

Output Ripple & Noise

1- General

1-1 Introduction

DC/DC switching power converters are natural generators of noise. There are two types of noise: conducted noise and radiated noise which are present at the fundamental switching frequency of the power converter and its higher order harmonics.

In general, power converters using Pulse Width Modulated topology, have a constant switching frequency, which create noise in a predictable bandwidth that can facilitate attenuation. Resonant or zero switching converters generate less intrinsic noise, but their load dependent variable switching frequencies tend to generate noise over a wide frequency excursions, making them difficult to control.

For any kind of converters, it is important to control or measure the two most significant type of noise:

- Radiated noise
- Conducted noise

1-2 Radiated Noise

There are 3 main sources of radiated noise as follows :

- The major cause of radiated noise is due to high current change (di/dt) in circuit leads during switching, generating magnetic radiation.
- Fast voltage changes (dv/dt) can generate electric-fields which do not usually cause system noise problems since they decrease quickly as a function of distance.
- The other effects that occur, are a result of the 50-70 MHz component on the main switch common mode noise.

1-3 Conducted Noise

The spectral conducted noise has two main components: differential mode and common mode.

- The differential mode component is a mode that occurs between the output V_o and its return line G_o as shown in fig 1. The differential mode

noise is generally less than 150 mVpp for GAIA converter modules

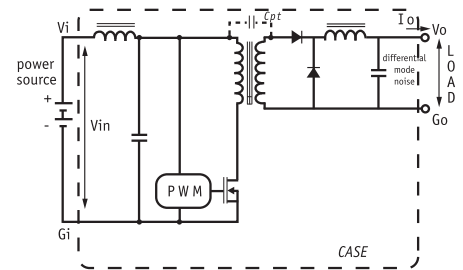


Fig 1 : Power converter output differential noise model with isolated case

- The common mode noise occurs between each of the output leads V_o or G_o and the EMI reference.

Two cases are possible:

- The EMI reference can be a measuring equipment ground if the case of the converter is not grounded (fig 2).
- The EMI reference can be the case of the converter if it is grounded (fig 3).

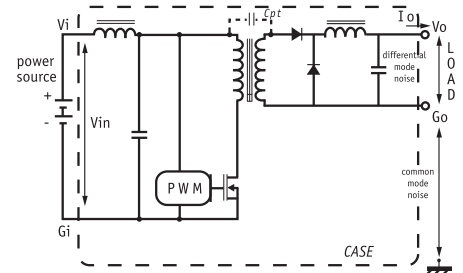


Fig 2 : Power converter output differential and common noise model with isolated case.

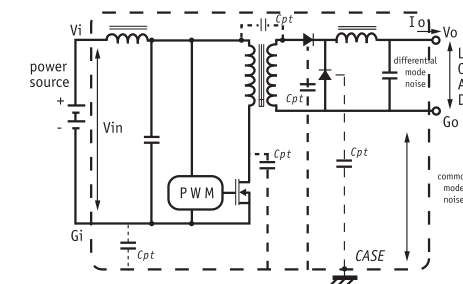


Fig 3 : Power converter output noise model with ground-case link

The conducted mode noise is due to common mode currents being pumped through parasitic capacitances (C_{pt}), generally less than a picofarad

These parasitic capacitances, which depend mainly on the dielectric constant substrate, are proportional to the area used and inversely proportional to the substrate thickness. The common mode noise can have a magnitude of several volts.

The common mode noise can interfere with the differential mode noise. It will result that common mode noise appears as differential mode noise and can cause misleading differential mode noise measurements. So the common mode noise spectrum magnitude has to be reduced before making differential mode noise measurements. The best way to suppress the common mode output noise is to shunt the power path to case parasitic capacitances.

2- Measurements

2-1 Measurement of Radiated Noise

Measurement of the radiated noise component, that requires specific and heavy equipments, is not described in this application note.

2-2 Measurement of Output Conducted Noise

Conducted output noise voltage measurements are difficult to make even under the best conditions. Depending on the technic used, results may vary widely. An oscilloscope with a differential mode bandwidth of 100 MHz or more is usually used to make noise measurements.

It should be noted, that oscilloscope have a finite ability to reject common mode signals, and these signals can be worsened by the use of long ground leads on the scope. Long ground leads adversely impact the common-mode rejection capability of oscilloscopes because the ground leads have an inductance not present on the signal lead. These differing impedances take common-mode noises and interfere with the differential mode signals that show up on the trace.

The differential mode noise measurement must be carried out at the outputs of the converter to reduce the pick up of radiated noise.

Leads lengths, including the ground must be as short as possible to reduce the pick up of radiated noise.

2-2-1 Measurement of Common Mode :

To measure the common-mode noise, put the scope probe on the ground lead connection of the probe while the ground lead is tied to either output return G_o or positive output V_o (Fig 4). If the noise is common-mode, you will still see «noise» even though you are looking at the same point

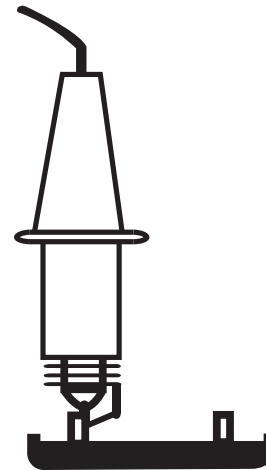


Fig 4 : Connection type to check output common mode

2-2-2 Measurement of Differential Mode

To measure differential mode noise, you must reduce the interferences of the other modes. There are two reliable ways to measure only differential mode:

- The first way is to short out the input and the output from G_i to the return lead G_o to ground with a high frequency capacitance (fig 5: CHF and CHF2)

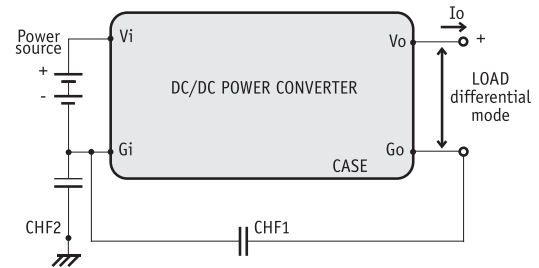


Fig 5 : Capabilities of HF capacitance connections for measuring output differential mode

- The second way is to connect high frequency capacitances to short out the parasitic capacitances (fig 6: CHF2 and CHF3) from G_i to case and from G_o to case.

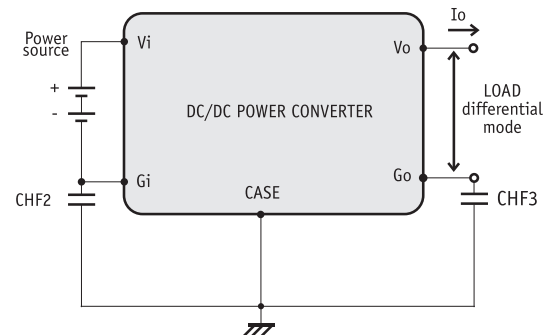


Fig 6 : Capabilities of HF capacitance connections for measuring output differential noise

We recommend to use high frequency capacitances > 10nF and the connection leads should be as short as possible. To make the measurement you must carry out the scope probe on Vo and the probe ground on Go as described in fig.7.

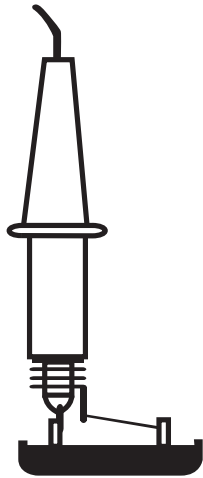


Fig 7: Connection type to measure output differential mode

GAIA Converter modules integrate an efficient filter to reduce output noise. If the internal EMI filter dedicated to the output is not sufficient to bring the noise levels within your system requirements, external LC unit may be added on the output.

3- Filtering

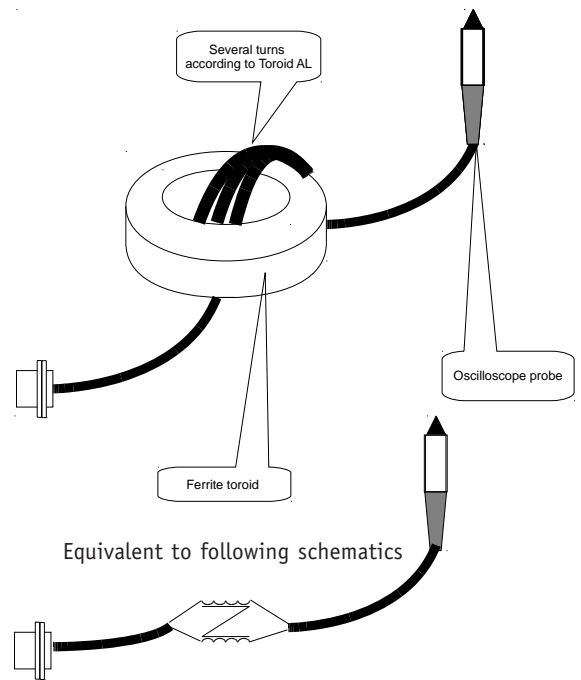
3-1 Filtering Conducted Common Mode

To filter the conducted mode, capacitors are sufficient. GAIA Converter recommend capacitors with low Equivalent Series Resistor (ESR) and low Equivalent Series Inductance (ESL) over the frequency band being filtered to make the attenuation vs frequency predictable.

We recommend to place a capacitance (fig 8 :C1) from the input and the output ground of the converter. These connections will shunt the Common-Mode current before it comes in (for the input) and comes out (for the output). The higher the switching frequency, the closer the capacitance must be placed.

3-2 Filtering Conducted Common Mode Noise during Measurement

It is not always possible to insert a common mode inductor into application circuit in order to perform a clean measurement. An alternate and easy to use solution consists of using a ferrite toroid across which the probe cord will wind around. This set will constitute a very efficient common mode inductor and the inductive effect will be applied on both conductors of the probe cord.



The table below shows example of toroid and equivalent common mode inductance.

Material	Toroid ref: (epcos)	AL (nH/S ²)	Turns Nb	Inductance (µH)
N30	B64290L0616X087	9160	3	82
N30	B64290L0616X087	9160	4	147
N30	B64290L0616X087	9160	5	229
T38	B64290L0616X038	21300	3	192
T38	B64290L0616X038	21301	4	341
T38	B64290L0616X038	21302	5	533

3-3 Filtering Conducted Differential Mode

To reduce the output differential mode noise, capacitances and inductances are necessary. An LC filter (fig 8) is recommended. GAIA Converter recommends the following schematic (fig 8) for its DC/DC converters. This recommended filter will reduce the output differential noise well below the most stringent requirements.

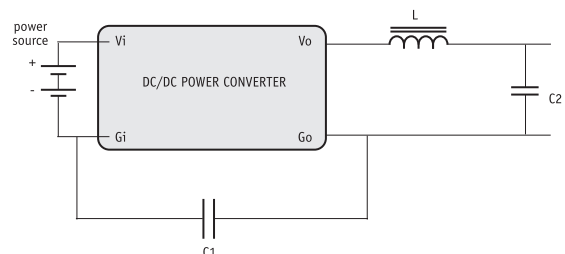


Fig 8/ Diagram connection for common and differential mode

- C1 : Common mode noise capacitance 10nF
- L : Equivalent inductance for differential mode 2.2µH type Murata LQH32CN2R2M23
- C2 : Capacitance 33µF tantalum SMD 293D type



For more detailed specifications and applications information, contact :

International Headquarters

GAIA Converter - France
ZI de la Morandière
33185 LE HAILLAN - FRANCE
Tel. : + (33)-5-57-92-12-80
Fax : + (33)-5-57-92-12-89

North American Headquarters

GAIA Converter Canada, Inc
4038 Le Corbusier Blvd
LAVAL, QUEBEC - CANADA H7L 5R2
Tel. : (514)-333-3169
Fax : (514)-333-4519

Represented by :