Current Standards Requirements for Using COTS DC/DC Converter in Avionics/Military Applications

1- General

This application note underlines the different requirements that are commonly in use for avionics and military power supplies and describes how to comply using GAIA Converter COTS products.

1-1 From Custom Power Supply to Standard Converters

Back in the 90's, military and avionics high-reliability power requirements were met in most cases by assembling discrete military components leading to custom-designed power supplies under a long and expensive process.
In the mid 90's, the release of a US Directive the «Perry's Directive» instructs military contractors to use Commercial off the Shelf (COTS) products. This philosophy directed military procurements to focuss less on military specifications (with the extensive use of hermetically sealed semiconductors, microcircuits, ..) and more on global application performance by stripping away all of extraneous requirements that drive cost.

1-2 Considering COTS Converters

Commercial off the Shelf (COTS) converters are standard, «ready to use», mutiple applications oriented products. There are a lot of positives associated with using COTS converters in military or avionics applications. The use of COTS parts «mass produced» are cost-effective, they are versatile and can be configured in distributed or centralized power supply formats, they are used and qualified in a lot of different applications. Development time is drastically shorter over a traditionnal custom approach.

1-3 Applying COTS Converters in Avionics/Military Applications

However just dropping into COTS converters for avionics/military power supplies has to be carefully analyzed as there are some barriers and specific requirements to meet.

This application note resume those special requirements to fullfill military or avionics power supply specifications with COTS.

The barriers can be grouped into 4 categories :

- Input voltage requirements,
- Electromagnetic interference requirements,
- Environmental requirements,
- Military/avionics unique aspects.

The following sections will describe the different barriers from input voltage that rarely coincide from one application to another, electromagnetic interference and levels with many different standards depending on type of service branch up to environmental requirements including a lot of aspect such as temperature, humidity, dust, salt, fog, solar radiation, explosive decompression, shocks ...., and military unique aspect including special outputs for special sensors, protections, choice of components, ... The different sections will explain how to comply with GAIA Converter COTS products.

For locations, phone, fax, E-Mail see back cover

2- Input Voltage Requirements

Input voltage requirements in avionics/military applications come from many different power sources depending on available power generating systems on-board aircraft, vehicles, shipboards, ... These possibilities can be divided in AC sources and DC sources.

- AC sources :
  Direct alternating current sources are coming from generators attached to engine, static inverters, ...

- DC sources :
  DC sources are coming either from direct battery source or indirect rectified DC sources from AC power source.

Input voltage sources are different for each service branch (aircraft, vehicle, shipboard, ...). The following table is an attempt to classify the different sources available depending on service branch and describes the different voltage sources available for power supplies :

Examples of Input Voltage avaible On-board

Type of Sources	Voltage Source	Service Branch
Alternate Current Sources	115Vac/400Hz single or 3 phases	Aircraft
	440Vac/60Hz 3 phases	Shipboard
	115Vac/60Hz 3 phases	Shipboard
DC Current Sources	28/24/12Vdc battery	Vehicles
	28/14Vdc battery	Aircraft
	155Vdc rectified from AC source	Shipboard
	270Vdc rectified from AC source	Aircraft

These voltage sources and requirements are governed by many different standards whereas the most frequently used are :

- The US MIL-STD-704/MIL-HDBK-704 standard : "Aircraft Electric Power Characteristics".
- The US MIL-STD-1275 standard : "Characteristics of 28 VDC Electrical Systems in Military Vehicles".
- The International DO-160 standard : "Environmental Conditions and Test Procedures for Airborne equipment".
- The European En 2282 standard : "Characteristics of Aircraft Electrical Supply".
- The British BSI 3G 100 : "Characteristics of Aircraft Electrical Power Supplies".
- The British DEF STAN 61-5 Part 6 Electical Power Supply 28 VDC Electrical Systems in Military Vehicles.
- The German VG96916-5 standard : " Electrical Systems for land vehicle Part 5 DC networks specification».
- The French AIR2021 standard : «Caractéristiques des Réseaux Electriques à Bord des Aéronefs».
- The Airbus ABD13 standard : «Equipment Requirement for Supplier, Electrical Power Supply.
- The Airbus ABD100 chap. 8 standard : «Equipment Requirement for Supplier, Electric.
- The Boeing 7E7B3-0147 « Eletrical power quality and design requirements».
- The US MIL-STD-1399 standard : "Interface Standard for Shipboard Systems, Electrical Power, Alternating Current".

These standards describe the many different conditions of input voltage configurations and in particular :
- The permanent input voltage range in normal, abnormal and emergency conditions,
- The brown-out and transient levels in normal and abnormal conditions,
- The spikes levels,
- The start up voltage, cranking levels
- The power interruption conditions

The following sections will describe for all different conditions the main input voltages requirements for :
- DC Input Voltage,
  28/14 Vdc input voltage requirements for airborne applications,
  24/12 Vdc input voltage requirements for groundborne applications,
  270 Vdc input voltage requirements for airborne applications
- AC Input Voltage,
  115 Vac input voltage requirements 60Hz, 400Hz or variable frequency for airborne, groundborne, shipborne,
  230 Vac and other input voltage requirements for various applications,

2- Input Voltage Requirements (continued)

2-1 Requirements for 28Vdc (& 14Vdc) Input Voltage (Airborne Applications)

For 28Vdc (& 14Vdc) input voltage used mainly for airborne applications, the different standard requirements are described in the following table.
The different standards describe for the 28Vdc input voltage the different conditions such as :

- Permanent conditions (Steady State) :
  - in normal conditions
  - in abnormal conditions
  - in emergency conditions

The permanent input ranges are achieved by using standard GAIA Converter DC/DC modules without any additional devices.

- Transient conditions (Surge) :
  - in low transient (brown-out) conditions
  - in high transient in normal/abnormal conditions
  - in shut-down conditions
  - in spike conditions

The transient and spikes are more aggressive in amplitude and are achieved by using GAIA Converter additionnal front-end module designated “PGDS” or «LGDS» series or GAIA Converter ultra wide input series of DC/DC’s (> 5:1 ultra wide input range).
The shut-down level is satisfied by an external hold up device (such as an external capacitance and/or a GAÏA Converter hold-up module «HUGD/LHUG» series).

International Standards	Start	<---------- Steady State ---------->			<------------ Transient ------------->			<- Spike ->
	Start Engine	Normal	Abnormal	Emergency	Low Normal	High Abnormal	Momentary Interruption	
MIL-STD-704D (cat A) 28Vdc Bus	12V	22 - 29V	20 - 31,5V	16 - 29V	18V/15ms	50V/50ms	0V/up to 7s	+/-600V/10µs/TBD Ohm
MIL-STD-704F 28Vdc Bus	12V	22 - 29V	20 - 31,5V	16 - 29V	18V/15ms	50V/50ms	0V/up to 7s	/
DO-160D/E/F/G (cat A) spike cat. A 28Vdc Bus	/	22 - 30,3V	20,5 - 32,2V	18V	17V/30ms 12V/7s	46,3V/100ms	0V/up to 1s	+/-600V/10µs/50 Ohm
DO-160D/E/F/G (cat B) spike cat. A 28Vdc Bus	10V/35s	22 - 30,3V	20,5 - 32,2V	18V	17V/30ms 12V/7s	60V/100ms	0V/up to 50ms	+/-600V/10µs/50 Ohm
DO-160D/E/F/G (cat B) spike cat. A 14Vdc Bus	5V/35s	11 - 15,15V	10,25 - 16,1V	9V	8,5V/30ms 6V/7s	30V/100ms	0V/up to 50ms	+/-600V/10µs/50 Ohm
DO-160D/E/F/G (cat Z) spike cat. A 28Vdc Bus	10V/35s	22 - 30,3V	20,5 - 32,2V	18V	12V/30ms 12V/7s	80V/100ms	0V/up to 200ms	+/-600V/10µs/50 Ohm
EN2282 28Vdc Bus	12V/5s	24 - 29V	21 - 32V	18 - 29V	12V/30ms	60V/50ms	0V/up to 5s	+/-600V/10µs/50 Ohm
BSI 3G100 Part 3 (from constant frequency AC generator 28Vdc Bus	/	24 - 29V	21 - 32V	18 - 29V	14V/50ms	80V/100ms	0V/up to 7s	+/-600V/10µs/50 Ohm
AIR2021E 28Vdc Bus	/	24 - 29V	20,5 - 32,2V	17V	12V/50ms	60V/100ms	0V/up to 5s	+/-600V/50µs/50 Ohm
ABD100-D (conventionnal DC network) 28Vdc Bus	/	27 - 30,3V	/	18,5 - 30,3V	18,5V/15ms	46V/100ms	0V/up to 5s	+/-600V/10µs/50 Ohm
ABD100-D (NBPT DC network) 28Vdc Bus	/	25,5 - 32V	/	20 - 32V	20V/5s	36V/1s	0V/up to 5s	+/-600V/10µs/50 Ohm

2- Input Voltage Requirements (continued)

2-2 Requirements for 28/24Vdc (& 12Vdc) Input Voltage (Groundborne Applications)

For 24/28Vdc input voltage used mainly for military vehicles, the different standard requirements are described in the following table.
The standards describe for the 24/28Vdc input voltage the different conditions such as :

- Permanent conditions (Steady State) :
  - in normal conditions

The permanent input ranges are achieved by using standard GAIA Converter DC/DC modules without any additional devices.

- Transient conditions (Surge) :
  - in low transient (brown-out) conditions
  - in high transient (surge) conditions
  - in spike/load dump conditions

- Engine start conditions (Engagement) :
  - in initial engine engagement conditions
  - in cranking conditions

The transients, spikes are more aggressive in amplitude and energy while the engine start engagement is very low value. Those requirements are achieved by using GAIA Converter additionnal front-end module designated “PGDS” or «LGDS» series.

International Standards	IES	Cranking	Steady State	<------ Surge ------> Low	High	Load Dump	Spike
MIL-STD-1275B (generator + battery) 28Vdc Bus	6V/1s	16V/30s	25 - 30V	18V/100ms	40V/50ms	/	+/-250V/0.1ms/15mJ
MIL-STD-1275B (battery only) 28Vdc Bus	6V/1s	16V/30s	20 - 27V	10V/500ms	100V/50ms	/	/
MIL-STD-1275B (generator only) 28Vdc Bus	/	/	23 - 33V	10V/500ms	100V/50ms	/	+/-250V/70µs/15mJ
MIL-STD-1275C/D (generator + battery) 28Vdc Bus	6V/1s	16V/30s	25 - 30V	20V/500ms	40V/50ms	/	+/-40V/1ms/15mJ +/-250V/70µs/15mJ
MIL-STD-1275C/D (battery only) 28Vdc Bus	6V/1s	16V/30s	20 - 27V	15V/500ms	100V/50ms	/	+/-40V/1ms/15mJ +/-250V/70µs/15mJ
MIL-STD-1275C/D (generator only) 28Vdc Bus	/	/	23 - 33V	15V/500ms	100V/50ms	/	+/-100V/1ms/15mJ +/-250V/50µs/15mJ
MIL-STD-1275E 28Vdc Bus	12V/1s	16V/30s	20 - 33V	18V/500ms	100V/50ms	/	+100V/1ms/2J +/-250V/70µs/2J
DEF STAN 61-5 Part 6 issue 5 (generator + battery) 28Vdc Bus	6V/1s	>15V	25 - 30V	20V/500ms	40V/50ms	/	+130V/-100V/<10µs +90V/-60V/10µs +70V/-40V/5ms
DEF STAN 61-5 Part 6 issue 5 (battery only) 28Vdc Bus	1V/1s	>10V	22 - 27V	/	/	/	+130V/-100V/<10µs +90V/-60V/10µs +70V/-40V/5ms
DEF STAN 61-5 Part 6 issue 5 (generator only) 28Vdc Bus	/	/	15 - 40V	15V/500ms	80V/80ms	/	+280V/-220V<10µs +130V/-70V/10µs +110V/-50V/5ms
DEF STAN 61-5 Part 6 issue 6 (platform) 24Vdc Bus	8V/50ms	15V/20s	25 - 30V	20V/500ms	40V/50ms	(174+28)V/350ms 1 Ohm	+90V/-60V/10µs +70V/-40V/1ms
DEF STAN 61-5 Part 6 issue 6 (platform) 12Vdc Bus	3V/15ms	5V/10s	12,5 - 15V	10V/500ms	20V/50ms	(87+12)V/400ms 0,5 Ohm	+45V/-30V/10µs +35V/-20V/1ms
VG 96916 part 5 24Vdc Bus	10V/50ms	20V/1s	16 - 32V	9V/10ms	/	151V/200ms 1 Ohm	/
VG 96916 part 5 12Vdc Bus	6V/15ms	6,5V/10s	8 - 16V	4,5V/10ms	/	79V/200ms 0,5 Ohm	/
ISO 16750 (Level III) 24Vdc Bus	3V/15ms	5V/1s	10 - 32V	9V/10ms	36V	202V/350ms	/

2- Input Voltage Requirements (continued)

2-3 Requirements for 270Vdc Input Voltage

For 270Vdc input voltage used mainly in airborne applications, the different standard requirements are described in the following table.
This table gives also the GAIA Converter DC/DC converter characteristics.

The different standards describe for the 270Vdc input voltage the different conditions such as :

- Permanent conditions (Steady State) :
  - in normal conditions
  - in abnormal conditions
  - in emergency conditions

The permanent input ranges are achieved by using standard GAIA Converter DC/DC modules without any additional devices.

- Transient conditions (Transient) :
  - in low transient (brown-out) conditions
  - in high transient in normal/abnormal conditions
  - in shut-down conditions
  - in spike conditions

The transient and spikes are also achieved by using GAIA Converter ultra wide input series (5:1) DC/DC module without any additionnal devices. The shut down level is satisfied by an external hold up device (such as an external capacitance and/or a GAÏA Converter hold up module «HUGD» series).
It has to be mentionned that the 270Vdc input voltage is coming from the rectification of the primary 115Vac/3 phases input bus.

International Standards	<------------Steady State---------->			<-------------- Transient ----------->		
	Normal	Abnormal	Emergency	Low Normal	High Abnormal	Low Abnormal
MIL-STD-704B	250 - 280V	245 - 285V	240 - 290V	125V/50ms	475V/10ms	0V up to 7s
MIL-STD-704C	250 - 280V	245 - 285	240 - 290V	125V/50ms	475V/10ms	0V up to 7s
MIL-STD-704D	250 - 280V	245 - 285V	240 - 290V	125V/50ms	475V/10ms	0V up to 7s
MIL-STD-704E	250 - 280V	240 - 290V	250 - 280V	200V/10ms	350V/50ms	0V up to 7s
MIL-STD-704F	250 - 280V	240 - 290V	250 - 280V	200V/10ms	350V/50ms	0V up to 7s
DO-160F/G (cat D)	235 - 285V	220 - 320V	235V	160V/30ms	425/100ms	140V/up to 7s

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2- Input Voltage Requirements (continued)

2-4 Requirements for 115Vac/400Hz Single Phase Input Voltage

For 115Vac single phase input voltage used mainly in airborne application, the different standard requirements are described in the following table.

The different standards describe for the 115Vac input voltage the different conditions such as :

- Permanent conditions (Steady State) :
  - in normal conditions
  - in abnormal conditions
  - in emergency conditions

The permanent input ranges are achieved by using standard GAIA Converter AC/DC modules without any additional devices.

- Transient conditions (Transient) :
  - in low transient (brown-out) conditions
  - in high transient in normal/abnormal conditions
  - in shut-down conditions
  - in spike conditions

The transient and spikes are also achieved by using GAIA Converter AC/DC modules without any additionnal devices. The shut down level is satisfied by an external hold up device (such as an external capacitance and/or a GAÏA Converter hold up module «HUGD» series).

- Power Factor Correction :

The standards also define the need of a PFC and the maximum total harmonic distorsion (THD) and current harmonic components admissible. This is achieved by GAIA Converter PFC series.

International Standards	<------------ Steady State	------------>		<-------------- Transient	------------->		PFC requirement
	Normal	Abnormal	Emergency	Low Normal	High Abnormal	Low Abnormal	Frequency Harmonic Distor.
MIL-STD-704A (cat. A)	110 - 118 Vac	104 - 124Vac	106 - 122 Vac	64 Vac/50ms	180 Vac/100ms	0V/up to 7s	400Hz THD : not applicable
MIL-STD-704A (cat. C)	104 - 118 Vac	98 - 124 Vac	100 - 122 Vac	64 Vac/20ms	180 Vac/100ms	0V/up to 7s	400Hz THD : not applicable
MIL-STD-704D/E	108 - 118 Vac	100 - 125 Vac	108 - 118 Vac	80 Vac/10ms	180 Vac/50ms	0V/up to 7s	400Hz THD : not applicable
DO-160D (cat. A) spike cat.A	100 - 122 Vac	97 - 134 Vac	/	/	180 Vac/100ms	0V/up to 7s	400Hz THD : not applicable
DO-160G (cat. A(WF)) spike cat.A	100 - 122 Vac	97 - 134 Vac	/	/	180 VAC/100ms	0V/up to 7s	360-800Hz THD : applicable
EN2282	108 - 118 Vac	98 - 132 Vac	102 - 122 Vac	60 Vac/30ms	180 Vac/50ms	0V/up to 5s	400Hz THD : not applicable
BSI 3G100 Part 3 (from constant frequency AC generator)	108 - 118 Vac	98 - 132 Vac	104 - 122 Vac	60 Vac/50ms	180 VAC/100ms	0V/up to 7s	400Hz THD : not applicable
AIR2021E	108 - 118 Vac	98 132 Vac	102 - 122 Vac	58 Vac/30ms	180 Vac/80ms	0V/ up to 5s	400Hz THD : not applicable
ABD 100-D (variable frequency)	104 - 122 Vac	96 - 130 Vac	104 - 122 Vac	71 Vac/15ms	180 Vac/100ms	0V/up to 5s	360-800Hz THD : < 10.55%
MIL-STD-704F (variable frequency)	108 - 118 Vac	100 - 125 Vac	100 - 125 Vac	80Vac/10ms	180 Vac/10ms	0V/up to 7s	360-800Hz THD : < 10%

2- Input Voltage Requirements (continued)

2-5 Others Input Voltage Requirements

Many other different input voltages are existing for a lot of other type of applications in ships, submarines, drones, missiles, vehicles, ...

Some of these different standards are resumed in the table thereafter with some of their different requirements such as :

- Permanent conditions (Steady State) :
  - in normal conditions
- Transient conditions (Transient) :
  - in low transient (brown-out) conditions
  - in high transient conditions
  - in shut-down conditions

Please consult GAIA Converter technical support to verify product compliance.

International Standards	Nominal input voltage	Steady state variation	Brownout	Transient
MIL-STD-1399 (Type I)	115Vac/60Hz	+/-5%	92Vac/2s	138Vac/2s
MIL-STD-1399 (Type II)	440Vac/60Hz	+/-5%	352Vac/2s	528Vac/2s
MIL-STD-1399 (Type III)	440Vac/60Hz	+/-2%	416Vac/0.2s	464Vac/0.2s
STANAG 1008 Edition 9	440Vac/60Hz	+/-7%	-22%/2s	+22%/2s
E509 (French Naval Standard)	440Vac/60Hz	+/-5%	-15%/0.5s	-15%/0.5s
STANAG 1008 Edition 9	115Vac/60Hz	+/-7%	-22%/2s	+22%/2s
C-26-003-001/MS (Canada)	115Vac/60Hz	+/-5%	120Vac/30ms	80Vac/70ms
E509 (French Naval Standard)	115Vac/60Hz	+/-5%	-15%/0.5s	+10%/0.5s
MIL-STD-704F	115Vac/60Hz	105-125Vac	31Vac/83ms	152Vac/83ms
MIL-STD-1399 section 390	155Vdc	+/-12%	114V/125ms	202V/150ms
MIL-PRF-GCS600A	600Vdc	565-635Vdc	475Vdc/15ms	725Vdc/15ms
ABD0013	26Vac/400Hz	23,7 - 27,8Vac	16,9V/15ms	40,7/50ms
ABD100 1.8 rev D.	26Vac/400Hz	23,7 - 27,8Vac	16,9V/15ms	40,7V/50ms

3- Electromagnetic Interference Requirements

Although most of the military specifications have been relaxed, there is still one area where it remains stringent is the electromagnetic interference area.
Without special care or additionnal filters, the majority of COTS converters will not meet alone those requirements. Dedicated filters from knowledgeable military or avionics power supply designers are required to achieve those specifications.

3-1 General

Electromagnetic interference compatibility is of primarly importance in avionics/military applications and are divided in 4 main classifications :

- conducted emission (CE)
- conducted susceptibility (CS)
- radiated emission (RE)
- radiated susceptibility (RS)

Conducted noise is transmitted along the electrical cables that connect the input power bus to the equipment while radiated noise occurs through the unintended transmission or reception of noise signals. EMI emission standards address noise generated by the equipment whereas EMI susceptibility standards describe the noise environments that the equipment must tolerate without malfunction.
From a design perspective conducted emission are further divided into common-mode and differential-mode noise. Differential-mode conducted noise results from current flowing in one terminal of the converter and out the other. Common-mode noise, on the other hand, flows through the ground and returns in the same direction in both the power and return lines. Differential-mode noise is generally associated with switching currents whereas common-mode noise are primarily a result of pulsating voltages in the circuit.

3-2 Requirements

The requirements to control the electromagnetic interference are governed by different standards whereas the most popular are as follow :

• The US MIL-STD-461C standard : "Electromagnetic Interferance Characteristics, Requirements for Equipment".

• The US MIL-STD-461D/E/F standard : «Requirements for the control of electromagnetic Interference Emissions and Susceptibility».

• The DO-160C/D/E/F/G standard : "Environmental Conditions and Test Procedures for Airborne Equipment".

• The French GAM-EG 13B standard : "Essais Généraux et Environnement des Matériels".

• The UK Def-Stan 59-41 standard : "Electromagnetic compatibility Part 1 - 7"

• The German VG 95-373 standard : "Elektromagnetische Verträglichkeit von Geräten"

One of the main functions of the various electromagnetic interference (EMI) standards is to establish a common technique for the measurement and characterization of EMI performance reproductable from one test lab. to another. A summary of tests applicable for power supply is shown hereafter.

International Standards	MIL-STD-461C	MIL-STD-461D/E/F	GAM-EG13B	DO-160C/D/E/F/G
Conducted emission (CE) : Low frequency High frequency	On power leads : CE01 : 30 Hz to 20 KHz CE03 : 20 KHz to 50 MHz	On power leads : CE101 : 30 Hz to 10 KHz CE102 : 10 KHz to 10 MHz	On power leads 62C1 : 30 Hz to 50 Mhz 62C2 : 10 Khz to 50 Mhz	Section 21
Conducted susceptibility (CS) : Low frequency High frequency Spikes :	On power leads : CS01 : 30 Hz to 50 KHz CS02 : 50 KHz to 400 MHz on power leads : CS06 : spikes CS10/11 : damped transient	On power leads & bulk cable : CS101 : 30 Hz to 150 KHz CS114 : 10 KHz to 200 MHz On bulk cable & power leads : CS115 : cable injection impulse CS116 : damped transient	On power leads 63C1 : 30 Hz to 50 KHz 62C3 : 10 KHz to 50 MHz 63C4 : 50 KHz to 400 MHz 63C4 : impulse	Section 20
Radiated emission (RE) : Magnetic Field Electric Field	RE01 : 30 Hz to 30 KHz RE02 : 30 KHz to 10 GHz	RE101 : 30 Hz to 100 KHz RE102 : 10 KHz to 18 GHz	62R1 : 30 Hz to 50 KHz 62R3 : 10 KHz to 10 GHz	Section 21
Radiated susceptibility (RS) : Magnetic field Electric field	RS01 : 30 Hz to 30 KHz RS03 : 14 KHz to 10 GHz	RS101 : 30 Hz to 100 KHz RS103 : 2 KHz to 40 GHz	63R1 : 30 Hz to 30 KHz 63R3 : 10 KHz to 10 GHz	Section 20

A further complicating issue for EMI compliance design is that not all standards measure the same characteristics in the same way as exemple :

- MIL-STD-461C measures input conducted emission using a current probe and states the emission in dBµA
- MIL-STD- 461D/E/F uses an input line impedance stabilization network (LISN) and measures noise in dBµV
- the DEF-STAN-59-41 uses a current probe an input LISN and specifies the emission in dBµA.

3- Electromagnetic Interference Requirements (continued)

3-3 GAÏA Converter Modules Compliance with EMI Requirements

This section applies for all GAÏA Converter modules consult also individual datasheet for further filter descriptions.

3-3-1 Conducted Emission (CE)

GAÏA Converter modules use soft-switching topologies to minimize switching noise. This noise is defined in terms of input ripple current and consists of relatively high fundamental component (switchning frequency above 500 KHz for majority of GAÏA Converters products) and its harmonic. As a result :

- GAÏA Converter modules comply with «low frequency» conducted emission stand alone.
- GAÏA Converter modules comply with «high frequency» conducted emission with simple additionnal external filter.

3-3-2 Conducted Susceptibility (CS)

Conducted susceptibility requirements definie various noise sources which when conducted on the power lines should not cause malfunction of the converter.

- GAÏA Converter modules integrate an input filter that provides in most cases input attenuation of approximatly 30 dB
- GAÏA Converter modules comply in most cases with «low frequency» conducted susceptibility stand alone with the output voltage maintained within it's total regulation limits, nevertheless a simple additionnal filter can be used.
- GAÏA Converter modules comply with «high frequency» conducted susceptibility with a simple additional external filter with the output voltage within it's total regulation limits
- GAÏA Converter modules comply with «Spikes» conducted susceptibility with additionnal external transient supressor with the output voltage within it's total regulation limits.

3-3-3 Radiated Emission (RE)

Radiated emission govern the electric and magnetic fields emitted.
GAÏA Converter modules switch above 500 KHz such that there is no noise source in the range of RE01 (or RE101).
GAÏA Converter modules are 5 sides metal package and the 6th side could be designed by a PCB ground shield under the converter which limits high frequency emission from the converter it self in the range of RE02 (or RE102).
Most radiation usually emanates from the input cabling or load circuitry and that is were carefull system design is essential.
Compliance should be tested at the complete system level and is heavily dependant on the system design grounding, shielding and cabling.
GAÏA Converter modules comply in most cases with electric and magnetic radiated emission stand alone with a PCB ground plane.

3-3-4 Radiated Susceptibility (RS)

Radiated susceptibility requirements dictate electric and magnetic fields level which should not cause degradation or malfunction of a system. As with emission, potential problem areas are input cables and output circuitry.
GAÏA Converter modules comply with electric and magnetic radiated susceptibility stand alone.

3-3-5 Compliance Summary

The following table resumes GAÏA Converter products compliance with EMI requirements for the most popular MIL-STD-461C, MIL-STD-461E/F and DO-160D/E/F/G standards. Consult individual datasheet for additionnal filter descriptions.

Specifications	MIL-STD-461C	MIL-STD-461E/F	DO 160D/E/F/G	GAIA Converter Module Compliance
Conducted emission (CE) :				
Low frequency	CE 01	CE 101	Section 21	module compliant stand alone (see product datasheet)
High frequency	CE 03	CE 102	Section 21	module compliant with additional filter
Conducted susceptibility (CS) :				
Low frequency	CS 01	CS 101	Section 20	module compliant with additional filter
High frequency	CS 02	CS 114	Section 20	module compliant with additional filter
Radiated emission (RE) :				
Magnetic field	RE 01	RE 101	Section 21	module compliant stand alone (see product datasheet)
Electrical field	RE 02	RE 102	Section 21	module compliant stand alone (see product datasheet)
Radiated susceptibility (RS) :				
Magnetic field	RS 01	RS 101	Section 20	module compliant stand alone (see product datasheet)
Electrical field	RS 03	RS 103	Section 20	module compliant stand alone (see product datasheet)

4- Environmental Requirements

Unlike it's commercial counterparts, military and avionics electronics has much more intensive operationnal micro-environment. They have to be qualified to tri-service requirements encompassing land mobile, airborne, surface and sub-surface naval conditions which include shocks, vibrations, humidity, temperature, salt, altitude, explosive decompression, fungus, ... and overall reliability metrics.

Environment specific criteria are developped based on the plattform and location of the converters, level of requirements qualification procedures are governed by many standard whereas the most popular are :

• The RTCA/DO-160 standard : "Environmental Conditions and test Procedures for Airborne Equipment".

• The US MIL-STD-810 standard : "Environmental Test Method".

• The US MIL-STD-202 standard : "Environmental Test Method".

• The French GAM-EG 13 standard : "Essais de comptabilité à l'environnement climatique, mécanique"

• The UK BS3G100 standard : "Environmental Conditions Test Method".

The following table presents some of the various environmental testing for the well-known standards MIL-STD-810E, MIL-STD-202G and DO-160D.

Tests	MIL-STD-810E Standard	MIL-STD-810G Standard	MIL-STD-202G Standard	DO-160D/E/F/G Standards
Life at high temperature	Method 501.3	Method 501.5	Method 108A	Section 4
Low temperature	Method 502.3	Method 502.5		Section 4
Temperature cycling	/	/	Method 102A	Section 5
Temperature shock	Method 503.3	Method 503.5	Method 107G	/
Low Pressure (Altitude)	Method 500.3	Method 500.5	Method 105C	Section 4
Humidity (Cyclic)	Method 507.3	Method 507.5	/	Section 6
Humidity (Steady state)	/	/	Method 103B	/
Solar radiation	Method 505.3	Method 505.5	/	/
Rain	Method 506.3	Method 506.5	Method 104A	Section 10
Salt spray	Method 509.3	Method 509.5	Method 101E	Section 14
Fungus	Method 508.4	Method 508.6	Method 106G	Section 13
Sand and dust	Method 510.3	Method 510.5	Method 110A	Section 12
Explosive atmosphere	Method 511.3	Method 511.5	Method 109C	Section 9
Leakage	Method 512.3	Method 512.5	Method 112E	/
Vibration	Method 514.4	Method 514.6	Method 201A	Section 8
Shock	Method 516.4	Method 516.6	Method 213B	Section 7
Acceleration	Method 513.4	Method 513.6	Method 212A	/
Acoustic noise	Method 515.4	Method 515.6	/	/
Gunfire	Method 519.4	Method 519.6	Method 207B	Section 7
Temperature, humidity, vibration	Method 520.1	Method 520.3	/	/
Icing	Method 521.1	Method 521.3	/	Section 24
Vibro-acoustic	Method 523.1	Method 523.3	/	/

4- Environmental Requirements (continued)

To verify the suitability of GAIA Converter modules, a complete qualification test program has been undertaking by an independent laboratory part of the French Defense Agency CELAR which includes the following environmental qualifications :

The levels applied are those generally admitted for aircrafts, shipboard, or vehicle applications. Please consult factory for higher levels or other environmental tests.

T ests	Standards	GAIA Converter DC/DC module qualification
Life at high temperature	per MIL-STD-202G Method 108A	Operation : 1.000 hrs @ +105°C case Storage : 1.000 hrs @ +125°C ambient
Low temperature	per MIL-STD-810E/G Method 502.3/502.5	Storage : 1.000 hrs @ -55°C ambient
Temperature cycling	per MIL-STD-202A Method 102A	Number of cycles : 200 Temperature change : -40°C / +85°C Transfert time : 40 min. Steady state time : 20 min
Temperature shock	per MIL-STD-202G Method 107G	Number of shocks : 50 Temperature change : -55°C / +105°C Transfert time : < 10 sec Steady state time : 30 min
Low Pressure (Altitude)	per MIL-STD-810E/G Method 500.3/500.5	40.000ft, unit functioning 1.000ft/min to 70.000ft,unit functioning
Humidity (Cyclic)	per MIL-STD-810E/G Method 507.3/507.5	Damp heat : 60% to 88% relative humidity Cycle I : (31°C to 41°C) : 240Hrs
Humidity (Steady state)	per MIL-STD-202G Method 103B	Damp heat : 93¨% relative humidity Temperature : 40°C Duration : 56 days
Salt spray	per MIL-STD-810E/G Method 509.3/509.5	Temperature : 35°C Duration : 48 hrs
Vibration Frequency range Acceleration	per MIL-STD-810D/G Method 514.3/514.6	10 cycles in each axis frequency : 10 to 60Hz/60 to 2 KHz acceleration : 0.7mm/10g
Shock (Half sinus) Peak acceleration Duration	per MIL-STD-810D/G Method 516.3/516/6	3 shocks in each axis Peak acceleration : 100g duration : 6ms
Bumps	per MIL-STD-810D/G Method 516.3/516.6	2000 bumps in each direction duration : 6ms peak acceleration : 40g

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5- Military/Avionics Unique Requirements

There are other military-unique aspects revolving around the demands of each military application among them the most typicals are :

- Overcurrent and overvoltage settings
- Synchronization
- Unique Output Voltages (trim function)
- Components Selection

5-1 Overcurrent and Overvoltage

Overcurrent protection (OCP) and overvoltage protection (OVP) are features that are commonly requested in military applications. OCP is the function of limiting the amount of current a power supply will provide during a condition of high current demand. This function protects the power supply against damage during this condition. On the other hand, OVP is a limiting function that prevents the power supply from providing too high of an output voltage. Should the power supply loose regulation, OVP will shut-off or prevent the power supply form delivering voltage higher than a set level. Typical trip ranges for OCP and OVP are 110-135% of the rated full load and 110-130% of the output voltage, respectively. However, many applications do not use the full rated load of the power supply and modified OCP is required for reduced levels. Often, standard OVP set points are set too high to provide the protection necessary to prevent downstream component damage should an overvoltage condition exist. If a lower limit is required, it should be specified and the internal OCP and/or OVP limits adjusted accordingly. This protection is provided when modules are manufactured to a customer's specific requirements.

5-2 Synchronization

Synchronization is the function of operating more than one module at the same switching frequency. By having the converters operate at the same frequency, certain power system predictability and signature occurs. On the input line the current demand when the module power switch is on occurs at the same time for all modules. Although this produces a very large momentary input current draw during each "on" cycle, it is predictable and for many tactical military applications this is very important because systems must operate at a known EMI level in order to manage radiated emissions. The same effect occurs on the output voltage during output rectifier, filter conduction and main switching activity. The alternative of free running modules may produce on average a lower peak current draw on the input, but some systems cannot live with the unpredictability of the input and output conducted and emitted spectral content.

5-3 Unique Output Voltages (Trim Function)

Standard output voltages such as 2.5, 3.3, 5, 12, 15, 24 and 28 volts are readily available; however, in addition to these standard voltages, unique output voltages for military systems may also be required. For various reasons, voltages outside the available range are required for unique applications such as radars (voltages such as 8 and 9 VDC are required to compensate for some line loss characteristics). Most GAIA Converter modules have a "trimming" function that allows the user to adjust the output voltage through an external resistor network. However, these adjustments are intended for fine-tuning the output voltage and not for establishing a new output voltage for the converter. Their range is limited and some functions with set limits, such as OIP and OVP, do not change with trimming. Finally, an modules optimum performance is designed around the specified output voltage. Once the module is adjusted externally to another voltage, it is no longer operating in its optimized range. When a unique voltage is required the integrating activity should specify the output required, the overvoltage point, as well as the overcurrent limit. Some military providers can accommodate non-standard output voltage.

5-4 Components Selection

Components selection covers wide areas, but a key point of focus is over-coming restricted materials—and we can point-out in particular aluminum electrolytic capacitors, optocouplers or component encapsulation.

Tactical military requirements still exist that restrict the use of aluminum electrolytic capacitors. This is because of their propensity to leak and stop working after a period of many years. Commercial applications do not have these restrictions; None of GAIA Converter modules are using electrolytic capacitors.
Another requirements is the restriction of optocoupler. This is because of their low life time. None of the GAIA Converter modules use optocoupler. Another requirement often pointed-out is the necessity to use sealed packages components instead of plastic encapsulated microcircuits (PEMS).
A lot of studies have been realized to demonstrate that plastic encapsulated components are as much reliable and certainly more industrialized and mass produced to their sealed counterparts.
At GAIA Converter we use plastic encapsulated microcircuits (PEM's), the global product being encapsulated into a protective potting to ensure protection against harsh environment.

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