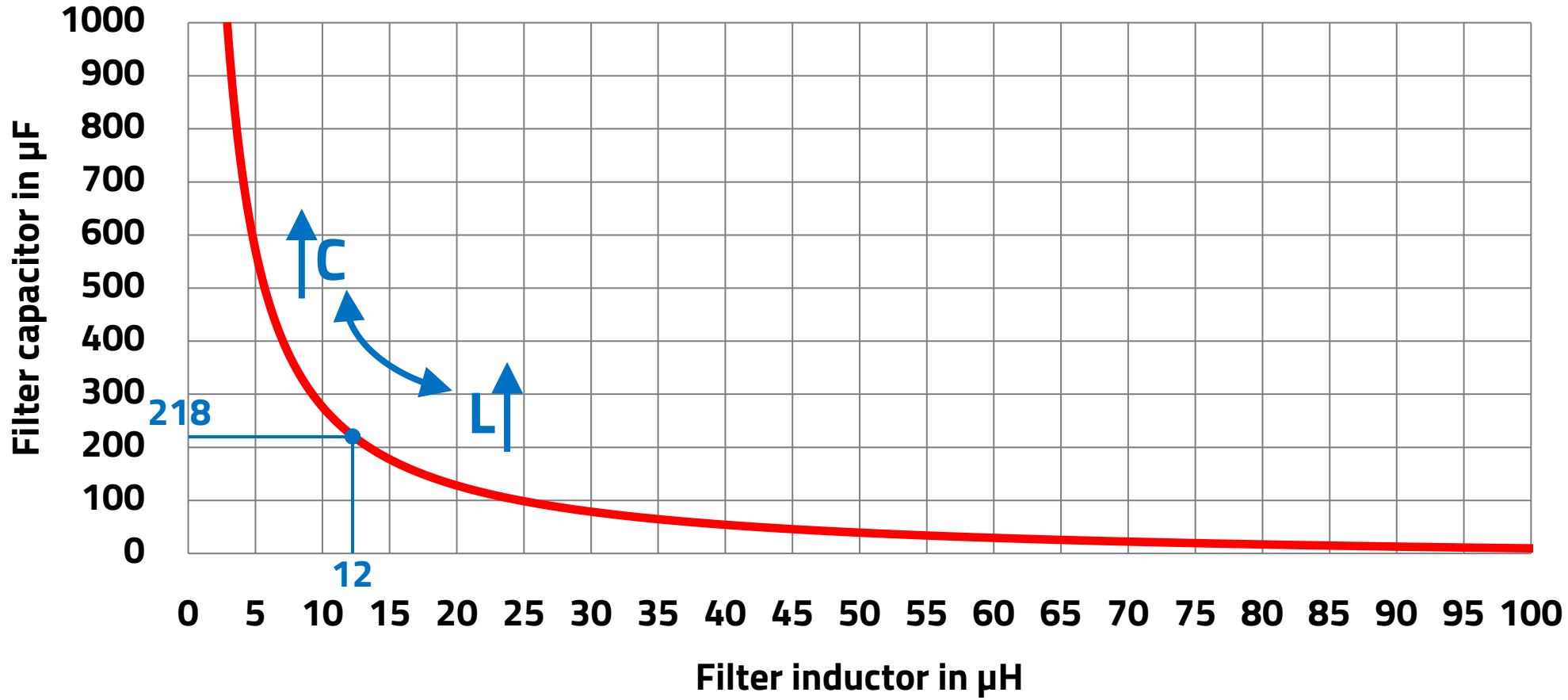
IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – Graphical Approach



IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – Graphical Approach



IMMUNITY FILTER DESIGN LIMITS

Immunity Filter Stage Two – C_{f_I} Comparison

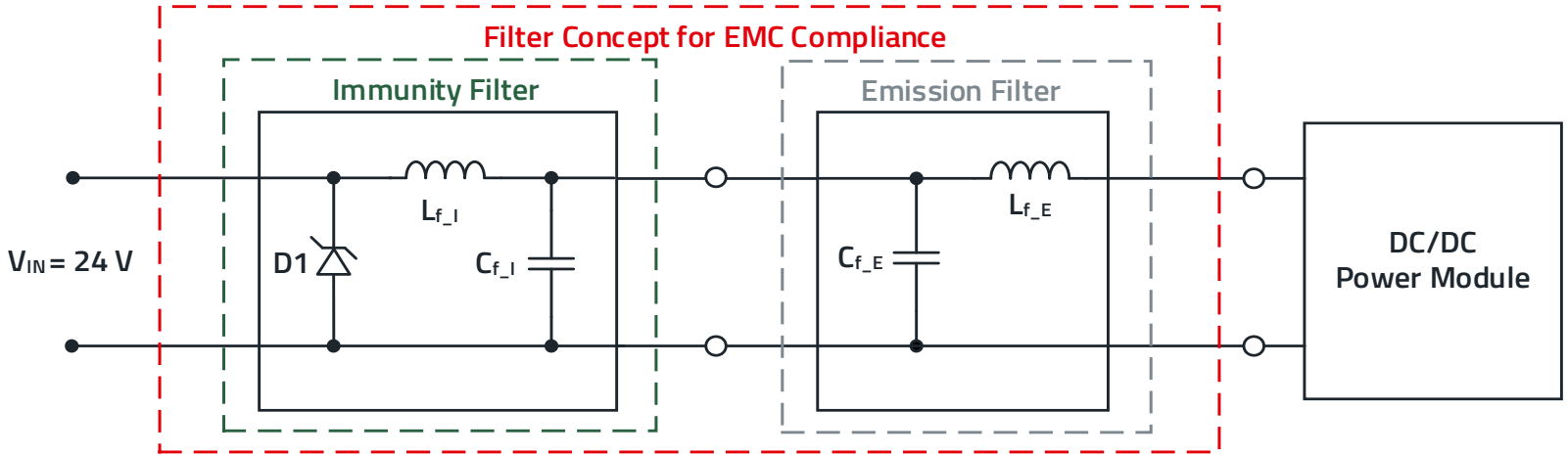
Ambient temperature	$V_{Clamb\ max}$	Filter capacitor
25 °C	48.4 V	178 µF
55°C	49.84 V	218 µF

Difference between 25°C and 55°C, C_{f_I} value ≈ 22%

→ Without consideration of the temperature transient filter would not damp enough

IMMUNITY FILTER DESIGN LIMITS

EMC Filter Concept – Two Stage Concept Design + Emission Filter



Ref. Des.	Description	Qty.	Order Code
D1	WE-TVSP Power TVS Diode V DC = 30 V V BR = 35.05 V I Peak = 62A V Clamp = 48.4 V	1	824550301
L_{f_I}	WE-PD2 SMT Power Inductor 12 µH / IR = 2.72 A; Isat = 3.15 A	1	744776112
C_{f_I}	WCAP-ATG8 Aluminium Electrolytic Capacitors THT Radial; 220 µF / 63 V	1	860010775018
C_{f_E}	WCAP-CSGP General Purpose MLCC 4.7 µF/50V X5R, 1210	2	885012209048
L_{f_E}	WE-PD2 SMT Power Inductor 4.7 µH, PD2 family, ISAT = 2.46 A, IR = 1.82 A	1	744773047

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Services

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- Design-In Support
- EMC Filter Design Support
- Layout Review Support
- Thermal Design Support

Services

- **ADM trainings**
- **ADM basic technical support**
- **ADM pricing and lead time support**
- **Customer trainings/seminars**
- **Visit focus customers**
- **Business tracking / reports**
- **Sales app (define and provide content)**
- **Sales tools (Product Overview, Show Boards)**

Thank you for your attention!!!

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Timur Uludag Senior Technical Marketing Manager

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT