



Surge Filter Recommendations for 4W up to 50W Modules

- To comply with transient requirements of :
 - EN50155 standard
 - 61000-4-5 standard
- To comply with EN55011 class A
- Power range up to 50W
- Small surface
- Temperature range : -40°C/+85°C (ambient)



1- Subject

This design note describes an electrical schematics that enables GAIA Converter DC/DC module to be protected against surges generally occurring in railways applications.

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 either 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. This design note will cover the surge levels described in different standards as follow:

- Surges requirement of :
 - EN50155
 - Direct spike line to line :
 - Level 1,8 KV waveform 5/50 μ s impedance 100 Ohm
 - Level 1,8 KV waveform 5/50 μ s impedance 5 Ohm
 - Direct spike line to earth :
 - Level 4 KV waveform 5/50 μ s impedance 100 Ohm
 - EN61000-4-5 (IEC-801-5)
 - Direct spike line to line :
 - Level 4 KV waveform 1,2/50 μ s impedance 2 Ohm
 - Level 4 KV waveform 10/700 μ s impedance 42 Ohm
 - Direct spike line to earth :
 - Level 4 KV waveform 1,2/50 μ s impedance 12 Ohm
 - Level 4 KV waveform 10/700 μ s impedance 42 Ohm
 - EN60255-4 part 2
 - Direct spike line to earth and line to line :
 - Level 5 KV waveform 1.2/50 μ s impedance 500 Ohm

GAIA Converter proposes 2 schematics depending on the input bus nominal voltage :

- **Schematics 1** : adapted for 24 or 37,5 VDC nominal input bus and GAIA Converter modules with 9-36 VDC (H series) or 16-40 VDC (J series) input range.
- **Schematics 2** : adapted for 48, 72, 96, 125 VDC nominal input bus and GAIA Converter modules with 36-140 VDC (Q series) input range.

These 2 schematics are based on the same basic principle. They include a filter cell and a surge protection cell with transil diodes.

2- Major Standards Related to Surges

The following standards for surges are covered :

- **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 with a rise time of 1.2µs and a time to half value of 50µs
- the other 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 applied :

| 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 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 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 D | 1.8 KV | 5 or 100 Ohm |
| Direct spikes level G | 8,4 KV | 5 or 100 Ohm |
| Indirect spikes level H | 1,8 KV | 100 Ohm |
| Indirect spikes level L | 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

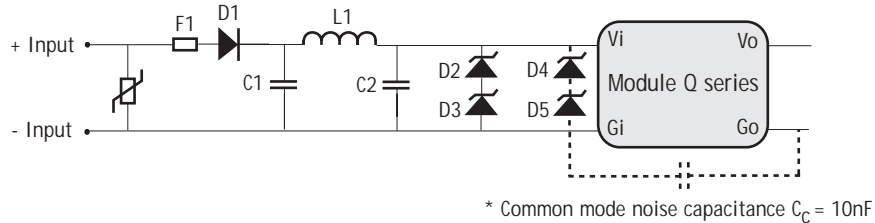
This standard specifies a surge wave forms with a rise time of 1.2µs and a time to half value of 50µs. The source impedance is 500 Ohm and the following levels applied depending of the class of equipement. No input voltage is applied on the DC/DC converter.

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

3- Schematics Adapted for Nominal Bus of 48, 72, 96, 110, 125 VDC

To sustain such energetic surges, protection devices must be capable of handling the high energy level and long duration of 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.

However MOV may not react quickly enough to a fast rise-time signal. MOV has to be used with faster avalanche devices such as Transzorbis or Zener diodes; this solution guarantees that the MOV will provide the high energy handling capability while the avalanche device suppresses the initial spike that the MOV cannot dampen.



- C1, C2..... : Capacitor standard type MKT 100nF, 275 Vac, 20% X2
- D1..... : Diode type Philips 1N4007
- D2, D3, D4, D5..... : Transil Diode standard type 5KP64A
- F1*..... : Fuse standard type SUB5-T2A
- L1..... : Inductance type Vishay-Aztronic IG 120 100 μH +/-20% R
- R1..... : Varistance Harris V150ZA8

Notes :

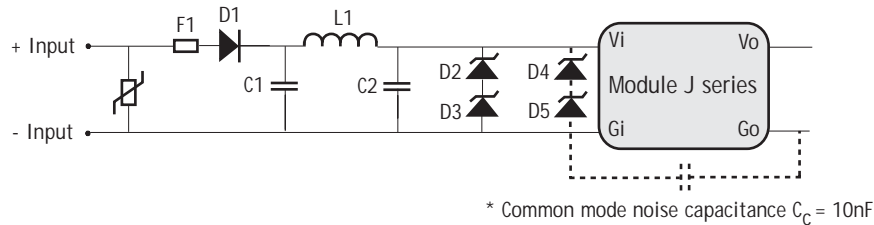
- **Note on fuse** : Fuse may be not allowed depending on the application and by some authorities. In any case please adjust fuse rating to power effectively used in the application.
- **Note on common mode noise capacitance** : The common mode noise capacitance C_c can be used to reduce noise well below the levels of EN55011 class A. The value of this capacitance depends on isolation requirements (typically 10nF/1.500V or 10nF/3.000V). In case of dielectric strength 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 heathered. 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.
- **Note on D2, D3, D4, D5** : the typical schematics include 4 transil diode components to sustain the highest energy level specified in the different standards. If your levels are lower you can use only two components (ex D2 and D3). The following table proposes some examples of achieved levels :

| Number of diodes | Standards | Levels achieved | Impedance |
|------------------|-------------|-----------------|-----------|
| 2 | EN61000-4-5 | 2 KV | 12 Ohm |
| 2 | EN50155 | 1.8 KV | 100 Ohm |
| 2 | HN-46-R01 | 5 KV | 500 Ohm |

4- Schematics Adapted for Nominal Bus of 24, 37.5 VDC

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

However MOV may not react quickly enough to a fast rise-time signal. MOV has to be used with faster avalanche devices such as Transzorb or Zener diodes; this solution guarantees that the MOV will provide the high energy handling capability while the avalanche device suppresses the initial spike that the MOV cannot dampen.



- C1,C2..... : Capacitor standard type MKT 100nF, 275 Vac, 20% X2
- D1..... : Diode type Philips BYV 29-500
- D2, D3..... : Varistance Harris type V22ZA2
- D4, D5..... : Varistance Harris type V22ZA2
- F1*..... : Fuse standard type SUB5-T2A
- L1..... : Inductance type Vishay-Aztronic IG 120 100µH +/-20% R
- R1..... : Varistance Harris type V47ZA7

Notes :

- **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 common mode noise capacitance :** The common mode noise capacitance C_c can be used to reduce noise well below the levels of EN55011 class A. The value of this capacitance depends on isolation requirements (typically 10nF/1.500V or 10nF/3.000V). In case of dielectric strength 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.
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5- Lay-out Recommendation

Good printed circuit board layout design is essential to achieve proper performance. The two key areas to consider while laying-out a board are :

- Grounding design,
- Component and trace routing.

5-1 Grounding design

GAIA Converter recommend to use four layer boards. The two outer layers will be used for power and ground planes, and the two inner layers for low levels signals. Where necessary, extra planes to beef-up high current paths can be added on the inner layers.

We recommend that the top layer, located closest to the modules, be used for the ground planes and divided into two parts as follow (see also schematics):

- primary ground part
- secondary ground part,

Both parts must be as large as possible and spread out over the entire surface of the board; a grid could be used to avoid a complete copper surface.

If a common mode noise capacitance can be used, GAIA Converter recommend to lay it out as close as possible of the module; this one can be layed-out under the converter. If more than one module is used, additionnal common mode noise capacitance are recommended.

The «case» pin of the modules (when available) can be connected either to primary or secondary ground plane and a 6 sides shielding can be achieved with the PCB ground plane.

5-2 Component and trace routing design

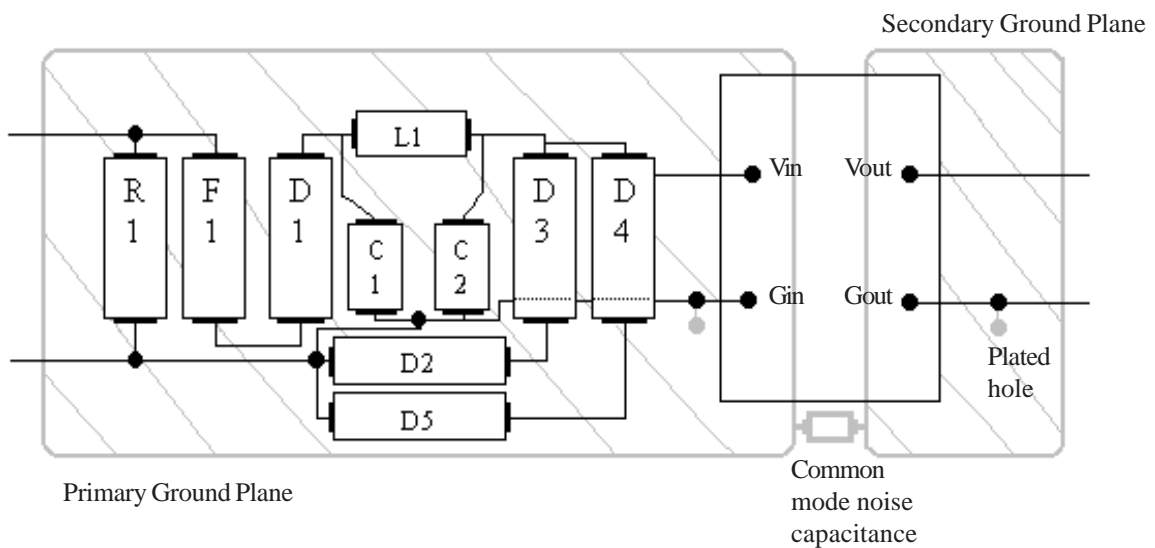
The component placement is also a key factor between a good result and a nightmare.

The first step in placing the component is to determine the power flow thru the board. The most popular flow structure is from one side of the board to the other and avoiding cross-overs.

If more than one DC/DC modules is used it is recommended to place the modules side-by-side so that the power signals can be easily routed avoiding croos-overs. It is also recommended to leave 1/2 inch between each module to avoid that radiation from power stage of one module can affect the control stage of the adjacent module and cause cross-talk.

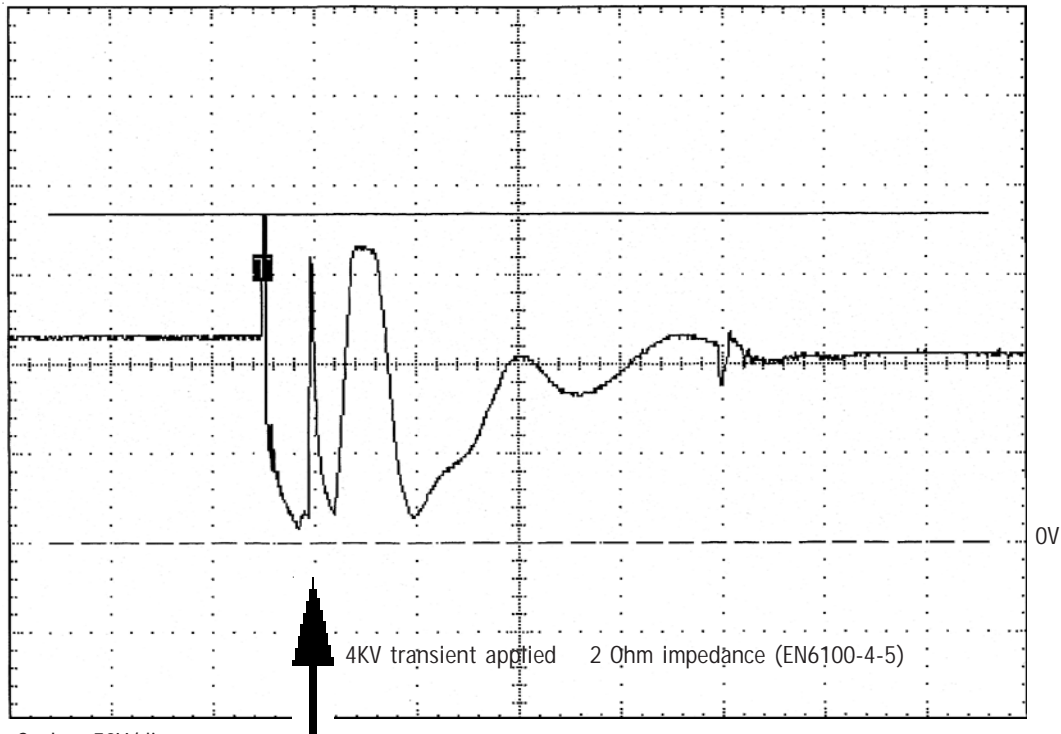
It is recommended to lay-out tracks large enough to accept the necessary power and spikes for D2, D3, D4, D5 and R1.

The following lay-out is recommended.



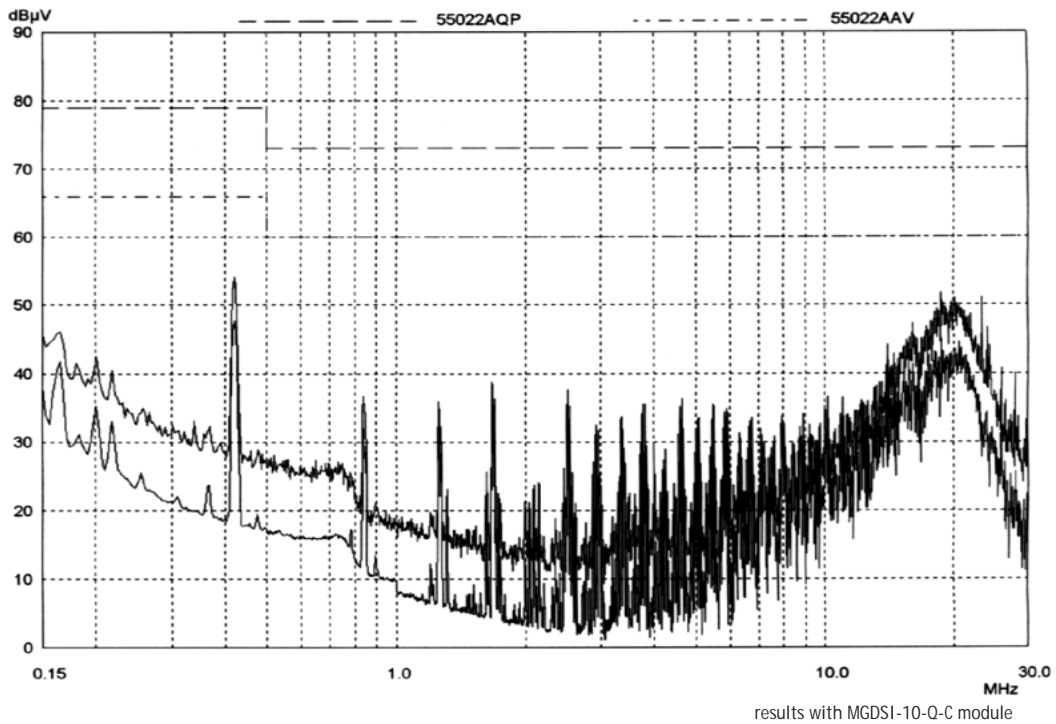
6- Waveform Level with Module Protected with Surge Filter :

6-1 Transient Response of Module with Front Filter



Scale : 50V/div
1ms/div

6-2 Emission Level with Module Filtered





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