How to Design MIL-STD-461C EMI Filters for 12V/24V/28V Input GAIA Converter DC/DC Modules

- To comply with MIL-STD-461C power leads :
  - CE 03 : Emission requirement over 15 kHz
  - CS 01 : Susceptibility requirement over 30Hz to 50KHz
  - CS 02 : Susceptibility requirement over 50KHz to 400MHz
  - CS 06 : Susceptibility requirement for spikes
- Current range up to 2A
- Reverse polarity protection
- SMD Components
- Small surface : 20 mm x 25 mm (0.8" x 1")
- Temperature range : -55°C/+105°C

1-Subject

The purpose of this design note is to describe an efficient and compact solution to meet the US military standard MIL-STD-461C requirements for electromagnetic interference (EMI) for GAIA Converter products below 50W power. The solution proposed is a double cell EMI filter integrating 15 discrete components.

1-1 Compliance with MIL-STD-461C

This filter is compliant with the following MIL-STD-461C Part 2. & 3. requirements :

- Conducted Emission (CE)
  - CE03, power leads, emission over 15KHz, narrowband, Class A1
  - CE03, power leads, emission over 15KHz, broadband, Class A1 curve# 1 & 2
- Conducted Susceptibility (CS)
  - CS01, power leads, frequency 30Hz to 50KHz, class A1, consult factory for criteria
  - CS02, power leads, frequency 50KHz to 400MHz, class A1
  - CS06, spikes, power leads, class A1, spike # 2

1-2 Applicability

This EMI front filter is applicable to all GAIA Converter DC/DC modules with J input range (16-40 Vdc) and H input range (9-36 Vdc) and associated pre-regulator PGDS-50 series and can sustain :

- **up to 2A input current,**
- **up to 50W input power,**
- **up to 50V permanent input voltage & 100V transient input voltage.**

2- Design Note Summary

This design note is divided into 6 sections :

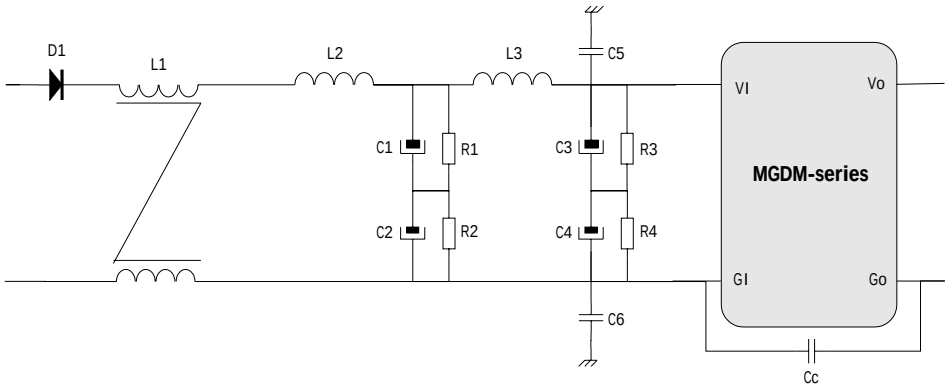
- Section 3 describes the recommended electrical schematics
- Section 4 is a general discussion for the choice of components
- Section 5 presents the EMI set-up, tests and results
- Last page describes the components that can be purchased directly at GAIA Converter

3- Recommended Electrical Schematics

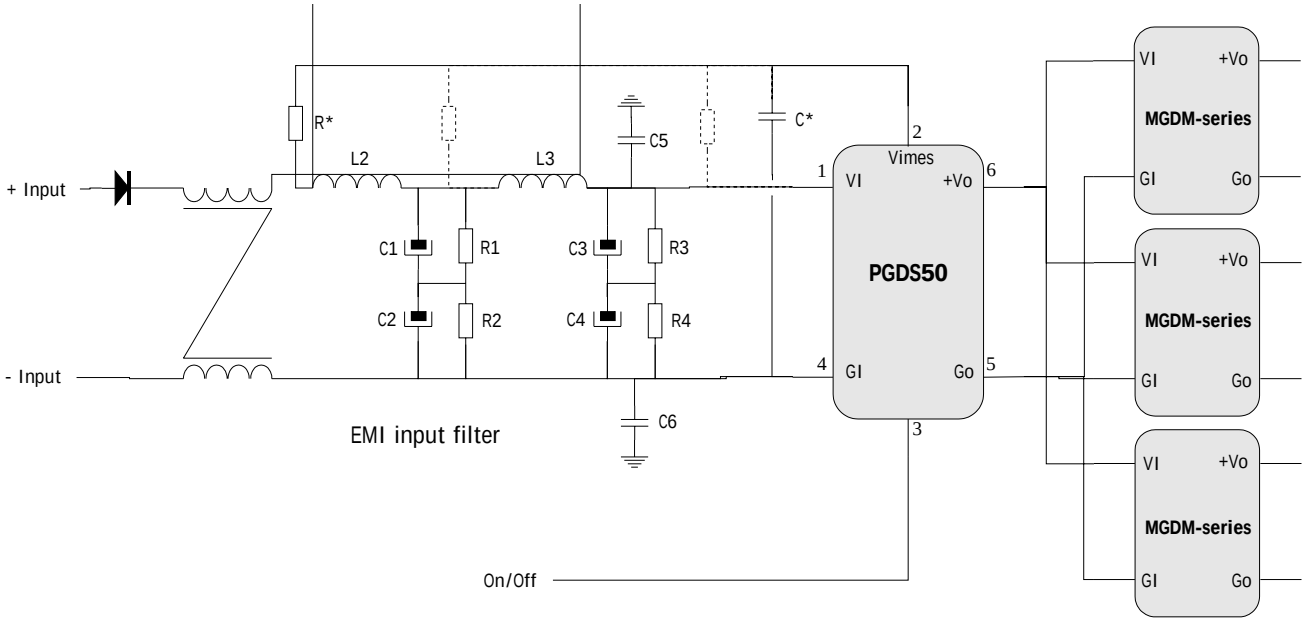
The EMI front filter can be used either :

- directly in front of any GAIA Converter DC/DC modules or assembly of DC/DC modules up to 50W power
- in front of GAIA Converter pre-regulator PGDS-50 series.

3-1 Direct Connection to GAIA Converter DC/DC Converter



3-2 Connection to GAIA Converter Pre-regulator PGDS-50 & DC/DC Converters



Notes : it is suggested to use a common mode capacitor Cc (10 nF/1.500V) for each DC/DC converter to increase EMI performance. This capacitor should be layed-out as close as possible from the DC/DC converter.

** For connection to chassis ground, if a higher isolation is required, it is suggested to use 100nF with voltage rating compliant with application requirements as capacitors C5 and C6.*

4- General Discussion for the Choice of Components

The components choice are driven by the following considerations :

D1 ..... : Diode . This diode is a reverse polarity protection diode. GAIA Converter can suggest a TO-220 format, BYW29-200 SGS-Thomson or Philips.

L1 ..... : Inductor . This inductor is a common mode choke. It has to be rated for the required input current. GAIA Converter recommends to use an inductor rated for 2A maximum input current. GAIA Converter can suggest a choke as exemple from Fair-rite : type 2744041447 or equivalent from Ferroxcube : type CMS2-5.6/3/4.8-4S2)

L2 ..... : Inductor .This inductor is a differential mode inductance. It has to be rated for the required input current. GAIA Converter recommends to use an inductor rated for 2A maximum input current. GAIA Converter can suggest a ferrite bead as example from Fair-rite : type 2743021447 or equivalent from Ferroxcube : type BDS 3/3/8.9-3S1).

L3 ..... : Inductor 4.7µH. This inductor is a differential mode inductance. It has to be rated for the required input current. GAIA Converter recommends to use an inductor rated for 2A maximum input current.

C1, C2, C3 & C4* ..... : Capacitors 10µF. These capacitors are SMD tantalum capacitor. The voltage transient value has to be chosen to sustain the input bus voltage transient requirements (ex 60v, 80v, 100v).

C5 & C6 ..... : Capacitors 100nF. These capacitors are SMD 1206 ceramic capacitor. The voltage rated value has to be chosen depending on isolation required between inputs and ground. For 500v isolation GAIA Converter can suggest to use SMD capacitor 100nF/500V.

Cc ..... : Capacitor 10nF. This capacitor is an SMD tantalum capacitor for common mode noise. The voltage rated value has to be chosen depending on isolation requirements between inputs and ground. For 1.500 Vdc isolation GAIA Converter can suggest 10nF/1.500V SMD capacitor. This capacitor has to be lay-out as close as possible from the DC/DC converter.

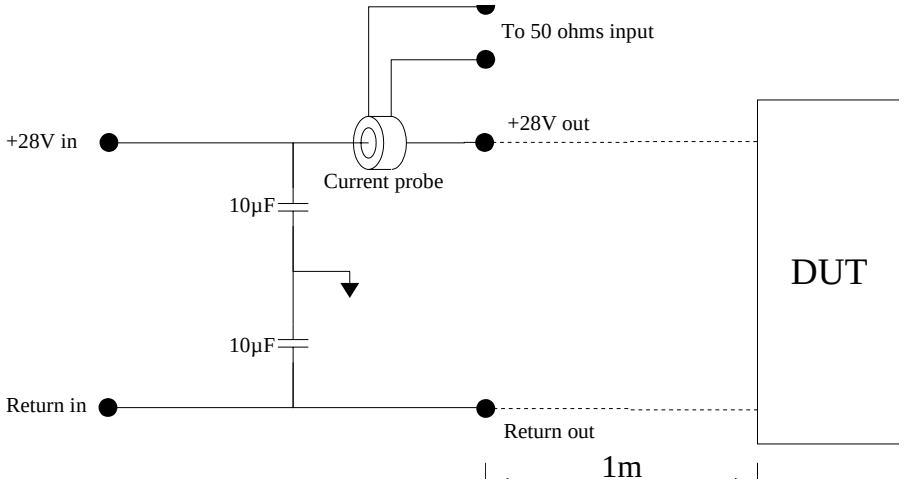
R1, R2, R3 & R4 ..... : Resistor . These resistors are SMD resistors with rated power value of 0.125W.

5- MIL-STD-461C Conducted Emission CE03 Tests Set-Up and Results

5-1 Measurement Method

The measurement method is described in MIL-STD-462C standard.
The «DUT» (Device under test) is powered thru a 1 meter lengh parallel wire.

One end is terminated with the DUT and the other end is terminated with 10µF capacitors to ground plane. The measures are made with a current probe, the unit of measurement being dBµA.

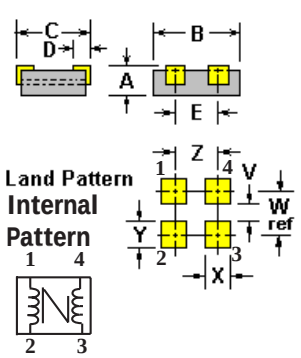


5-2 List of Components used for the EMI Test

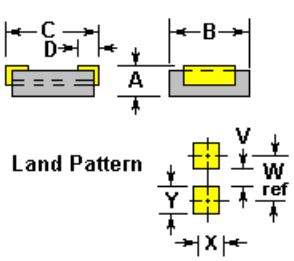
For the MIL-STD-461C EMI tests of different DC/DC converters, GAIA Converter has chosen related to section 4, the following components :

Compone-nt	Value	Voltag-e	Curre-nt	Reference
D1				SGS Thomson or Philips reference : BYW29-200
L1		/	/	Ferroxcube reference : CMS2-5.6/3/4.8-4S2
L2				Ferroxcube reference : BDS 3/3/8.9-3S1
L3	4.7 µH			Coilcraft reference : D03316P-472
C1, C2, C3, C4	10 µF	50V	/	tantalum capacitor 7343D 10µF 20% 293D serial D package CTC3
C5, C6	100 nF	50V	/	ceramic capacitor 100nF/50V 20% X7R Vishay reference : VJ1206Y104MXAT or TDK reference : C3216x7R1H104KT
R1, R2, R3, R4			/	SMD resistor 1M 5% 200PPM 150V 0.125W

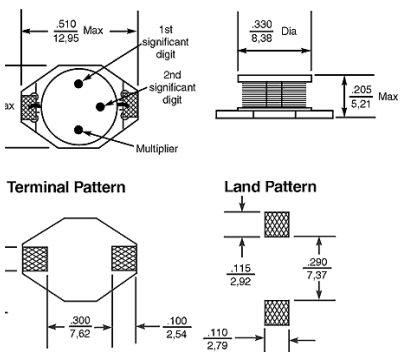
Common Mode Choke (L1)



Ferrite Bead (L2)



Differential Mode Inductance (L3)



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5- Lay-out Recommendations

5-1 Grounding Design

GAIA Converter recommends to use four layer boards PCB. 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 :

- primary ground part, divided into two sub-parts
- secondary ground parts,

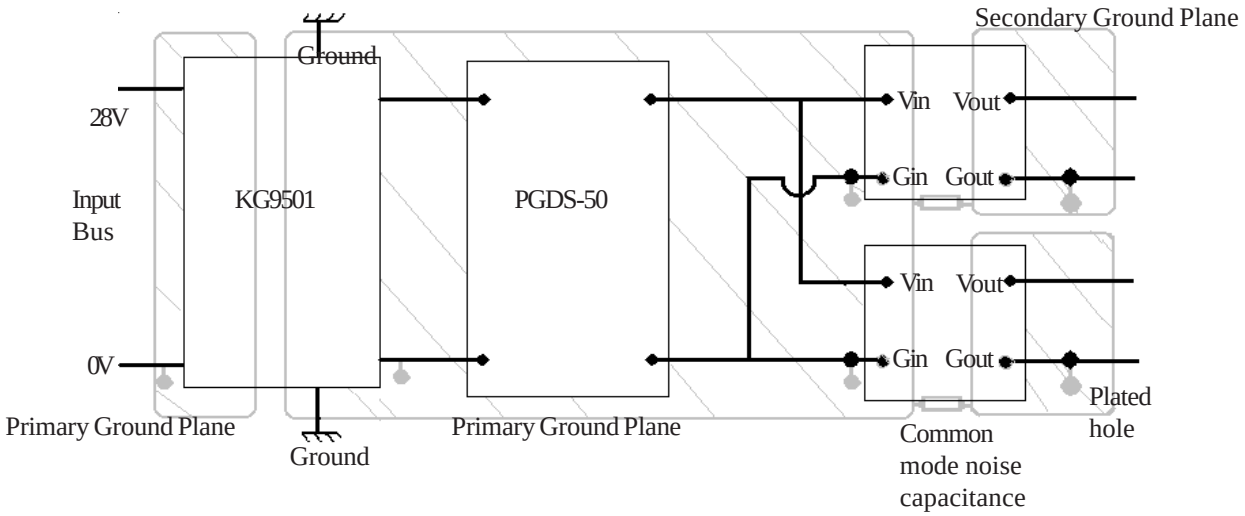
Both parts must be as large as possible and spread out over the entire surface of the board; a grid could be used to avoid a complete copper surface.
GAIA Converter recommend the use of a decoupling common mode noise capacitance (10nF) between primary and secondary ground planes. If more than one module is used, additionnal common mode noise capacitance are recommended.
The «case» pin of the modules (if available) can be connected either to primary or secondary ground plane and a 6 sides shielding can be achieved with the PCB ground plane.

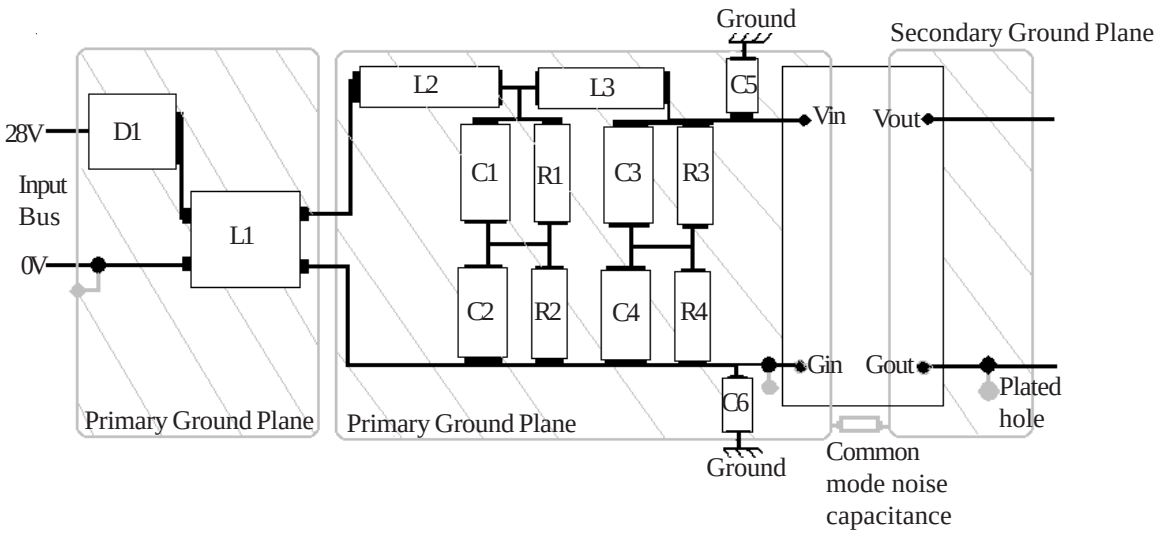
5-2 Component and Trace Routing Design

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 through 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.

The second step is to place the EMI filter next and as close as possible to the modules minimizing trace lenghts to avoid «antenna» phenomenum and minimize loop areas and straight inductances that can limit the effectiveness of the filter. When placing theses components make sure to leave enough room for power carrying traces to run through.

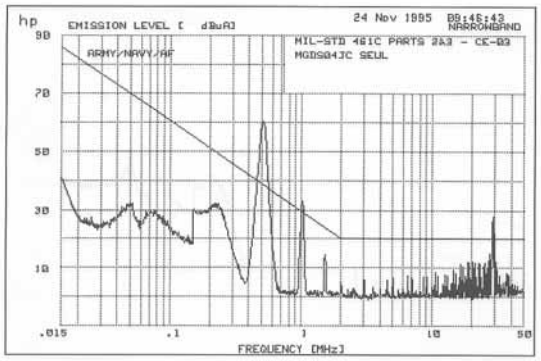




6- MIL-STD-461C Conducted Emission CE03 Results

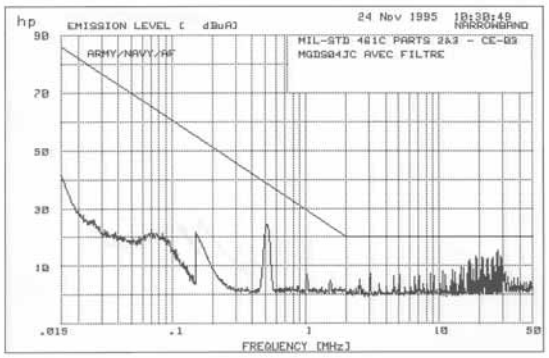
6-1 Emission Level CE03 Results with Single Module

Single module without filter



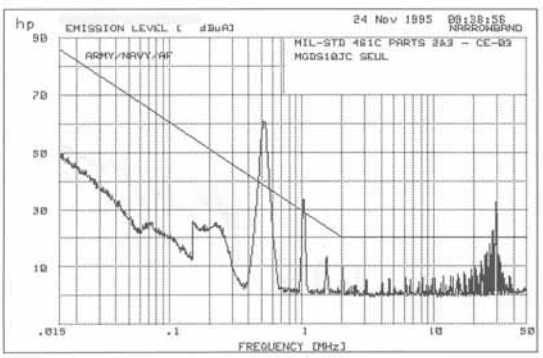
(MGDS-04-J-C module)

Single module with front filter



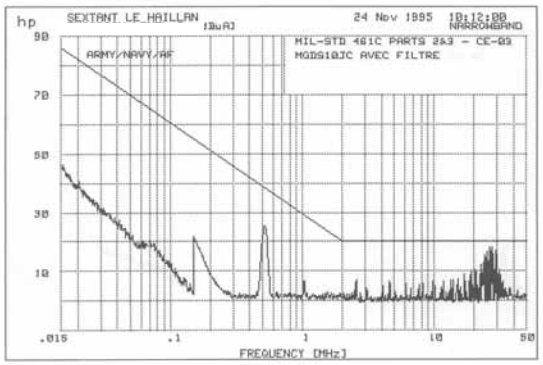
(MGDS-04-J-C module)

Single module without filter



(MGDS-10-J-C module)

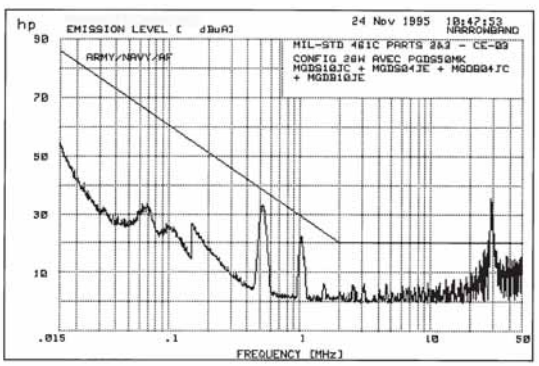
Single module with front filter



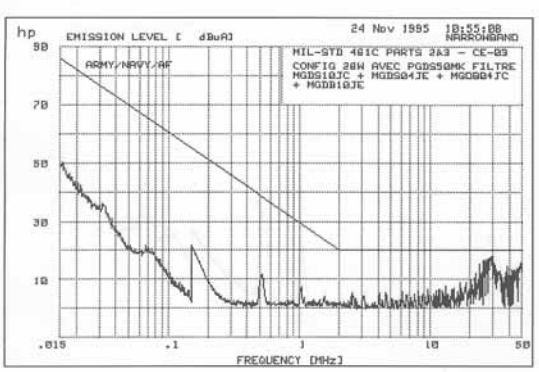
(MGDS-10-J-C module)

6-2 Emission Level CE03 with Multiple Module Architecture

Module architecture stand alone



Module architecture with front filter



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KG9501
Kit of Components available at GAIA Converter

GAIA Converter proposes this electrical schematics as a kit of components under the reference KG9501 that includes :

D1 ..... : Diode TO-220 format, BYW29-200 SGS-Thomson or Philips

L1 ..... : Common mode choke Fair-rite type 2744041447 or equivalent Ferroxcube CMS2-5.6/3/4.8-4S2 (replacement of obsolete Philips type 12NC433003036881)

L2 ..... : Ferrite bead Fair-rite type 2743021447 or equivalent Ferroxcube type BDS 3/3/8.9-3S1 (replacement of obsolete Philips type 12NC43300303645)

L3 ..... : Ferrite bead Fair-rite type 2743021447 or for better performances differential mode inductance Coilcraft type DO3316P-472 *(both components are provided in the GAIA Converter kit.)*

C1, C2, C3 & C4 ..... : SMD 10µF tantalum capacitor, 7343D 10µF 20% 293D serial D package CTC3 type

C5 & C6 ..... : SMD 1206 ceramic capacitor, 100nF/50 V 20% X7R type Vishay reference VJ1206Y104MXAT or TDK reference C3216x7R1H104KT

R1, R2, R3 & R4 ..... : SMD 0805 resistor, 1M 5% 200 PPM 150V 0.125W

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