- To comply with transient requirements of EN50155 and 61000-4-5
- To comply with EN55011 class A
- Power range up to 50W
- Small surface
- Temperature range : -55°C/+85°C (ambient)

1- Subject

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. To protect DC/DC modules against these surges, Gaia Converter proposes an application schematics that make GAIA Converter DC/DC converter fully compliant with the surge levels described in different standards as follow:

- **Surges requirement of :**
  - **EN61000-4-5 (IEC-801-5)**
    - Direct spike line to line :
      - Level 4 KV waveform 1,2/50µs impedance 2Ω
      - Level 4 KV waveform 10/700µs impedance 42Ω
    - Direct spike line to earth :
      - Level 4 KV waveform 1,2/50µs impedance 12Ω
      - Level 4 KV waveform 10/700µs impedance 42Ω
  - **EN50155**
    - Direct spike line to line :
      - Level 1,8 KV waveform 5/50µs impedance 100Ω
      - Level 1,8 KV waveform 5/50µs impedance 5Ω
    - Direct spike line to earth :
      - Level 4 KV waveform 5/50µs impedance 100Ω
  - **HN46-R-01**
    - Direct spike line to earth and line to line :
      - Level 8 KV waveform 5/50µs impedance 500Ω
  - **EN60255-4 part 2**
    - Direct spike line to earth and line to line :
      - Level 5 KV waveform 1.2/50µs impedance 500Ω
- **EMI requirements of :**
  - EN55011 class A conducted noise emission

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

- **KG9503J :** 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.
- **KG9503Q :** 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 Spikes

The following standards for spikes are covered by the KG9503 kit of components :

- **EN61000-4-5** : «Electromagnetic, compatibility, testing and measurement. Immunity Standard - Surge Immunity»
- **EN50155** : «Railways application electronic equipment used on rolling stock»
- **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	2Ω or 42Ω
2	1 KV	2Ω or 42Ω
3	2 KV	2Ω or 42Ω
4	4 KV	2Ω or 42Ω

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 100Ω and can be 5Ω in specific cases.

Test level	Test voltage KV	Impedance
Direct spikes level D	1.8 KV	5Ω or 100Ω
Direct spikes level G	8,4 KV	5Ω or 100Ω
Indirect spikes level H	1,8 KV	100Ω
Indirect spikes level L	8,4 KV	100Ω

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 500Ω 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	500Ω
A2	5 KV	5 KV	500Ω
B	5 KV	5 KV	500Ω
C1	5 KV	5 KV	500Ω
C2	3 KV	3 KV	500Ω
D	1 KV	1 KV	500Ω
E	0.5 KV	0.5 KV	500Ω

2-4 EN60255

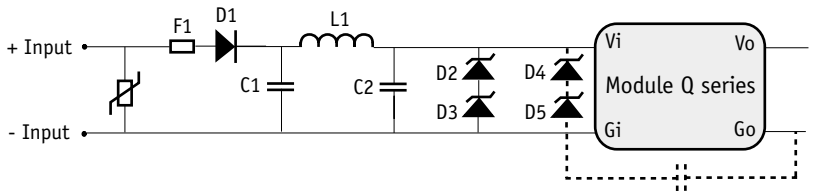
This standard specifies a surge wave forms with a rise time of 1.2µs and a time to half value of 50µs. The source impedance is 500Ω and the following levels applied depending of the class of equipement. No input voltage is applied on the DC/DC converter.

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

3- KG9503Q : 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 Transzorbs or Zener diodes; this solution guarantees that the MOV will provide the high energy handling capability while the avalanche device supresses the initial spike that the MOV cannot dampen.



* Common mode noise capacitance C_C = 10nF

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 100µH +/-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 Cc 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 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.

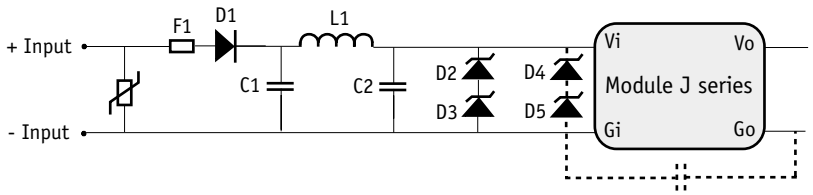
• **Note on D2, D3, D4, D5** : the KG9503 typical schematics include 4 transil diode components to sustain the highest energy level specified in the different standards. If your levels are lower you can use only two components (ex D2 and D3). The following table proposes some examples of achieved levels :

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

4- KG9503J : 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 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 Transzorbs or Zener diodes; this solution guarantees that the MOV will provide the high energy handling capability while the avalanche device supresses the initial spike that the MOV cannot dampen.



* Common mode noise capacitance C_C = 10nF

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 Cc 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 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.

• **Note on D2, D3, D4, D5** : the KG9503 typical schematics include 4 varistance components to sustain the highest energy level specified in the different standards. If your levels specified in the different standards 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 Ω
2	EN50155	1.8 KV	100 Ω
2	HN-46-R01	5 KV	500 Ω

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):

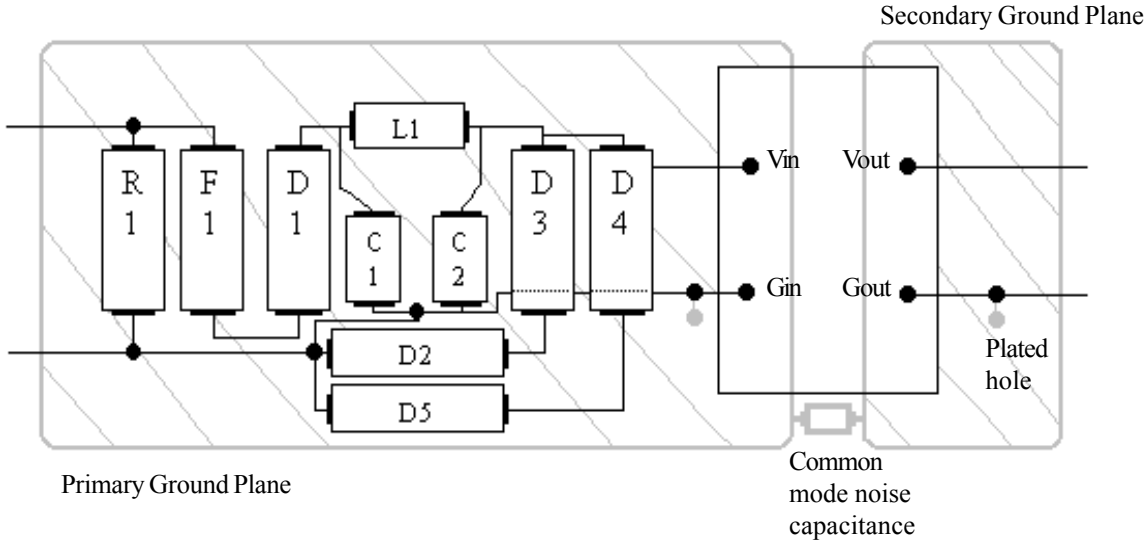
- primary ground part
- secondary ground part,

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

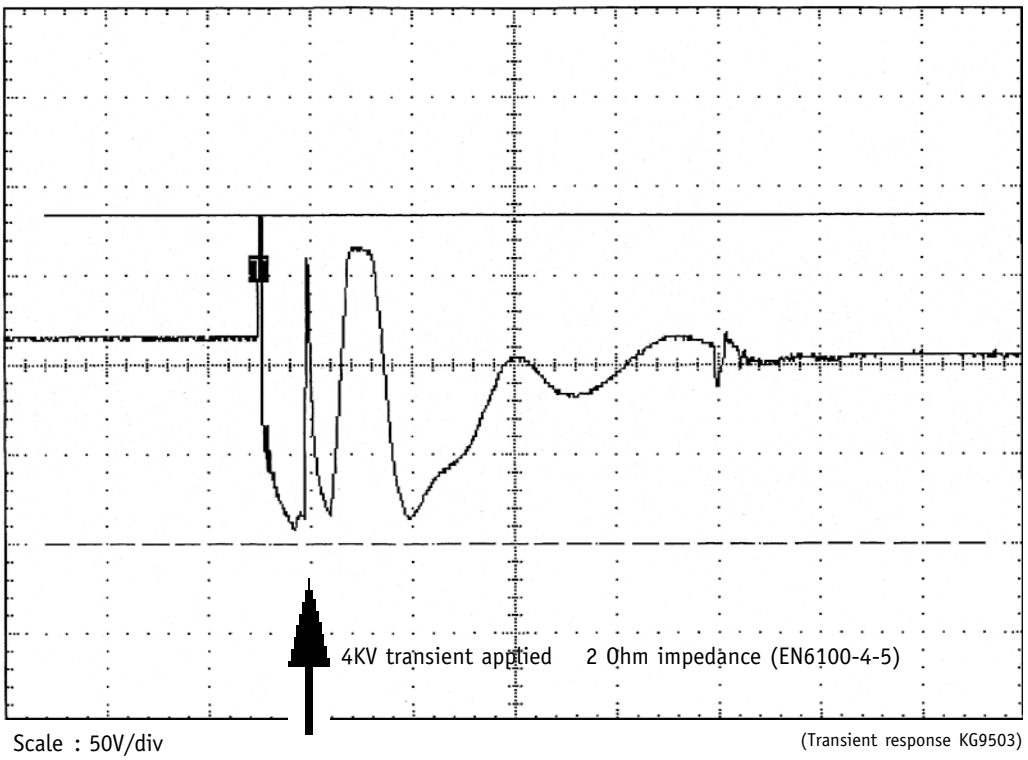
The component placement is also a key factor between a good result and a nightmare.

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 by KG9503 :

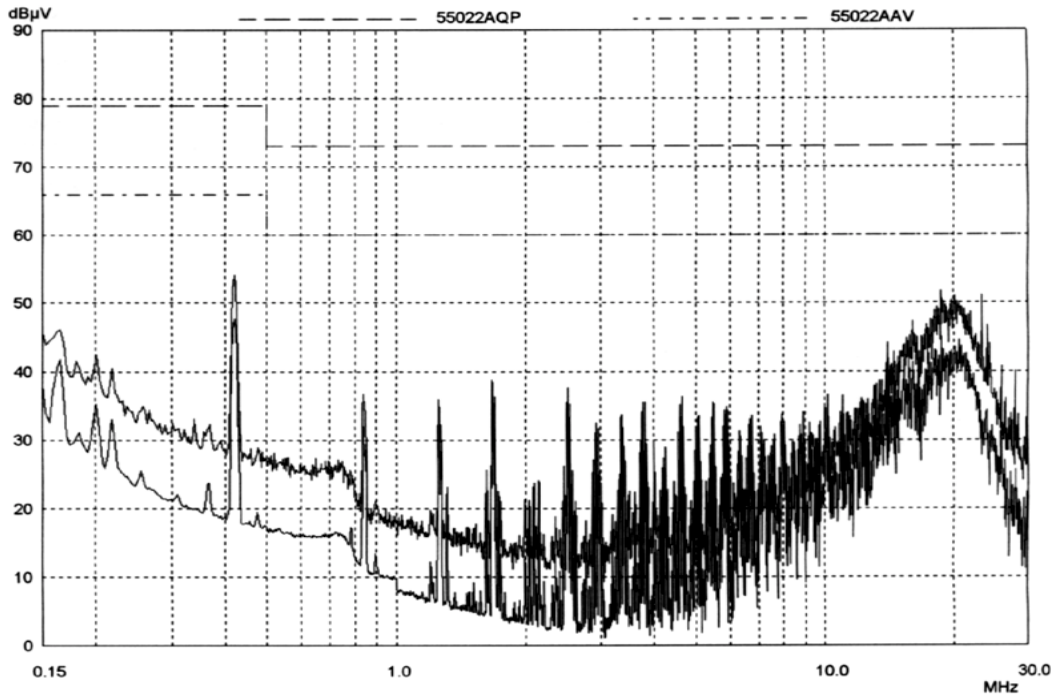
6-1 Transient Response of Module with Front Filter KG9503Q



Scale : 50V/div
1ms/div

(Transient response KG9503)

6-2 Emission Level with Module Filtered by KG9503Q :



(MGDSI-10-Q-C with KG9503)

For more detailed specifications and applications information, contact :

International Headquarters
Marketing and Sales department
GAÏA Converter - France
Address : B.P. 26 - 33186 LE HAILLAN - FRANCE
Tel. : + (33)-5-57-92-12-80
Fax : + (33)-5-57-92-12-89

North American Headquarters
GAÏA Converter Canada, Inc
Address : 6611 Thimens
ST-LAURENT, QUEBEC - CANADA H4S 1W2
Tel. : (514)-333-3169
Fax : (514)-333-4519

Represented by :

Printed in France by GAIA Converter Gaia Converter FC97-018.08/04 Revision G. Graphisme : Philippe Clicq