Surge & EMI Filter Recommendations for 4W up to 200W Modules

- To comply with surge requirements of :
  - EN50155 standard
  - 61000-4-5 standard
- To comply with EMI requirements of :
  - EN50121-3-2
  - EN50121-4
  - EN55011 class A
- Power range up to 200W

1- Subject

This design note describes some electrical schematics that enables GAIA Converter DC/DC module to be protected against surges and to be compliant with EMI requirements.

Surges are 'short term' high transient voltage on the input bus that are mainly generated by lightning strokes, arcing faults, load changing or short circuits.
A surge may be of each polarity. The effective value of the source impedance will depend upon the manner of its generation but will in many circumstances be very low and energetic. Stand alone DC/DC modules cannot sustain such levels.

EMI levels are those described in generic standards.

This application note will describe filters that are compliant with the following standards :

- **Surges requirement of :**
  - **EN50155**
    - Direct spike line to line :
      - Level 1,8 KV waveform 5/50µs impedance 100 Ohm
      - Level 1,8 KV waveform 5/50µs impedance 5 Ohm
    - Direct spike line to earth :
      - Level 4 KV waveform 5/50µs impedance 100 Ohm
  - **EN61000-4-5 (IEC-801-5)**
    - Direct spike line to line :
      - Level 2 KV waveform 1,2/50µs impedance 2 Ohm
      - Level 2 KV waveform 10/700µs impedance 42 Ohm
    - Direct spike line to earth :
      - Level 2 KV waveform 1,2/50µs impedance 12 Ohm
      - Level 2 KV waveform 10/700µs impedance 42 Ohm

- **EMI requirement of :**
  - **EN50155** which is linked to EN50121-3-2 and EN55011 for rolling stock equipment
  - **EN50121-4** for signalling and telecommunications equipement
  - **EN50121-5** for fixed power supply installation

2- Requirements Related to Surges

Major requirements related to surges are described in various standards :

- **EN50155** : «Railways application electronic equipment used on rolling stock»
- **EN61000-4-5** : «Electromagnetic, compatibility, testing and measurement. Immunity Standard - Surge Immunity»
- **HN-46-R01** : «General guidelines for the design and manufacturing of control, protection and telecommunication equipment for electrical network»
- **EN60255** : «Electrical Relays- section 4 part 1»

The standards EN61000-4-5 and EN50155 specify that the input voltage supply shall be present.
The standards HN-46R01 and EN60255 specify that no input voltage supply shall be present during the test.

2-1 EN61000-4-5

This standard specifies two different surge wave forms :

- one wave form with a rise time of 1.2µs and a time to half value of 50µs
- the other wave form with a rise time of 10µs and a time to half value of 700µs.

The source impedance for the 1.2/50µs is 2 Ohm for line to line coupling and 12 Ohm for line to earth coupling. The 10/700µs surge impedance is 42 Ohm both for line to line coupling and line to earth coupling.

Coupling for both waveforms is performed via a coupling/ decoupling network with coupling capacitors of 0.1, 0.5, 9 or 18 µF, or with arrestors, depending on the kind of lines to be tested.
The following levels are described :

Test level	Open circuit test voltage KV	Impedance
1	0.5 KV	2 or 42 Ohm
2	1 KV	2 or 42 Ohm
3	2 KV	2 or 42 Ohm
4	4 KV	2 or 42 Ohm

2-2 EN50155

This standard specifies :

- one surge wave forms (A) with a rise time of 5µs and a time to half value of 50µs with a level of 1,8 KV.
- one surge wave forms (B) with a rise time of 0.05µs and a time to half value of 0.1µs with a level of 8,4 KV.

The source impedance is 100 Ohm and can be 5 Ohm in specific cases.

Test level	Test voltage KV	Impedance
Direct spikes level A	1.8 KV	5 or 100 Ohm
Direct spikes level B	8,4 KV	5 or 100 Ohm
Indirect spikes level A	1,8 KV	100 Ohm
Indirect spikes level B	8,4 KV	100 Ohm

2-3 HN-46-R01

This standard specifies a surge wave forms with a rise time of 5µs and a time to half value of 50µs. The source impedance is 500 Ohm and the following levels applied depending of the class of equipement. No input voltage is applied on the DC/DC converter.

Class	Level line earth	Level line to line	Impedance
A1	8 KV	8 KV	500 Ohm
A2	5 KV	5 KV	500 Ohm
B	5 KV	5 KV	500 Ohm
C1	5 KV	5 KV	500 Ohm
C2	3 KV	3 KV	500 Ohm
D	1 KV	1 KV	500 Ohm
E	0.5 KV	0.5 KV	500 Ohm

2-4 EN60255

This standard specifies a surge wave forms with a rise time of 1.2µs and a time to half value of 50µs. The source impedance is 500 Ohm and the following levels applied depending of the class of equipement. No input voltage is applied on the DC/DC converter.

Test level	Open circuit test voltage KV	Impedance
2	1 KV	500 Ohm
3	5 KV	500 Ohm

3- Requirements Related to Electromagnetic Interference

Railway electronic systems are subjected to different level of electromagnetic interference requirements.
Those requirements are defined by the most commonly used EN50121 standard : "EMC standard for the Railway Environment" which is divided in different sections :

- EN50121-3-2 section : "Railways Applications Electromagnetic Compatibility Part 3-2 Rolling Stock Apparatus",
- EN50121-4 section : "Railways Applications Electromagnetic Compatibility Part 4 : Emission and Immunity of the Signalling and Telecommunication Apparatus",
- EN50121-5 section : "Railways Applications Electromagnetic Compatibility Part 5 : "Emission and immunity of fixed power supply installations and apparatus",

The applicability and the different requirements and levels are depending on location and are resumed in the different sections of EN50121 standard.
EN50121-3-2 for on board equipement (locomotive, driver's cab, passenger components, interior of power equipment)
EN50121-4 for signalling and telecommunication equipments.
EN50121-5 for fixed power supply installation (substation)

It is important to note that DC/DC converters are considered as components and the requirements are applicable to the total electronic equipment apparatus defined as "a finished product with an intrinsec function intended for implementation into a rolling stock installation, but not at a component level".

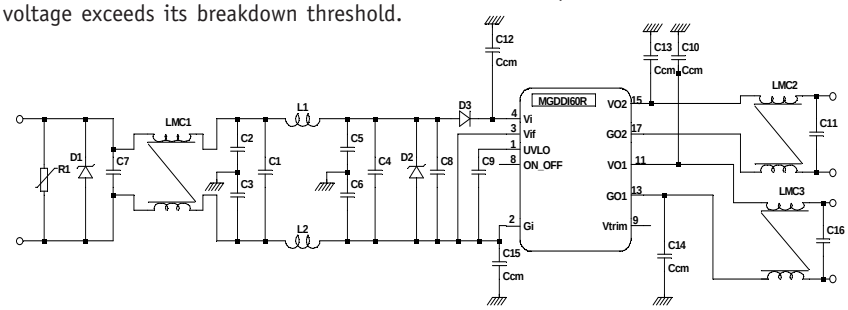
The table there after resumes the requirements related to radiated and conducted emission only.
EN50155 is only referring to EN50121-3-2 section.

Requirements	Generic Standards	Requirements	GAIA Converter module compliance
Electromagneticconducted emission <30MHz 0,09 - 0,15 MHz (quasi peak) 0,15 - 0,5 MHz (quasi peak) 0,5 - 30 MHz (quasi peak)	EN50155 EN50121-3-2	EN55011 level +20 dB : No limits 79 dB/µV/m+20dB (quasi peak) 73 dB/µV/m+20dB (quasi peak)	Compliant with filter
Radio magnetic emission 30 MHz - 230 MH 230 MHz - 1 GHz	EN50155 EN50121-3-2	Measurement at 10 m 40 dBµV/m 47 dBµV/m	Compliant with filter
Electromagneticconducted emission <30MHz 0,15 - 0,5 MHz (quasi peak) 0,5 - 5 MHz (quasi peak) 5 - 30 MHz (quasi peak)	EN50121-4	EN55011 level : 79 dB/µV/m (quasi peak) 73 dB/µV/m (quasi peak) 73 dB/µV/m (quasi peak)	Compliant with filter
Radio magnetic emission 30 MHz - 230 MH 230 MHz - 1 GHz	EN50121-4	Measurement at 10 m 40 dBµV/m 47 dBµV/m	Compliant with filter
Electromagneticconducted emission <30MHz 0,15 - 0,5 MHz (quasi peak) 0,5 - 5 MHz (quasi peak) 5 - 30 MHz (quasi peak)	EN50121-5	EN55011 level : 79 dB/µV/m (quasi peak) 73 dB/µV/m (quasi peak) 73 dB/µV/m (quasi peak)	Compliant with filter
Radio magnetic emission 30 MHz - 230 MH 230 MHz - 1 GHz	EN50121-5	Measurement at 10 m 40 dBµV/m 47 dBµV/m	Compliant with filter

3- Proposed Schematics & Components

To sustain such energetic surges, protection devices must be capable of handling the high energy level during surge. Most commonly selected components for this purpose are «Metal Oxyde Varistor» (MOV), which offers the unique feature of being very good conductors of current if the applied voltage exceeds its breakdown threshold.

MOV has to be used with companion avalanche devices such as Transzorbs or Zener diodes; this solution guaranty that the MOV will provide the high energy handling capability while the avalanche device supresses the initial spike that the MOV cannot dampen.



Ref.	Components Type	Max. Power	Components for input 24V	Components for input 48V	Components for input 72V	Components for input 96V	Components for input 110V
R1	MOV Varistor	up to 50W	V56Z8X1347 Little Fuse	V100ZA15 Little Fuse	V150ZA8 Little Fuse	V150ZA8 Little Fuse	V150ZA8 Little Fuse
		up to 80W	V56Z8X1347 Little Fuse	V100ZA15 Little Fuse	V150ZA8 Little Fuse	V150ZA8 Little Fuse	V150ZA8 Little Fuse
		up to 200W	V56Z8X1347 Little Fuse	V100ZA15 Little Fuse	V150ZA8 Little Fuse	V150ZA8 Little Fuse	V150ZA8 Little Fuse
F1*	Fuse	up to 50W	10A slow	10A slow	8A slow	5A slow	5A slow
		up to 80W	10A slow	10A slow	8A slow	5A slow	5A slow
		up to 200W	20A slow	10A slow	8A slow	5A slow	5A slow
D1/D2	Transorb TVS	up to 200W	5KP40A	5KP70A	5KP100A	5KP130A	5KP150A
D3	Diode	up to 200W	schottky diode	schottky diode	schottky diode	schottky diode	schottky diode
LMC1*	Common Mode Choke	up to 50W	No LMC1 required	No LMC1 required	NO LMC1 required	No LMC1 required	No LMC1 required
		up to 80W	2 x 450 µH 6,5A	2 x 450 µH 6,5A	2 x 0.5 mH 6,5A	2 x 0.5 mH 6,5A	2 x 0.5 mH 6,5A
		up to 200W	2 x 1 mH 20A	2 x 1 mH 20A	2 x 1 mH 20A	2 x 1 mH 20A	2 x 1 mH 20A
L1, L2	Inductor	up to 50W	100 µH, L2 not required	100 µH, L2 not required	100 µH, L2 not required	100 µH, L2 not required	100 µH, L2 not required
		up to 80W	10 µH	10 µH	10 µH	10 µH	10 µH
		up to 200W	10 µH	10 µH	10 µH	10 µH	10 µH
C1, C4	Capacitor	up to 50W	100 nF, type MKP339serie (Vishay)	100 nF, type MKP339serie (Vishay)	100 nF, type MKP339serie (Vishay)	100 nF, type MKP339serie (Vishay)	100 nF, type MKP339serie (Vishay)
		up to 80W	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)
		up to 200W	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)
C7	Capacitor	up to 50W	No C7 required	No C7 required	No C7 required	No C7 required	No C7 required
		up to 80W	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)
		up to 200W	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)	220 nF, type MKP339serie (Vishay)
C8	Aluminium Electrolytic Cap.	up to 50W	22µF type UPW1H220MDD1TD	22µF Type UPW2A220MPD1TD	22µF Type UPW2A220MPD1TD	22µF TypeUPW2D220MPD1-TD	22µF TypeUPW2D220MPD1TD
		up to 80W	47µF type UPW1H470MED1TD	47µF type UPW2A470MPD1TD	47µF type UPW2A470MPD1TD	47µF type UPW2D470MHD1TO	47µF type UPW2D470MHD1TO
		up to 200W	100µF type UPW1H101MPD1TD	100µF type UPW2A101MHD1TO	100µF type UPW2A101MHD1TO	100µF type EKMG201ELL101ML2-5S	100µF type EKMG201ELL101ML25S
C9*	Ceramic capacitor	up to 200W	10 µF ceramic low ESR	10 µF ceramic low ESR	10 µF ceramic low ESR	10 µF ceramic low ESR	10 µF ceramic low ESR
C2, C3, C5, C6,	Capacitor	up to 50W	Not required	Not required	Not required	Not required	Not required
		up to 200W	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage
C10,C12,C-13,C14,C1-5	Ceramic capacitor	up to 50W	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage
		up to 200W	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage	10 nF rated voltage
LMC2 LMC3	Common mode inductor	depends on output voltage & current	output common mode inductor are not mendatory but can be used for noise sensitive application (ex : output voltage distributed over long wire, video , audio or radiofrequency applications...) values can be from 220µH to 470µH with rated current.				
C11,C16	Aluminium Electrolytic Cap.	depends on output voltage & current	C11, C16 are not mendatory but can be used for noise sensitive applications (ex : output voltae distributed over long wire, video , audio or radiofrequency applications...) values can be from 47µF to 220µF				

* notes : see on following page

3- Notes on Proposed Schematics & Components

Notes* :

This precedent schematics is proposed as multi-purpose filter that may need to be optimized according to customer application.

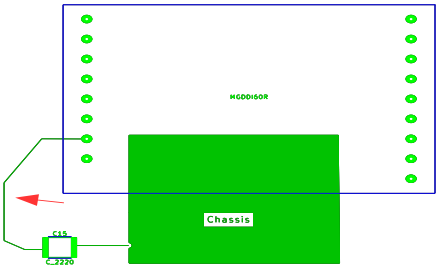
• **Note on fuse :** fuse may be not allowed depending on the application and by some authorities. In any case please adjust fuse rating to power effectively used in the application.

• **Note on inductors :** inductors LMC1, L1 and L2 can be rated according to input current required.

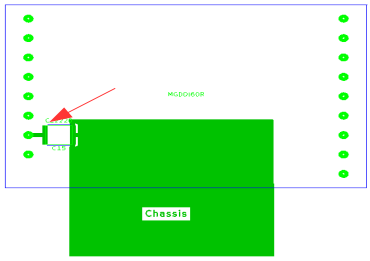
• **Note on capacitor C9** : This capacitor is used only for those converters which have a Vif function.
In all other cases, this component is not required.

• **Note on common mode noise capacitance C12 to C15 and C10:** The common mode noise capacitance Cc can be used to reduce noise well below the levels of EN55011 class A. Those capacitors need to be placed as closer as possible to the converter pin to be efficient. The value of this capacitance depends on isolation requirements (typically 10nF/1.500V or 10nF/3.000V). In case of dielectric strengh test in AC mode, adapt the capacitance value in order to be compatible with maximum admissible leakage current required.
In some applications the secondary side of the DC/DC converter has to be hearthed. In this case **it is not recommended** to use common mode noise capacitance as in case of disturbance, it will flow over to the earthing point creating negativ effects. In such a case EMI levels will be compliant with EN55011 class A.

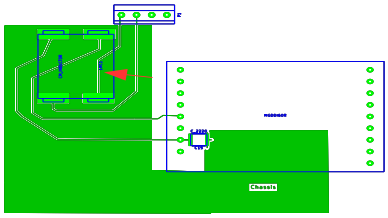
The following pictures here under show good and bad practises concerning common mode component positions, and connections.



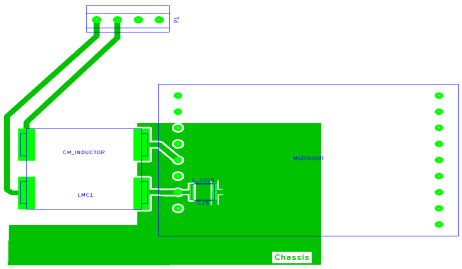
Poor connection of ccm capacitor, too far from the dc/dc pin and too thin tracks become inductive and source of oscillation



Good position and connection of ccm capacitor



Poor connection of LCM1, Tracks are too thin,tracks coupled noise from one side to the other of the inductor, inductor is too far from source noise



Goor position and connection of LCM1, no chassis plane below LCM1

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