AN6154

Application note

Use of LC filters for EMI optimization of EVALSTISO62XV1

Introduction

When discussing the regulatory testing and compliance of electronic and electrical products, we often refer to electromagnetic compatibility (EMC) and electromagnetic interference (EMI).

While EMI is the interference caused by an electromagnetic disturbance that affects the performance of a device, EMC is a measure of a device's ability to operate as intended in its operating environment, not generating additional EMI that affects the operation of other nearby devices.

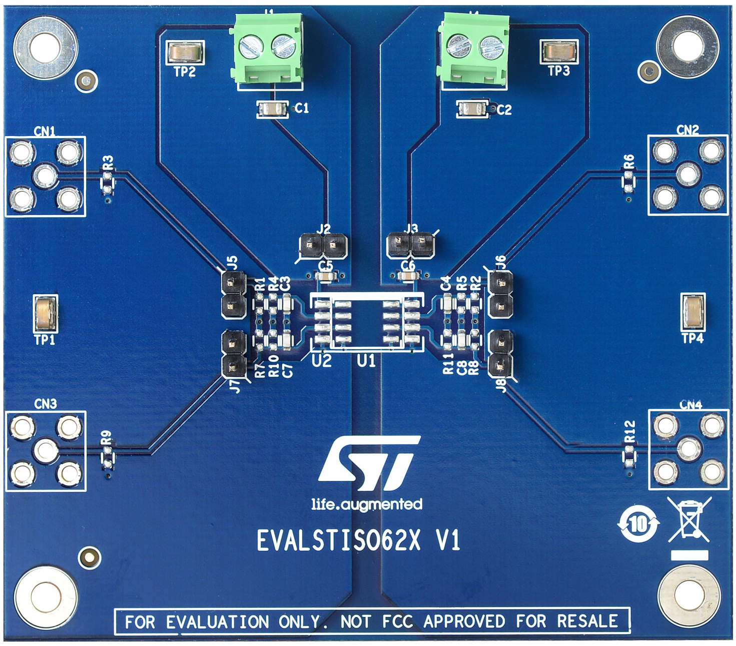
Sources of EMI can be environmental, such as lightning strikes, solar radiation, atmospheric electrical storms, and static electricity but is more commonly another electronic device or electrical system.

Electromagnetic interference often manifests as undesirable noise. It may also lead to the wrong or disrupted function of electrical, electronic, and RF systems.

This is the reason why EMI LC filters are required in electronic equipment, which improve the quality of a signal passing through the electronic devices, hence improving the functionality of electrical equipment.

This document discusses a practical example of how an EMI filter can be used to reduce the noise emitted as in this case with the EVALSTISO62XV1 evaluation board.

Figure 1. **EVALSTISO62XV1 evaluation board**



1 Types of Electromagnetic Interference (EMI)

EMI can be classified into types based on several factors, which include:

- Source
- Duration
- Bandwidth

1.1 Source of EMI

As a source of interference, we can consider **Naturally Occurring EMI** (related to natural phenomena such as lightning, electric storms, solar radiation) and **Human-made EMI** (resulting from the activity of other electronic devices near the device experiencing the interference).

1.2 Duration of EMI

Based on the period of time that the interference was experienced, EMIs are grouped into **Continuous EMI** (emitted continuously by a source, until the coupling mechanism exists between the EMI source and the receiver) and **Impulse EMI** (emitted intermittently or within a very short duration). For both, the source can be natural or human-made.

1.3 Bandwidth of EMI

The bandwidth of an EMI refers to the range of frequencies involved: it could be a **Narrowband EMI** (typically due to a single frequency or a narrowband of interference frequencies) or a **Broadband EMI** (that occupies a large part of the frequency spectrum).

2 EMI coupling mechanisms

There are four basic coupling (or noise) mechanisms from a source to a receiver:

- Conduction
- Radiation
- Capacitive
- Inductive/Magnetic

2.1 Conduction

Conducted coupling occurs when emissions flow through wires connecting the source of the EMI and the receiver together: this is typical on the power supply lines. Coupling on power lines could be either:

- **Common mode** (where the noise current flows in the same direction, through one or more conductors)
- **Differential mode** (where the noise current flows in an opposite direction through adjacent wires).

2.2 Radiation

This is the most common form of EMI coupling, caused by radiating electromagnetic fields. Unlike conducted, there is no physical connection between the source and the receiver since the interference is emitted (radiated) via space to the receiver.

2.3 Capacitive

Due to the coupling capacitance between the source and the receiver, a voltage variation in the source induces unintentional currents in the receiver, causing capacitively-coupled EMI.

2.4 Inductive/magnetic

Inductive coupling uses the principle of electromagnetic induction to induce currents in the receiver due to the changing magnetic field between the source and the receiver.

3 Basics of EMI filters

An electromagnetic interference filter, also known as an EMI filter, is an electronic circuit device used to suppress conducted electromagnetic interference, especially noise in power lines or control signal lines.

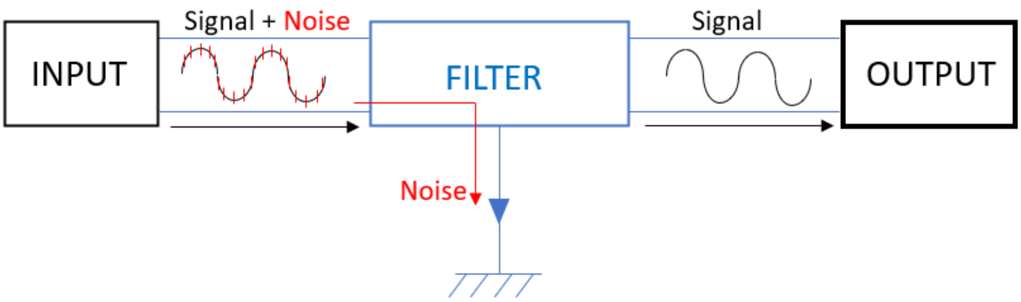
It may be used to suppress the interference generated by the device itself, as well as the interference generated by other equipment, to improve the immunity of a device to the EMI signals present within its electromagnetic environment.

Most EMI filters are designed to suppress both common mode and differential mode interference. They are usually composed of a network of passive electronic components including capacitors and inductors, which make up an LC circuit.

3.1 How an EMI filter works

Basically, an EMI filter is a low-pass filter that blocks high frequencies while allowing lower frequencies to pass through:

Figure 2. Noise filtering



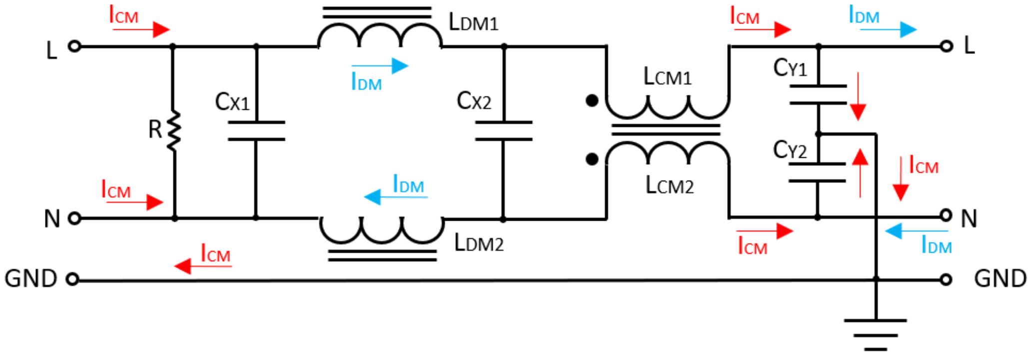
Since EMI filters only protect against conducted EMI, they often pair with shields that block radiated EMI. Noise could get emitted from a wire on one side of the EMI filter and then propagate to the device by recoupling with the wire on the other side.

Putting a shield at the attachment point of the electromagnetic interference filter could effectively block all forms of EMI. Anyway, if the conductor length between the filter and the source of EMI is very short, using only the filter could be enough.

3.2 EMI filter elements

With reference to the block in Figure 1, the figure below shows the building elements of an EMI filter:

Figure 3. EMI filter elements



where:

- R discharge resistor
- Cx_1, Cx_2 differential mode filter capacitors
- L_{CM1}, L_{CM2} common mode inductors (CM choke)
- L_{DM1}, L_{DM2} differential mode inductors (DM choke)
- C_{Y1}, C_{Y2} common mode filter capacitors.

L_{DM1}, L_{DM2} placed in series with the input power path form a low-pass LC filter with Cx_1, Cx_2.

These capacitors, placed across the input power lines, serve to shunt differential conducted voltage noise avoiding the noise being propagated toward the external voltage source.

The target saturation current for these inductors has to be great enough to tolerate the maximum input current during normal operation. They should be selected with low DCR (parasitic DC resistance), so the power dissipation is acceptable.

The input resistor R discharges Cx_1, Cx_2 when the power is turned off.

The common mode noise is suppressed using a double-winding choke (L_{CM1}, L_{CM2}). These inductors are wound on a single core, so they present a high impedance to attenuate common mode currents flowing along the input conductors.

In addition, C_{Y1} and C_{Y2} bypass the high-frequency common mode noise to ground.

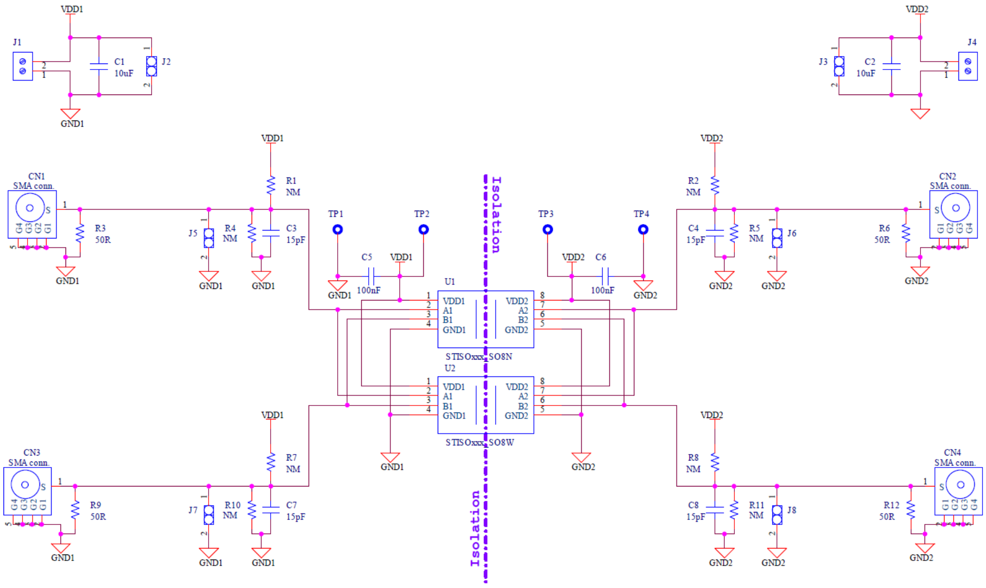
Unlike the differential mode choke, the common mode choke has very little current flowing in common mode, hence the saturation current rating is normally not an issue.

4 EMI performance of EVALSTISO62XV1

EVALSTISO62XV1 is the evaluation board for the dual-channel digital isolators family STISO62X. In our case, the board is assembled with the STISO620 device.

4.1 EVALSTISO62XV1 schematic

Figure 4. EVALSTISO62XV1 schematic



The STISO620 device provides 2 independent channels in the same direction. For the radiated emission test, the signal is transmitted with both inputs connected together.

4.2 Testing method

Measurements were made on a semi-anechoic chamber. Preliminary (peak) measurements were performed at an antenna to EUT separation distance of 3 meters with the receiving antenna located at a fixed height (from 1 to 4 meters) in both horizontal and vertical polarities.

Then final measurements (quasi-peak) were performed by rotating the EUT 360° and adjusting the receiving antenna height from 1 to 4 meters.

All frequencies were investigated in both horizontal and vertical antenna polarity.

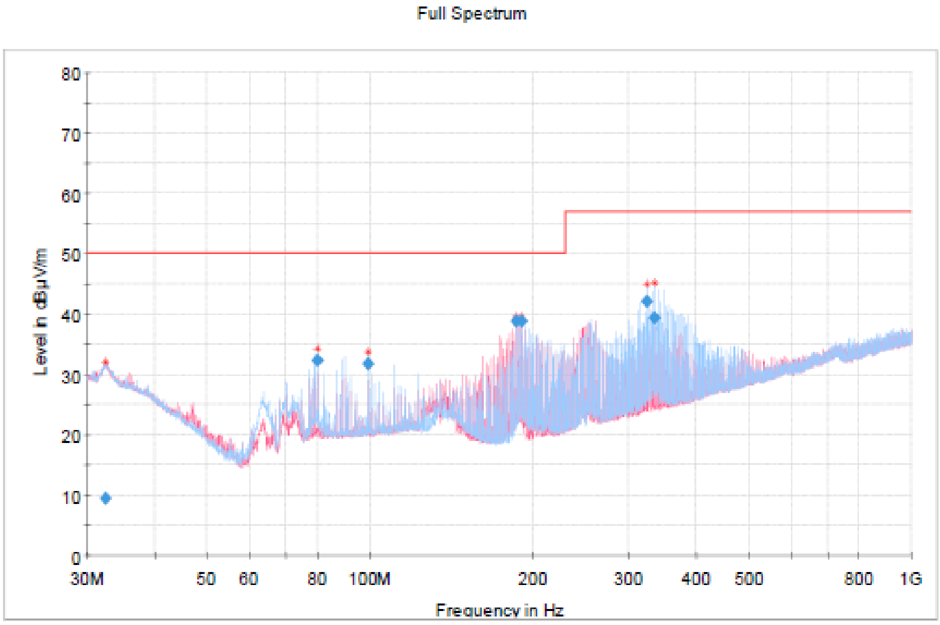
Figure 5. Method standard: CISPR 16-2-3, EN 55016-2-3

Frequency (MHz)	Radiated emission at frequencies up to 1GHz	
	Quasi-Peak limit @ 3 m (dBµV)	
	Class A	Class B
30 to 230	50	40
230 to 1000	57	47

4.3 EVALSTISO62XV1 testing results

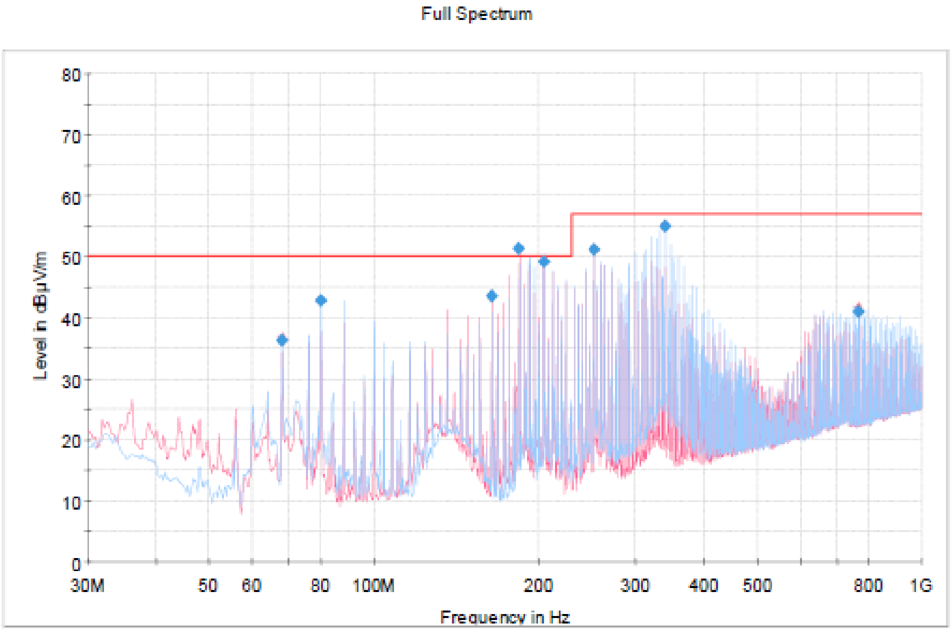
The board has been tested, regarding the radiated emission, for different frequencies of the signal transmitted. Operating conditions are VDD1 = VDD2 = 3.3 V; f = 1 MHz, 4 MHz, 10 MHz, and sweep from 2 to 20 MHz.

Figure 6. Radiated emission @ 1 MHz (STD board)



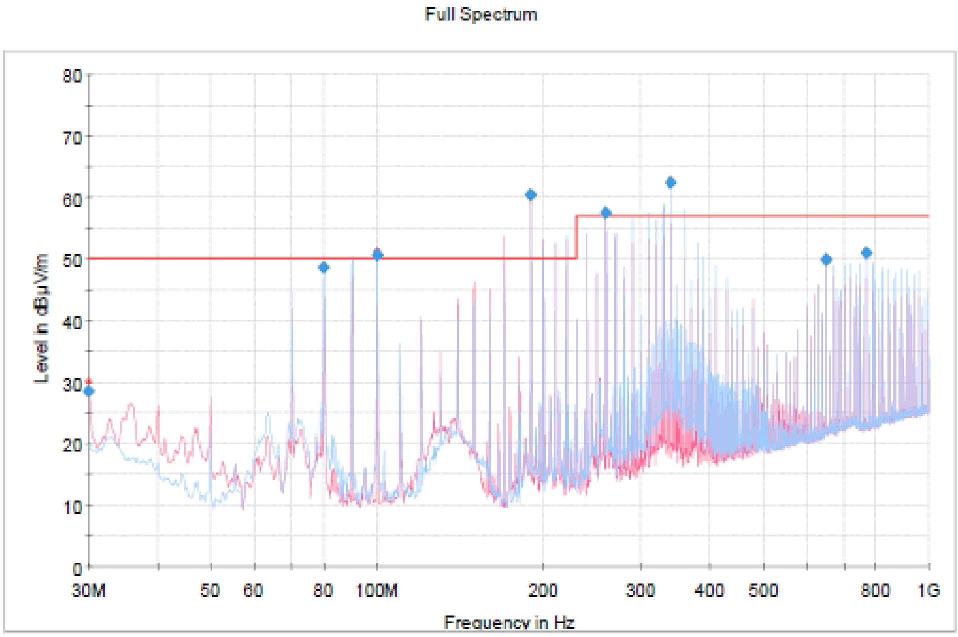
TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ◆ Quasi-peak final measure.

Figure 7. Radiated emission @ 4 MHz (STD board)



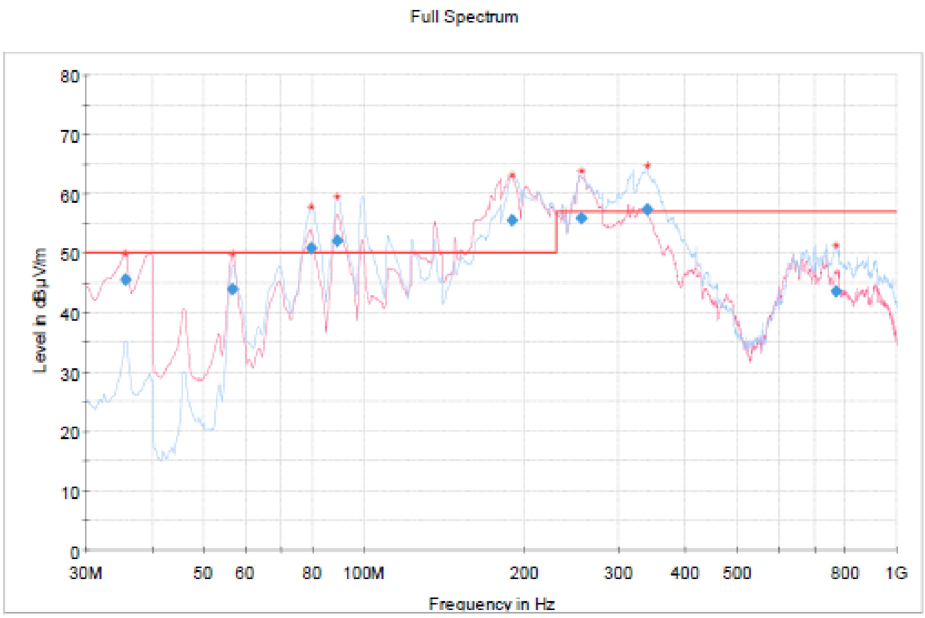
TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ◆ Quasi-peak final measure.

Figure 8. **Radiated emission @ 10 MHz (STD board)**



TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ♦ Quasi-peak final measure.

Figure 9. **Radiated emission @ frequency sweep from 2 MHz to 20 MHz (STD board)**



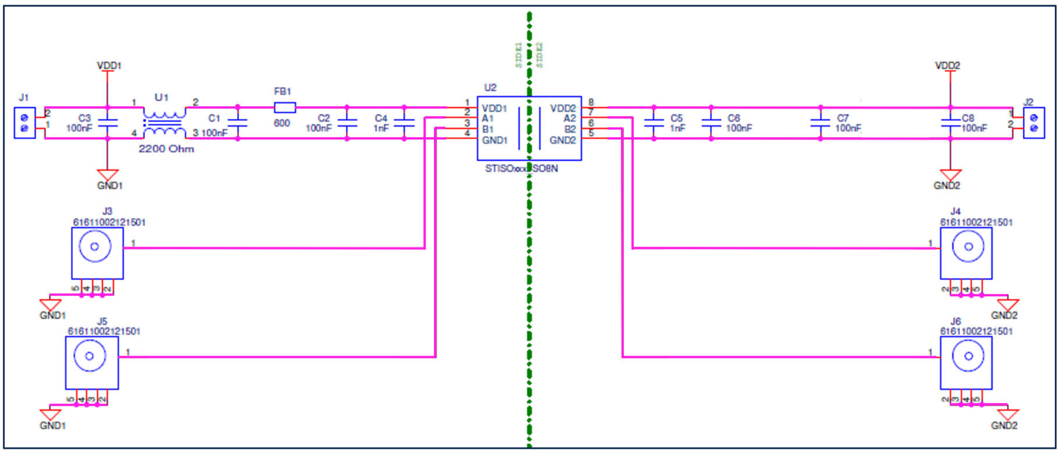
TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ♦ Quasi-peak final measure.

Based on these results, the board is not compliant, even with the class A, when the frequency of the transmitted signal is above 4 MHz.

4.4 Use EMI filter to reduce radiated emission

An experimental board based on the STISO620 has been developed, see Figure 9:

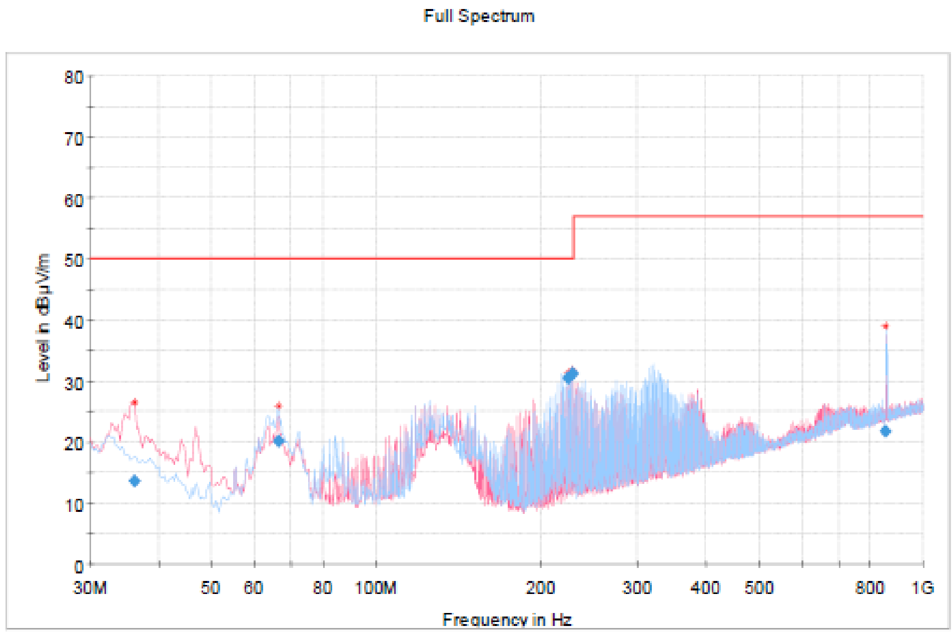
Figure 10. Optimized board for EMI with STISO620



where U1 is a common mode line filter and FB1 is a ferrite bead.

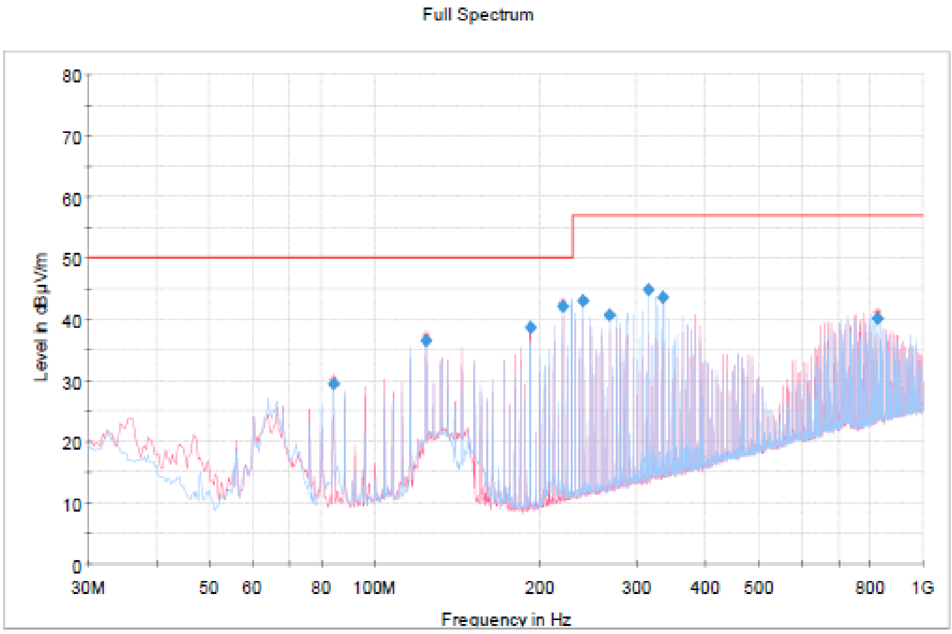
The same tests as the EVALSTISO62XV1, with the same operating conditions, were performed on this board.

Figure 11. Radiated emission @ 1 MHz (OPT board)



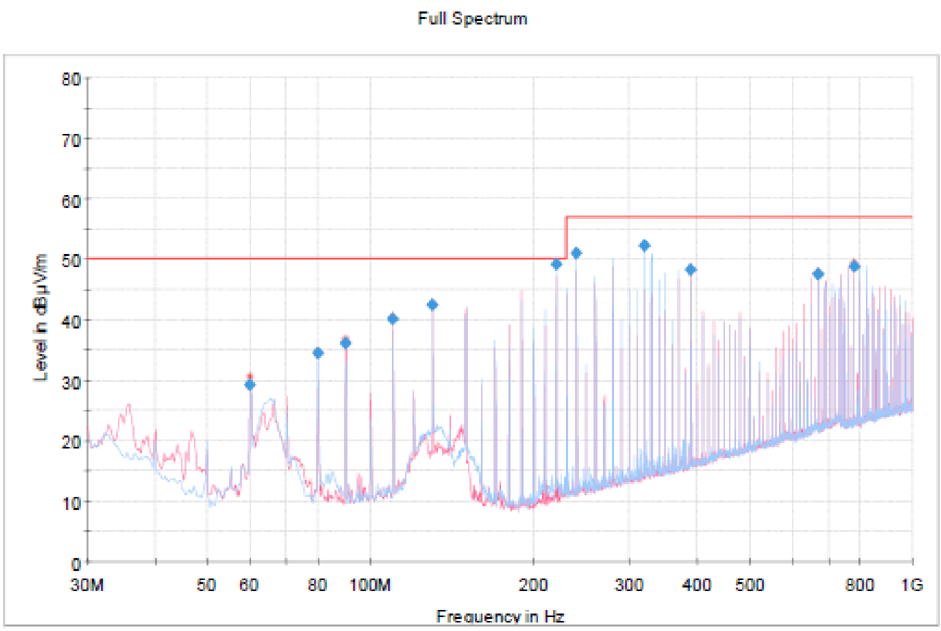
TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ♦ Quasi-peak final measure.

Figure 12. **Radiated emission @ 4 MHz (OPT board)**



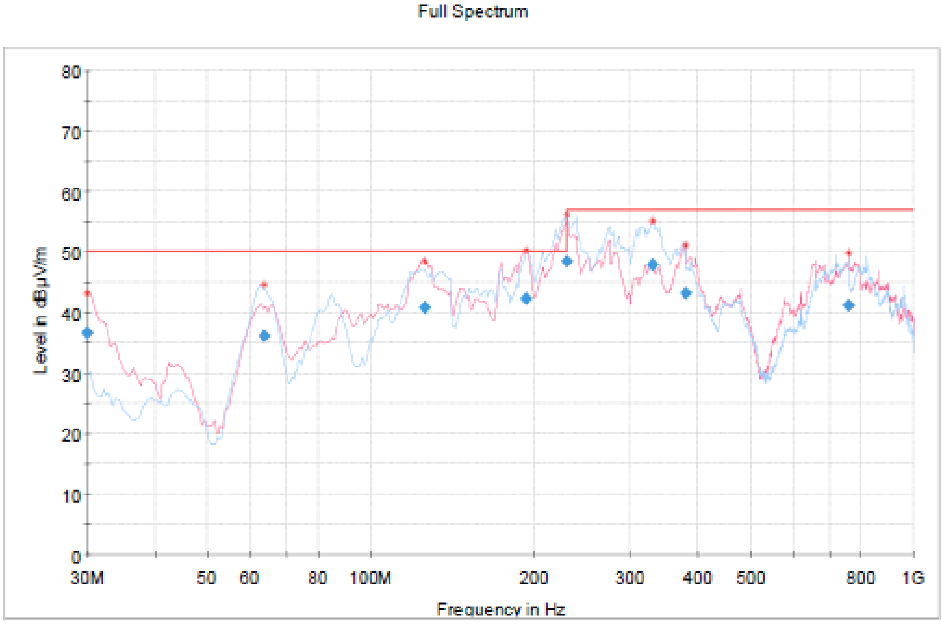
TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ♦ Quasi-peak final measure.

Figure 13. **Radiated emission @ 10 MHz (OPT board)**



TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ♦ Quasi-peak final measure.

Figure 14. **Radiated emission @ frequency sweep from 2 MHz to 20 MHz (OPT board)**



TRACE REMARK: limit 1 (red line): Quasi-Peak limit line. Detector 1 (magenta line): Peak - vertical polarization. Detector 2 (cyan line): Peak - horizontal polarization. * Peak prescan measure, ◆ Quasi-peak final measure.

Based on the previous results, the board developed in order to reduce the radiated emission is compliant with class A, as reported in Figure 4 for the frequencies tested.

Appendix A

A.1 Bill of material for optimized EMI board

With reference to the schematic in Figure 9, the BOM of the EMI optimized board is provided in the following table.

Table 1. **Bill of material for EMI optimized board**

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	6	C1 C2 C3 C6 C7 C8	100nF 0402 (1005 metric) 10V 10%	SMT ceramic capacitor	Wurth Elektronik	885012205018
2	2	C4 C5	1nF 0402 (1005 metric) 10V 10%	SMT ceramic capacitor	Wurth Elektronik	885012205006
3	2	J1 J2	MORSV-350-2P_screw	Terminal block T.H. 2 positions, 3.5mm	Wurth Elektronik	691214110002
4	4	J3 J4 J5 J6	61611002121501	SMB JACK R/A, 50 Ohm RECEPTACLE SMB-J/RA	Wurth Elektronik	61611002121501
5	1	FB1	600 Ohm	WE-CBF SMT EMI suppression ferrite beads	Wurth Elektronik	7427927161
6	1	U1	2200 Ohm	WE-CNSW SMT common mode line filter	Wurth Elektronik	744232222
7	1	U2	STISO620	Dual channel digital isolator	STMicroelectronics	STISO620TR

Revision history

Table 2. **Document revision history**

Date	Version	Changes
22-Aug-2024	1	Initial release.

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