Bulletin of the *Transilvania* University of Braşov • Vol. 12 (61) No. 2 - 2019
Series I: Engineering Sciences
https://doi.org/10.31926/but.ens.2019.12.61.1.18

ON THE INFLUENCE OF THE CONNECTION TO THE PCB GROUND OF AN ANTI-DISTURBANCE FILTER

N.D. FLOREA[1] C. URSACHI[2] L.E. ACIU[2]

Abstract: *The material presents a study made on the effectiveness of anti-disturbance filters when they are connected on a PCB in different ways. Depending on the connection to the ground the results showed the importance of the practical way to have a reference point and also the importance of the design of the PCB to ensure a ground to the signal circuits. Also a module for different types of connection have been realized and tested for a same type of anti-disturbance filter to reveal the importance of the montage on the PCB.*

Key words: *electromagnetic compatibility, anti-disturbance filter, ground loop, reference point.*

1. Introduction

Anti-disturbance filters are used for two main reasons [1]:

- to prevent electrical shocks and fire hazards, if a very high level of voltage is present on the housing of an equipment due to the lightning or accidental failure of the cables or components;
- to reduce the effects of electromagnetic interference that appear by the common impedance or other forms of disturbance coupling.

In the context of studying disturbances that may occur and the introduction of anti-disturbance filters, understanding the difference between common and differential perturbations is crucial. There are two ways to report the disturbance referred to, *the common mode* when the signal is related to a common ground (reference point) and *the differential mode* when the signal is the potential difference between two signal lines. The differential mode, which is also called the transverse mode, refers to what we want regarding the power supply of the network for the electrical and electronic equipment we use and regarding the control signals or communications that they exchange with other equipment [5].

It is known that the currents of the common mode loops (Figure 1), are much wider than those of the currents of differential mode, generating therefore an electromagnetic field in a much wider area, the common mode being most often the one that creates the

[1] Master student in Advanced Electrical Systems, *Transilvania* University of Braşov, Romania
[2] Electrical Engineering and Applied Physics Dept., *Transilvania* University of Braşov, Romania.

so-called ''accidental antennas'' and therefore issues related to emission and immunity in the frequency range 1 MHz - 1 GHz [4].

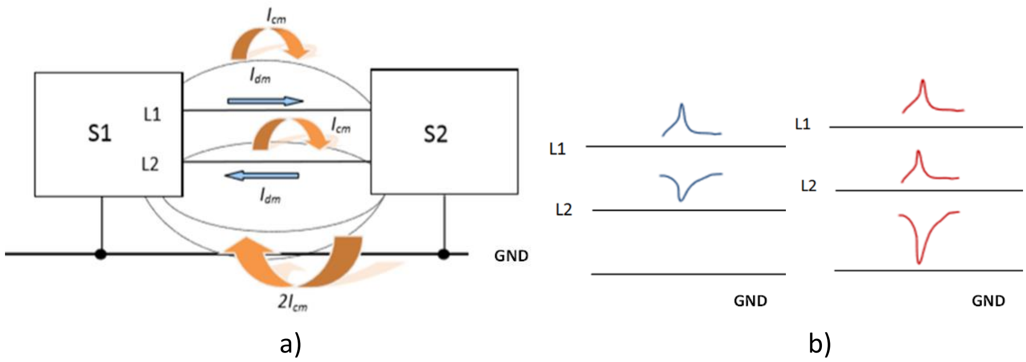


Fig. 1. a) *Common mode and differential mode current loops*; b) *Current impuls shape* [5]

I_{cm} and I_{dm} are the common mode current and the differential current.

An analysis between the differential and the common modes highlights the following differences [3]:

- Differential mode:
- Refers to the normal operation of the circuits;
- The current circulates in loops that are intended for them by design;
- It has documentation (electronic, location diagrams, wiring diagrams), and it is easy to understand.
- Common mode:
- It is not related to the normal functioning of the circuits;
- The current is closed by parasitic loops;
- There is no documentation, and it is more difficult to understand.

Ground, in the context of electronics, is the reference point for all signals or a common path in an electrical circuit where all of the voltages can be measured from [2]. But this definition does not portray the reality regarding the electric conductors or conductive surfaces that make the ground, as a way of closing the current loop, because they are not at the same electrical potential. Also, this definition does not emphasize the importance of the actual path of the current in the ground circuit. It is important for the designer to know the actual path of the return path of the current in order to evaluate the emission or susceptibility to the radiated disturbance of a circuit.

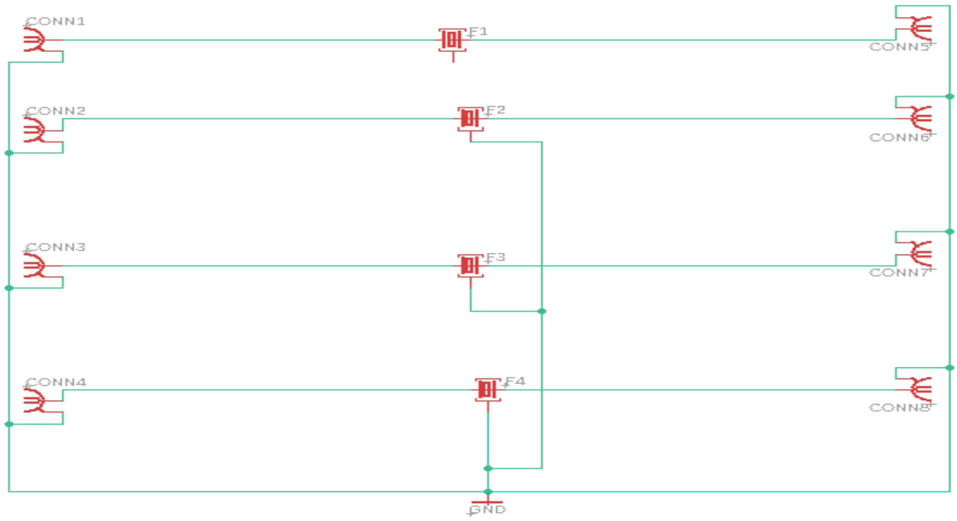
In order to understand the limitations and problems of ground systems, it is better to use a more illustrative definition for the real situation: the path to the ground could be the signal path that has a low impedance to allow the current to return to the source interrupt. The return current path will be the smallest one and can be influenced by disturbances. This implies that, as the current passes through finite impedance, there will be a potential difference between any two physically separated points of the return path, of the ground.

The definition of a ground (GND) for voltage defines what it should ideally be, while the definition based on the concept of return current defines more closely what actually ground is.

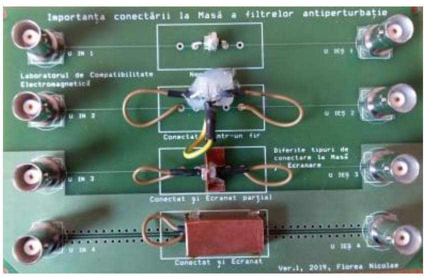
In designing the ground, it is important to ask: How does the current flow through the ground? Should the trajectory of the current through the ground be determined? Since a voltage drop will appear on any conductor carrying current, the effect of this voltage drop on the performance of grounded circuits at various points, geometrically located at certain distances from each other, must be evaluated.

2. Anti-Disturbance Filter Efficiency

An assessment assembly of anti-disturbance filters has been designed that demonstrates the importance of their connection mode to the GND. The effectiveness of the filter is dictated by the practical, concrete, way of achieving the connection to the ground.



a)



b)

Fig. 2. *Different types of connection to GND surface for an anti-disturbance filter mounted on a PCB: a) Electric scheme; b) Implementation on a PCB*

The central element of the stand for evaluation of anti-disturbance filters is a prototype test module with a circuit made on a PCB on which several anti-disturbance filters of the same type have been fitted (Figure 2). The realized module highlights the geometry of the return path for the signals that the filter must stop and the way it affects the behavior of the filter.

As it can be seen in Figure 2, the plate has four identical filters, mounted in different modes. According to the manufacturer's specification, the filter attenuation for frequencies above 10 MHz should be above 50 dB. The designed test module has four input connectors and four outputs. The filters were mounted towards the middle of the plate. The bottom of the PCB is the ground for each route.

Thus, the filter connection modes of the test module are:

1. No connection to the GND.
2. Filter connected with long wires (about 5 cm) and connected by a wire to the GND.
3. The filter is mounted on an L-shaped copper plate holder, connected to the GND.
4. Filter fitted with the shortest possible connection, and the entrance completely shielded by a copper metallic housing. In addition, there is a GND on the top of the plate. The GND on both sides are not only connected to connectors, but also thru more PCB via along the signal path.

For the construction of the mechanical parts (for the last two assemblies) 0.4 mm thick copper plate was used, but any value between 0.3-1 mm is good. The proposed shielding casing is almost cube-shaped, but two sides are missing.

The anti-disturbance filters used are of the "π" symmetrically type, so the direction in which they are mounted is not important. The wire used for the input circuit has a certain inductance and is required to make the low frequency characteristics of the filters identical. Only the fourth mount has no output wire. The connection from this filter to the plate must be as short as possible and the filter is completely enclosed in the protective metal housing.

In order to study the performance of each mount, a spectrum analyzer with tracking generator was used to measure the attenuation of each filter, in the assemblies performed on the test board, one by one. The generator is connected to the U_{in} connector while the analyzer input is connected to the U_{out} connector on the board. The obtained results are shown in Figure 3.

The values of the attenuations obtained by experimental determination for the type of filter studied connected in different PCB modes are given in Figure 4. The following were observed:

- The first type of mounting, with the filter not connected to the GND, has a very low attenuation (Figure 4, At1M);
- In the second type of mounting, the filter has poor performance, but slightly better than the first filters (Figure 4, At2M);
- In the third type of mounting, the filter performs much better. The attenuation reaches -46 dB, but then slowly begins to decrease in frequency (Figure 4, At3M);
- In the fourth mounting type, the filter has a slightly lower attenuation at lower frequency than in the third mounting type, but at higher frequencies it attenuates better than the other mounting types (Figure 4, At4M).

Following the study performed with the same type of anti-disturbance filter in different types of mounting on a PBC board, the following were found:

- Binding the filter to the GDN has a profound impact on the filter's performance.

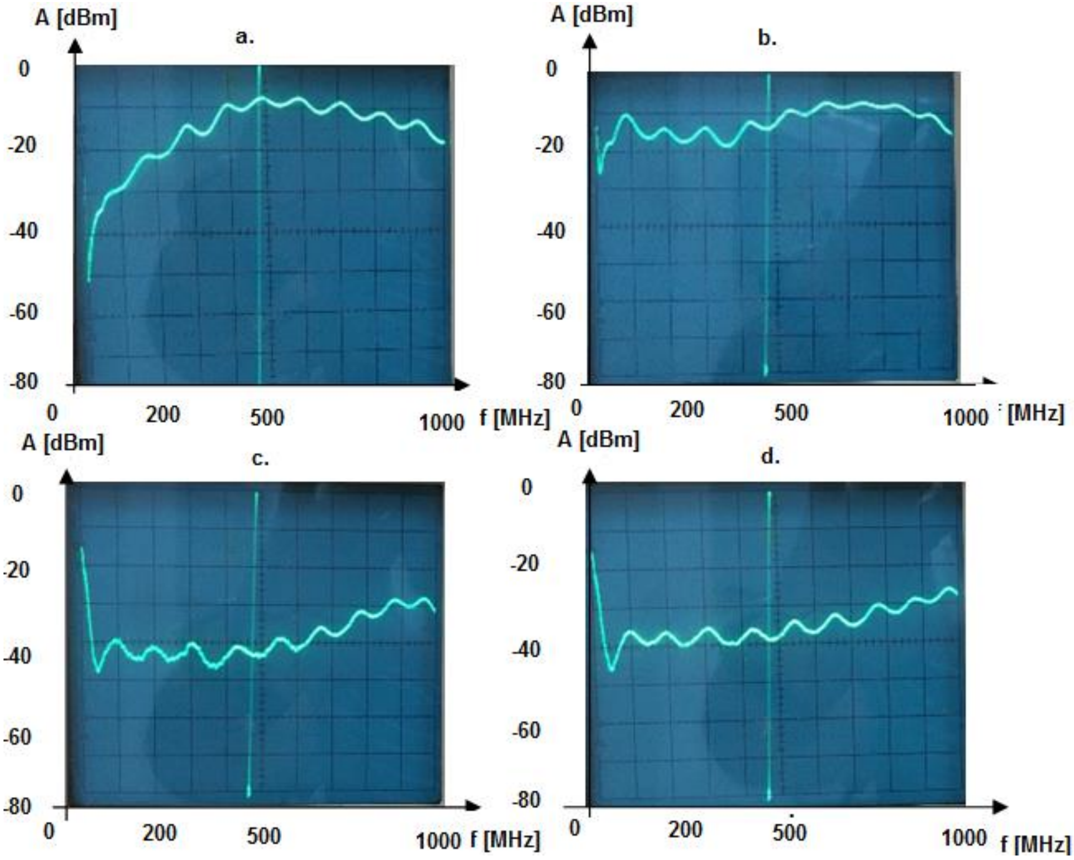


Fig. 3. *The results of the experimental determinations for the filter studied in different types of assembly: a) no connection to GND; b) filter connected with long wires; c) filter is mounted on an L-shaped copper plate holder; d) filter connected with short wires*

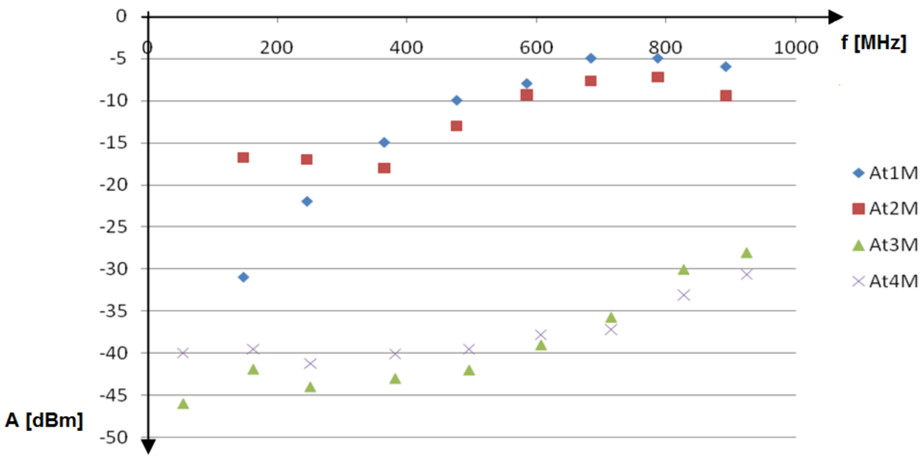


Fig. 4. *The attenuation introduced by the filters in the 4 types of mounting (horizontal is the frequency in MHz, and vertical is the measured attenuation of the filters)*

- The filter GND must be connected to the ground.
- The filter input path must be such that it has not an inductive or capacitive coupling to the filter output. This is a delicate problem. It was tried to solve it by constructing the filter in a metal housing, but experiments show that it is not enough. An additional shielding enclosure, like that of the filter in mount 4, is the solution.
- The longer the path to the reference point, the more it is advisable to separate the filter input from the filter output. Particular attention should also be paid to the lengths of the thread: it should be as short as possible.
- The best installation is with the separation between the input and output of the filters through a metal shield. The filter is fully integrated into a copper sheet metal casing.

3. Conclusions

The necessity, the usefulness and even the compulsory use of anti-disturbance filters is unanimously accepted. But the efficiency of their action depends very much on the quality of the design and their concrete installation in the electronic equipment.

The applied study of anti-disturbance filters must start from understanding some fundamental concepts of electromagnetic compatibility, namely those of earthing - grounding and common-way differentiation.

The experimental determinations presented above highlighted:

- The existence of common and differential currents and their mode of manifestation depending on the quality of the signal circuit design and especially the GND circuits.
- The difficulties and solutions of providing the same reference potential to the ground connection of each subassembly or integrated circuit.

References

1. Aciu, L.E., Ogrutan, P.L., Ursachi, C.: *Electromagnetic Compatibility Applications*. Brașov. *Transilvania* University Press, 2017.
2. Buesink, F.J.K.: *Printed Circuit Boards for the Education aimed at Understanding Electromagnetic Effects*. University of Twente, 2009.
3. Clayton, R.P.: *Introduction to Electromagnetic Compatibility*. New Jersey. John Wiley & Sons, Inc., Hoboken, 2006.
4. Ott, H.W.: *Electromagnetic Compatibility Engineering*. New Jersey. John Wiley & Sons, Inc., Hoboken, 2009.
5. Ursachi, C.: *Electromagnetic Disturbances Evaluation of Electrical and Electronic Equipment at Conducted Disturbances*. In. PhD Thesis. *Transilvania* University of Brasov, 2014.