EMI design considerations for PSOC™ Automotive 4

About this document

Scope and purpose

This document describes how to design PSOC™ Automotive 4 systems for Electromagnetic Interference (EMI) compliance. The purpose of this application note is to help engineers meet EMC standards by addressing the radiated and conducted emissions and susceptibility, ensuring robust, low-cost, and compliant system designs.

Intended audience

This application note is intended for design engineers, hardware developers, and system architects who are working with PSOC™ Automotive 4 microcontrollers in embedded systems and involved in designing, testing, or certifying electronic products for Electromagnetic Compatibility (EMC). The document targets professionals seeking practical guidance to meet regulatory requirements for radiated and conducted emissions and immunity, especially in automotive applications.

Note: *Prior familiarity with PSOC™ Automotive 4 devices and basic circuit board design is assumed, making it ideal for both experienced engineers and those new to PSOC™ Automotive 4 who aim to ensure robust, compliant designs.*

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1 Introduction

Every electronic device is required to comply with specific limits for emitted energy and susceptibility to external upsets. These limits are specified by the ISO, CISPR, and by similar regulatory bodies. The regulations help ensure that the electronic devices will not interfere with each other; for example, vehicle ECU module will not interfere with infotainment system, or worse, a mobile phone or other hand held electronic device will not corrupt the operation of a critical sensor module in vehicle.

Modern high-speed digital electronics are capable of generating very high-speed signals that have the potential to radiate substantial amounts of noise.

With the increasing use of high-speed digital circuits, wireless connectivity, and sensitive analog functions—especially in mixed-signal SoCs like PSOC™ Automotive 4, EMI (Electromagnetic Interference) has become a critical design challenge. Poor EMI design can lead to:

- Failed compliance testing
- Costly redesigns and delays
- Field failures in noisy environments (e.g., industrial, automotive, medical)
- Customer dissatisfaction due to erratic behavior

CMOS analog and digital circuits have essentially infinite input impedance. As a result, they can be sensitive to external fields, so suitable precautions must be taken to ensure their proper operation in the presence of large amounts of radiated and conducted (interfering) energy.

PSOC™ Automotive 4 device integrate programmable analog and digital blocks with microcontroller cores, making them incredibly flexible, but also potentially prone to both generating and being affected by electromagnetic noise. For example:

- Fast-switching digital I/Os and clocks can radiate noise
- Analog systems (like CAPSENSE™) can pick up interference and lead to false touches
- Power supply transients can cause glitches or resets

This application note outlines the basic specifications involved and provides guidance for secure and compliant designs.

Before starting about this EMI design consideration, if you are new to PSOC™ Automotive 4, refer to AN79953 - Getting started with PSOC™ 4 to learn about the device.

1.1 Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC) fundamentals

1.1.1 Electromagnetic Interference (EMI)

Electromagnetic Interference (EMI) is the unwanted noise that affects an electronic device or circuit due to an external source. It can come from natural sources (like lightning) or man-made sources (like motors, radios, or other electronics). When a device is exposed to an electromagnetic field, this noise can disrupt its normal operation, causing errors or poor performance.

EMI happens when energy from one system "couples" into another through the air (radiated) or through wires (conducted). It is often a short, sudden burst of energy that interferes with signals. EMI is also sometimes called Radio Frequency Interference (RFI).

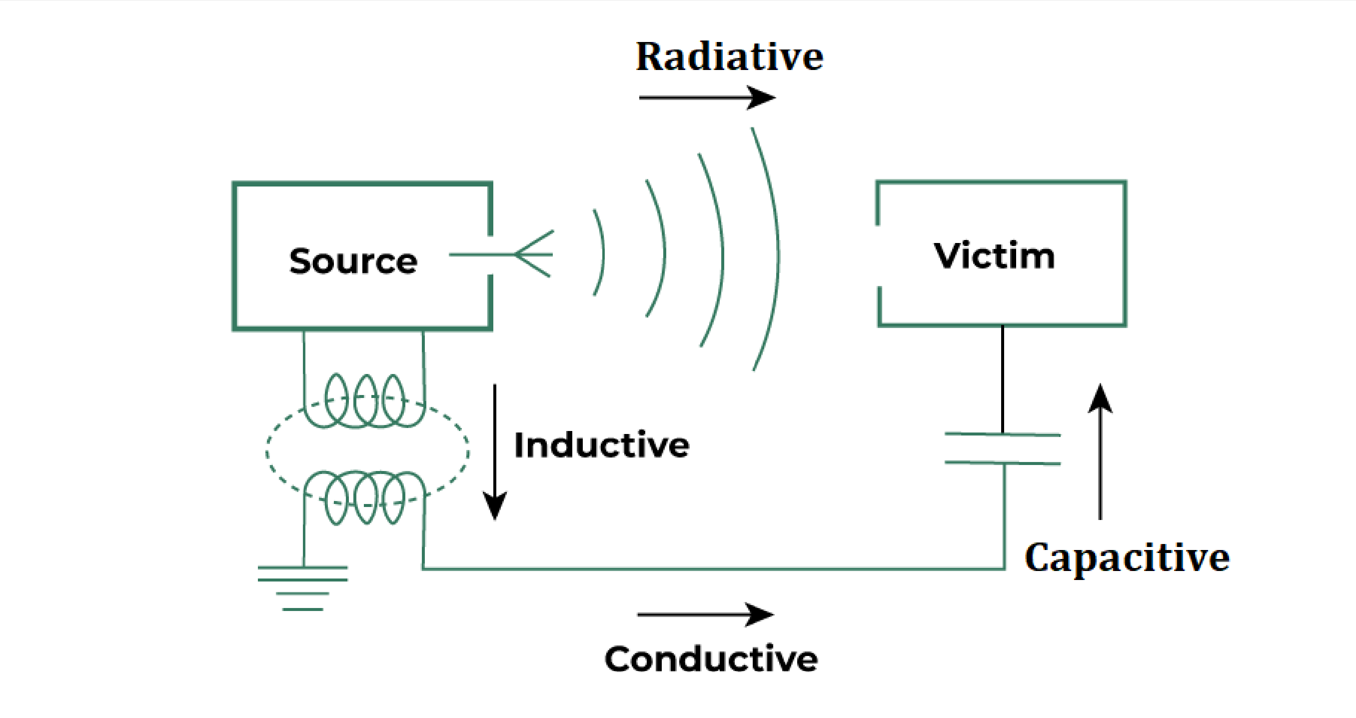

Figure 1 EMI coupling methods

In Figure 1, the source is the device which is responsible for generating the EMI via different types of coupling like radiative, inductive, conductive, capacitive, and victim is the device which is being affected due to that Interference.

The four types of coupling mechanisms of EMI are:

- **Conductive coupling:** Noise travels directly through physical connections like power or signal wires. It happens when two circuits share a common path, allowing interference to flow. Use clean power lines, filters, and separate grounds to reduce this type of noise
- **Capacitive coupling:** Electric fields between nearby traces transfer unwanted AC signals. This parasitic coupling acts like an invisible capacitor between wires. Reduce it by increasing spacing, using ground guards, or slowing down signal edges
- **Inductive coupling:** Changing currents create magnetic fields that induce noise in nearby loops. The stronger the current or the larger the loop, the worse the interference. Minimize loop areas and keep noisy and sensitive traces apart to reduce coupling
- **Radiated coupling:** EMI travels through the air as electromagnetic waves, like radio signals. It affects systems with long cables or poor shielding, especially at high frequencies. Use proper shielding, grounding, and layout to block or reduce received noise

In simple terms, EMI is the electrical noise that causes electronic devices to misbehave.

1.1.2 EMI transmission

EMI transmission

The source of EMI can be natural or man-made. EMI travels in two main ways: conducted and radiated.

- **Conducted EMI:** Conducted EMI requires physical connection and can travel through the wires or signal cables. It flows through the connections that link the equipment together. Common paths include power cords and interconnecting wires. Conducted EMI can also happen through unwanted (parasitic) capacitance between circuits. At low frequencies, noise usually travels as conducted EMI

- **Radiated EMI:** Radiated EMI does not need any physical connection and can travels through the air like a radio wave. This kind of EMI is created when a device gives off electromagnetic energy, either on purpose or by accident. The energy spreads out and can affect nearby devices, even at a distance. This interference can enter a device through induction. It may also disrupt the source device itself if the emitted energy is strong enough to affect its own circuitry. At high frequencies, noise mostly travels as radiated EMI. Sometimes, radiated EMI can affect a system in a way that looks like it came through a wire

1.1.3 Electromagnetic Compatibility (EMC)

Electromagnetic Compatibility (EMC)

Electromagnetic Compatibility (EMC) refers to a device's ability to function properly in its electromagnetic environment without causing interference to other devices. EMC testing ensures that electronic products meet this requirement by evaluating two key aspects: emissions and immunity.

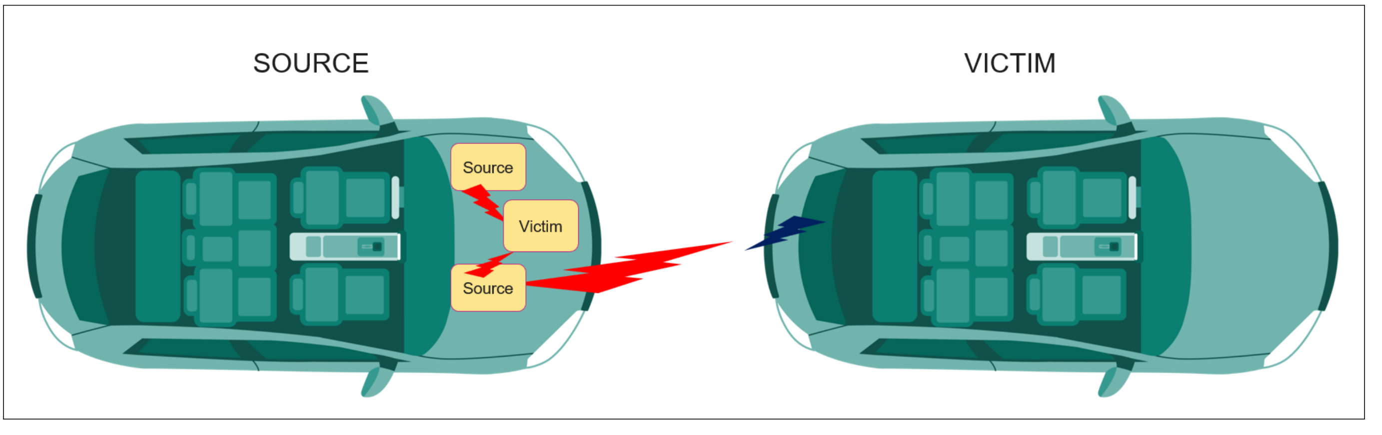

Figure 2 EMC testings

- **Emissions testing** checks how much electromagnetic energy a device unintentionally generates and releases, either through wires (conducted emissions) or through the air (radiated emissions). If a device emits too much noise, it can interfere with nearby electronics like radios, medical equipment, or communication systems
- **Immunity testing (also called susceptibility testing)** checks how well a device can continue to operate when exposed to external electromagnetic disturbances. These disturbances can come from sources like mobile phones, power lines, or nearby industrial equipment. The goal is to ensure that the device doesn't malfunction, reset, or lose data when exposed to such interference

EMC regulations are set by international and national bodies, such as the ISO, CISPR/EN, SAE standards and are mandatory in most markets before a product can be sold. Passing EMC certification is not just a legal requirement but also improves product reliability, safety, and enhanced user experience. See Table 1 for the standards list.

While full compliance tests are performed in certified laboratories, engineers often use pre-compliance testing during development to identify and fix EMI issues early. Common pre-compliance checks include:

- Radiated emissions
- Conducted emissions
- Radiated immunity
- Electrostatic discharge (ESD)

This application note will focus on the two radiated tests: radiated emissions (how much RF noise the PSOC™ Automotive 4 emits) and radiated immunity/susceptibility (how well it resists external RF fields). These are especially important for when the device is surrounded by the sensitive analog components.

1 Introduction

By understanding and designing for EMC from the start, engineers can avoid costly redesigns, reduce time-to-market, and build more robust and reliable electronic products.

2 Specifications

Automotive products EMI/EMC specifications are guided by regulatory bodies such as UNECE, CISPR, ISO, and SAE and are governed by standards like CISPR 25, ISO 11452, SAE J551, and UNECE Regulation No.10.

Table 1 lists the some of the applicable EMI standards.

Table 1 Few of the applicable EMI standards in automotive products

Regulatory body	Region	Emission standard	Immunity standard	Notes
CISPR (International Special Committee on Radio Interference	Global	CISPR 12, CISPR 25, CISPR 36	ISO 7637	Most common for Emissions
ISO (International Organization for Standardization)	Global	CISPR25	ISO 11452, ISO 10605, ISO 11451	Most common for Immunity (BCI testing)
UNECE (United Nations Economic Commission for Europe)	Europe	UNECE R10	UNECE R10	Most common for whole vehicle approval
IEC (International Electrotechnical Commission)	Global	IEC 61967	IEC 62132	IC level tests
SAE (Society of Automotive Engineers)	Global	SAE J551, SAE J1113	SAE J551, SAE J1113	Vehicle and component-level testing for emissions and immunity
OEM specific	Global	OEM-specific standards from respective vehicle manufactures		

1. **CISPR, ISO, SAE:** These are international bodies providing standards widely adopted across regions and OEMs for both vehicle-level and component-level EMI/EMC testing
2. **UNECE:** Focused on Europe, with UNECE R10 being critical for vehicle type approval in the EU
3. **OEM-Specific:** Major OEMs like BMW, Ford, GM, and others have proprietary standards that often build upon CISPR, ISO, or SAE standards but include additional requirements tailored to their vehicles
4. Test types include radiated/conducted emissions (measuring electromagnetic interference from the vehicle/component) and immunity (resistance to external electromagnetic disturbances like ESD, BCI, or RF fields)

3 Emissions

Electromagnetic emissions are a critical aspect of EMC compliance. In PSOC™-based systems, emissions primarily stem from high-speed digital switching, clock signals, and power supply transients. These emissions are categorized into two types (radiated and conducted). Proper design techniques at both the IC and PCB level can significantly reduce emission levels and help achieve regulatory compliance.

To ensure low emissions:

- Minimize high-frequency energy in signal paths
- Use proper bypassing and filtering
- Control slew rates and signal integrity
- Follow good PCB layout practices

The following sections provides a breakdown of each emission type and the recommended mitigation strategies.

3.1 Radiated

Radiated emissions in electronic systems are primarily caused by fast digital switching transients on input and output (I/O) pins. These rapid voltage changes (high dV/dt) generate high-frequency harmonics that can radiate from PCB traces, cables, or connectors, acting as unintentional antennas. In PSOC™ Automotive 4 designs, even moderate-speed digital signals can contribute significantly to electromagnetic interference (EMI), especially if layout and drive settings are not optimized.

To minimize the radiated emissions, the bandwidth of digital outputs should be limited as much as possible without compromising the functionality. This can be achieved through two configurations - slew rate control and drive strength.

Slew rate control in PSOC™ devices:

- **Slew rate control in PSOC™ devices**

  PSOC™ Automotive 4 devices include programmable I/O with configurable slew rates. While the maximum clock frequency for general-purpose I/Os is typically limited to 33 MHz, the ability to select slower rise and fall times allows designers to suppress high-frequency harmonic content in digital signals.

  Slower edge rates reduce the amplitude of higher-order harmonics (e.g., 100 MHz, 300 MHz), which are often responsible for failing radiated emission tests. The best practice is always to use the slowest slew rate that meets the system timing requirements, especially for non-critical signals like LEDs, status indicators, or control lines.

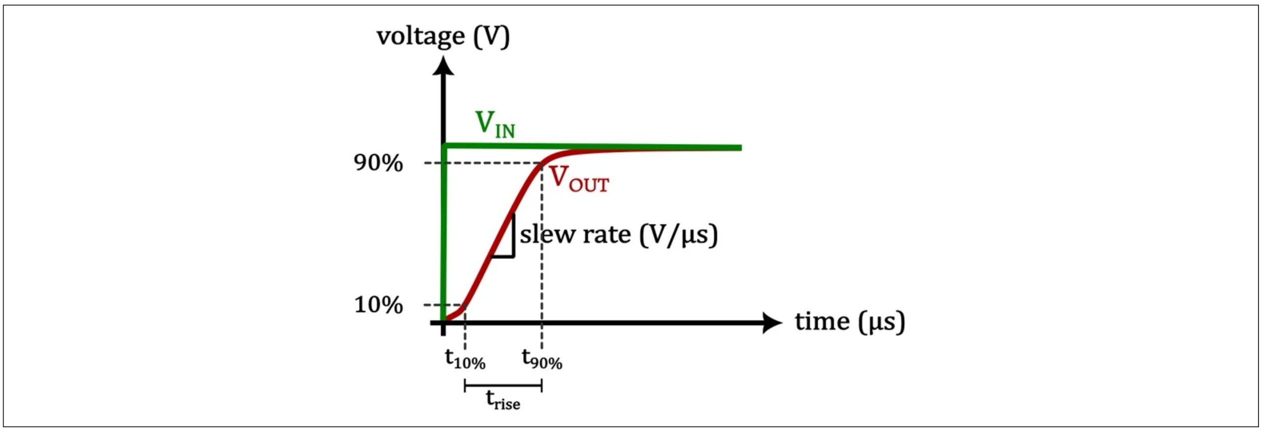

Figure 3 Slew Rate

PCB layout recommendations for high-speed signals:

- **PCB layout for high-speed signals**

Even with controlled drive strength, poor PCB layout can turn a well-designed circuit into a strong radiator. Hence, the following are recommended:

- Keep high-speed traces as short as possible. This includes clock lines, SPI, UART, I2C, and any digital signals switching above 10-15 MHz
- For signals that must leave the board (e.g., to an external display, sensor, or connector), add a series termination resistor (15-50 Ω) at the source (PSOC™ output pin). This resistor:
  - Damps signal ringing (overshoot/undershoot)
  - Limits peak current
  - Acts as a low-pass filter when combined with trace capacitance

Coupling considerations for high-speed signals:

- **VDD coupling via output drivers:**

  A critical yet frequently neglected aspect is that when a PSOC™ digital output is HIGH, it connects directly to VDD through the P-channel FET's RDS(ON). This means that any noise present on the VDD rail will appear directly on the output pin. This coupling path can turn seemingly clean digital signals into carriers of power supply noise, effectively amplifying conducted noise into radiated emissions.

  To break this path, use high-frequency ceramic bypass capacitors placed as close as possible to each VDD pin of the PSOC™ device. The capacitor bypass traces should be very short, and ground and power planes should be used where possible.

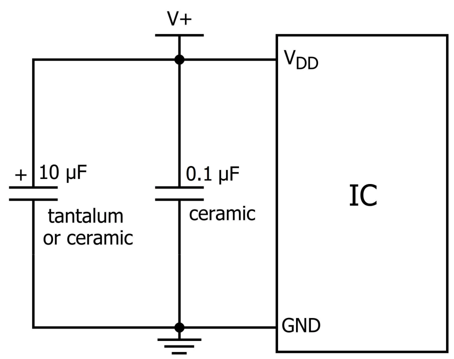

Figure 4 Bypass capacitor to filter VDD supply noise

If you are using CAPSENSE™, for capacitive touch sensing feature in PSOC™, refer to the AN64846 – Getting Started with CAPSENSE™ external documentation for EMI considerations.

3.2 Conducted

Conducted emissions are unwanted electrical noise that travels through wires or power cables. Unlike radiated emissions (which fly through the air), conducted emissions move along the power lines — either going into the device from the power source or out of the device back into the power system.

How does this noise happen?

When digital circuits inside the PSOC™ switch on and off quickly, they draw sudden bursts of current from the power supply. These fast current changes can create voltage spikes and high-frequency noise on the power lines. If there's no good path for this noise to go, it flows back through the power cable and into the main power system, this is what causes conducted emissions.

How to reduce conducted emissions?

The key is to keep the PSOC™ power supply clean and stable, so that the noise doesn't escape into the system. Some of the best practices are:

1. **Using high-frequency bypass capacitors**

Place small ceramic capacitors (usually 100 nF) very close to each VDD pin of the PSOC™ chip as shown in Figure 4.

- They helps to short high-frequency noise to ground, stopping it from spreading
- Make sure that the capacitor traces are very short as long traces reduce their effectiveness

2. **Power supply switching**

   The biggest source of conducted emissions is often the switching power supply (also called as DC-DC converter), not the PSOC™ itself. These supplies switch very fast and can inject a lot of noise into the system. For appropriate countermeasures refer to the supplier of the power supply

3. **Add a bulk capacitor near the chip**

   A bulk bypass capacitor is added near the chip to support large instantaneous load demands near the PSOC™ device effectively. Additionally, it prevents decoupling of the PSOC™ chip and its direct loads from the power system

4. **Use filters on the power input**

   To stop noise from leaving the system, ferrite beads can be used to suppress emission from supply lines, by this way all the high frequency conducted emissions will get blocked

5. **Connect to Chassis Ground**

   The chassis acts as a global 0-volt reference potential for the entire vehicle's electrical system. This ensures that all components have a common, stable reference point. Hence by connecting circuit's ground to chassis ground it helps to shunt away the noise safely using the filtering capacitors

Why this matters?

Even if your PSOC™ design is perfect, a noisy power supply can cause your whole product to fail EMC testing. By using proper filtering and bypassing, you:

- Keep the PSOC™ running smoothly
- Prevent noise from leaking into the power grid
- Increase the chances of passing compliance tests the first time

4 Susceptibility

While emissions focus on how much noise your system generates, susceptibility (or immunity) deals with how well your system can withstand external electromagnetic interference (EMI) without malfunctioning. A robust design must not only be quiet but also resilient to real-world electrical noise from sources such as:

- Nearby radio transmitters
- Switching power supplies
- Electric motors
- Electrostatic discharge (ESD)
- ISO 7637 pulses (for Fast transient bursts)

PSOC™ devices, with their high-impedance CMOS inputs and mixed-signal architecture, are inherently sensitive to external disturbances. Therefore, board-level design practices are critical to ensure reliable operation in noisy environments.

Susceptibility is tested under standards like IEC 61000-4-X, which define test levels for radiated and conducted immunity, ESD, surge, and fast transients. This section outlines key strategies to improve system immunity.

4.1 Radiated

Electrical energy can influence system measurements and potentially the operation of the processor core. The interference enters the PSOC™ chip at the PCB level through the pins. Radiated energy is highly unlikely to interfere directly with the chip.

Careful board layout, as well as a good PSOC™ project design, prevents the upsets from the radiated energy. The precautionary steps include:

1. High-impedance analog sources (e.g., resistive sensors) are more susceptible to noise. Use the onboard signal conditioning (amplifiers, buffers) to lower output impedance before routing to the PSOC™device. This reduces the source impedance of the analog signals and hence, the noise
2. Large loops between a signal trace and its return path makes a device prone to electromagnetic interference (EMI). Keep sensor, analog, and communication traces short and always route them close to a solid ground plane
3. A continuous ground plane beneath the signal layers provides a low-impedance return path and shields sensitive circuits from the RF fields. Avoid splitting the ground plane, especially under analog or high-speed digital sections
4. Leave no pin floating. Configure the unused PSOC™ pins as:
   - Strong digital output driven LOW (preferred)
   - Strong digital output driven HIGH
   - Open-drain with pull-up/down enabled

   Floating pins can pick up RF energy and couple it into the device core

4.2 Conducted

Conducted susceptibility involves the immunity of PSOC™ Automotive 4 against the noise that enters the system through power and signal cables, such as:

- Voltage transients (EFT, surge, ESD)
- RF noise coupled via data lines

Hence, as mentioned above, the electrical energy influences system measurements and upsets the operation of the processor core by driving the PSOC™ chip's power supply out of range, which can lead to various issues such as:

- ADC reading errors

- CPU resets
- Memory corruption
- Peripheral lockups

Power-line inputs should be protected with protection techniques such as:

1. **Power line filtering:**
   - Ferrite beads can be used to suppress the high frequency noise that enters via the Power line Inputs
   - Include a π-filter (LC filter) for sensitive subsystems (e.g., analog supply VDDA)
2. **Transient voltage suppression (TVS):**
   - Sudden surges like ISO 7637 pulses and ESD ISO 10605 are contributes to the Transient Fast voltages which may damage the device
   - Using series Diode, resistor followed by a parallel capacitor will suppress the Transient voltages caused by ISO pulse 1 on power supply lines
   - Use appropriate parallel ESD diodes or a RC-filter for data lines and other signals
3. **Bulk and high-frequency Decoupling:**
   - Use 10–100 µF bulk capacitors near the power entry point as shown in Chapter Radiated
   - Combine with 100 nF ceramic capacitors at the PSOC™ power pins to handle high-frequency transients
   - Consider ferrite beads in series with VDD, followed by local bypassing (form an LC filter)

For more details, see the References section.

5 EMI testing

Radiated emission measurements are made first in an anechoic chamber to generate a list of suspect frequencies. The equipment under test is then relocated to an open area test site. Radiated emission measurements are made at the EUT azimuth and antenna height such that the maximum radiated emission level can be detected. This requires the use of a turntable and an antenna positioner that can adjust the antenna's height as well as shift its orientation from horizontal to vertical.

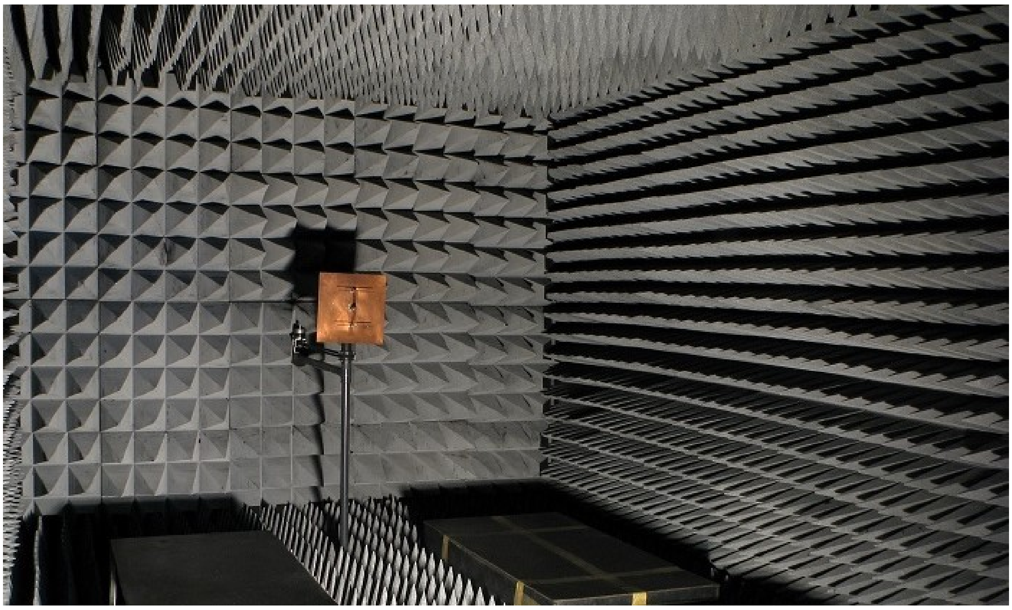

Figure 5 Anechoic chamber

Conducted emission measurements are made over the frequency range from 150 kHz to 2500 MHz (standard: CISPR-25) to determine the line-to-ground radio noise voltage conducted from the device power input terminals that are directly (or indirectly via a separate transformer or power supplies) connected to a public power network. Equipment is tested with power cords that are normally used or that have electrical or shielding characteristics that resemble the cords normally used.

Radiated immunity is measured in a shielded anechoic chamber large enough to contain the system under test and allow adequate control over field strength over the frequency range from 80 MHz to 2500 MHz (standard: ISO 11452-2). The system under test is maintained in uniform field strength.

Frequency stepping and power requirements are as specified in the relative standards. The output of the system under test is monitored for disturbance.

Conducted immunity is tested by applying the RF signal to external power and signal cables with clamps that surround the cable. In this case, the power and signal cables act as passive, receiving antenna networks.

Table 2 EMI/EMC compliance verified with PSOC™ Automotive 4

Test category	Test type	Specification
System level	Radiated immunity	ISO11452-2
	Radiated emissions	CISPR-25
	Conducted immunity	ISO11452-4
	Conducted emissions	CISPR-25
IC level	Radiated immunity	IEC 62132-8
	Radiated emissions	IEC 61967 -8

(table continues...)

Table 2 (continued) EMI/EMC compliance verified with PSOC™ Automotive 4

Test category	Test type	Specification
	Conducted immunity	IEC 62132-4
	Conducted emissions	IEC 61967-4

IC level testing is used to determine the EMC properties of Infineon products independently of a system in which they are incorporated.

These results can help system designers to determine the EMC filtering effort, that is required for their individual applications to pass system EMC tests.

IC level EMC testing is conducted according to the Generic IC EMC Test Specification.

System level EMC tests are performed only for some selected cases, which serve as a demo or example application.

6 Design example

The images in this section demonstrates the EMI/EMC test results, which are validated using Infineon's internal EMI/EMC test board.

Table 3 lists the radiation pattern results for the mentioned emission test cases and radiated immunity test cases.

Table 3 Radiated emission test cases

Frequency	Antenna position	Antenna direction
30 MHz - 200 MHz	Harness	Biconical - Vertical
30 MHz - 200 MHz	Harness	Biconical - Horizontal
1 GHz - 2.5 GHz	DUT	Horn antenna - Vertical
1 GHz - 2.5 GHz	DUT	Horn antenna - Horizontal

All the above tests are done with the Infineon's PSOC™ 4100S Plus Internal EMI/EMC test board. The block diagram of the board and the radiation results are mentioned below.

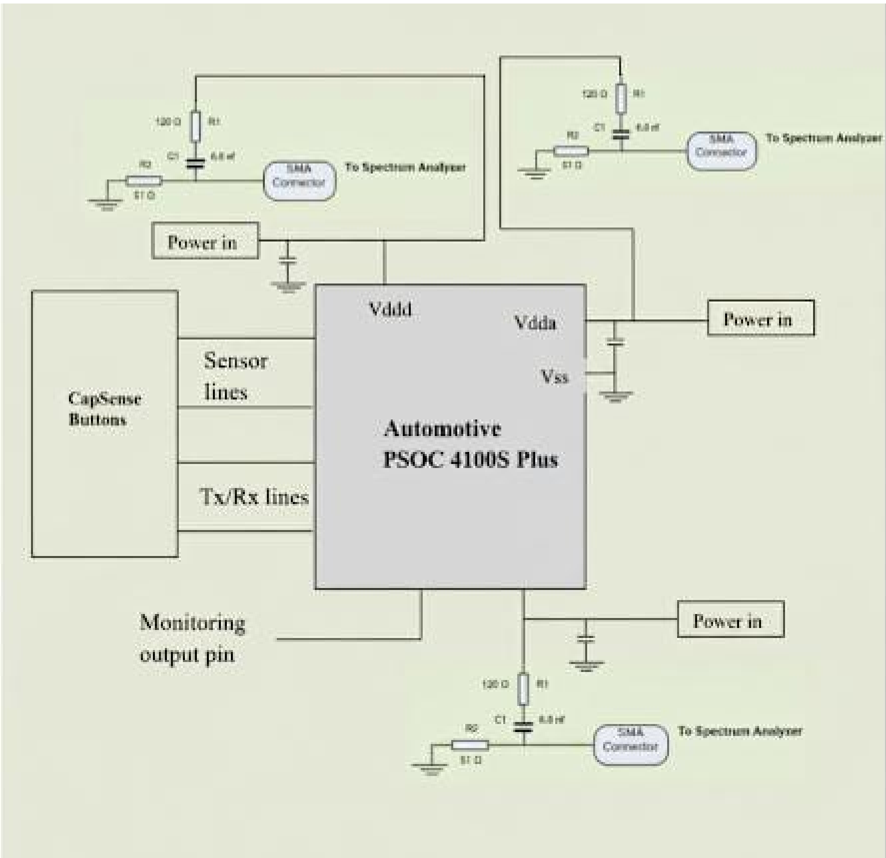

Figure 6 Block diagram of PSOC™ 4100S Plus Internal EMI/EMC test board

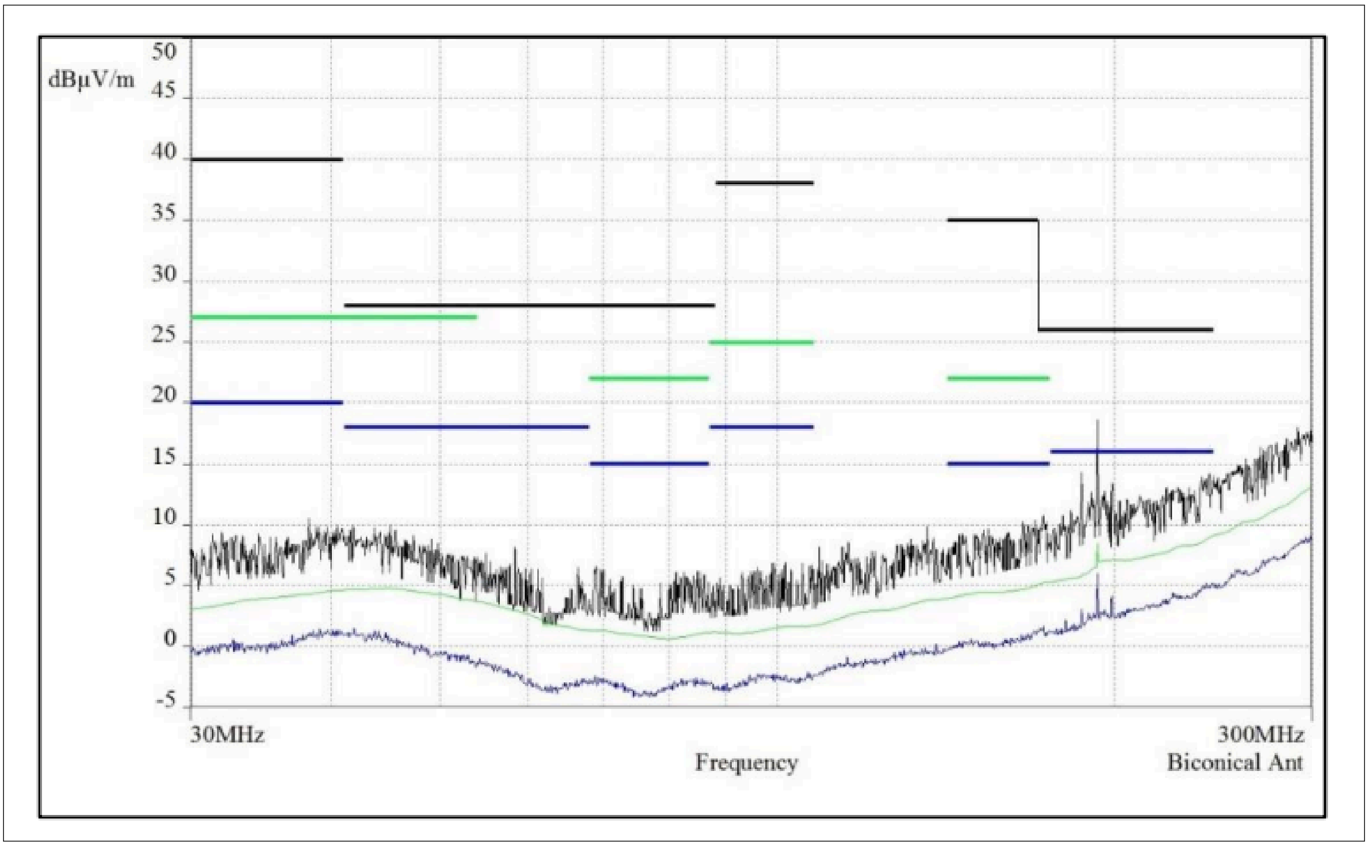

Figure 7 **Radiated emission range from 30 MHz to 200 MHz - Biconical antenna at harness, vertical direction**

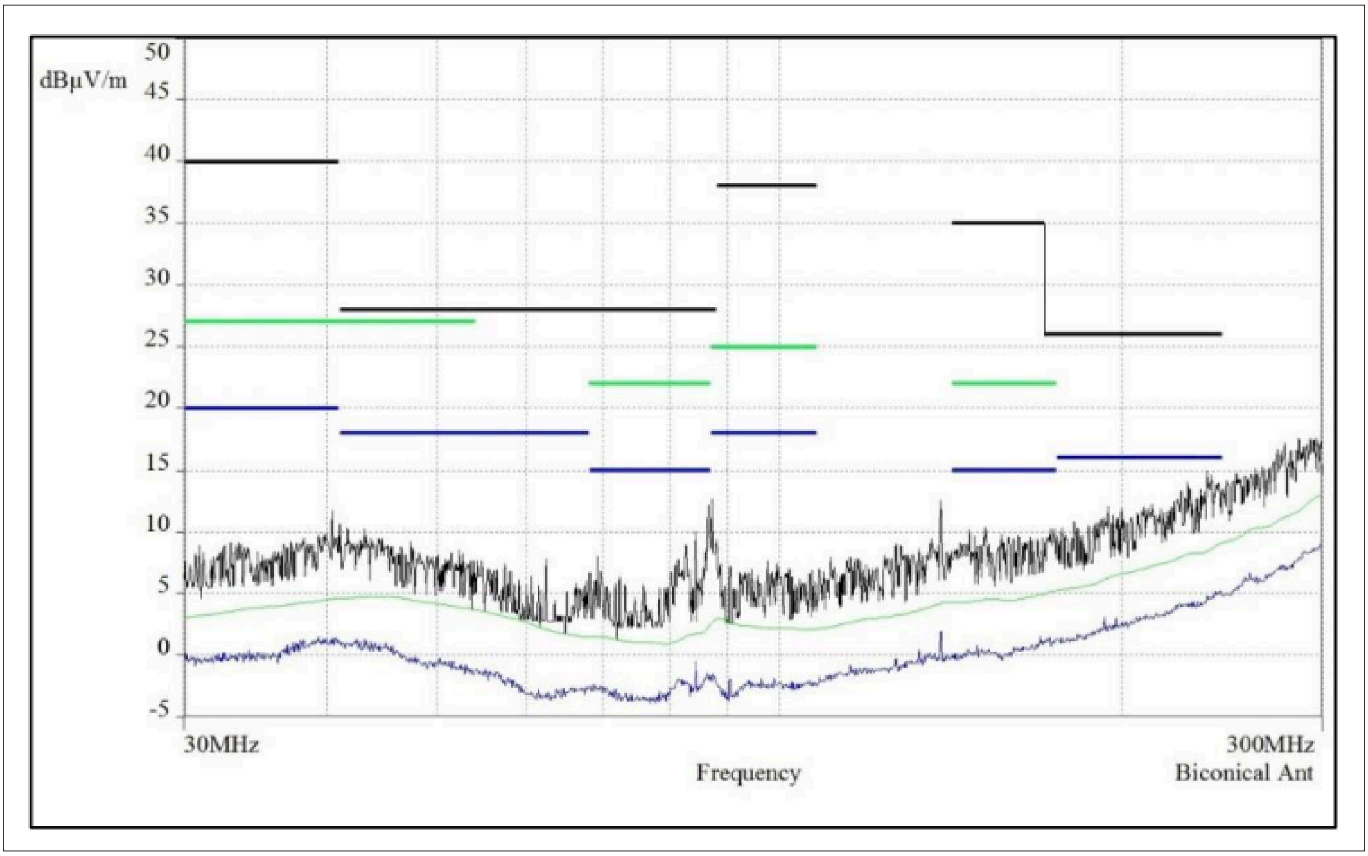

Figure 8 **Radiated emission range from 30 MHz to 200 MHz - Biconical antenna at harness, horizontal direction**

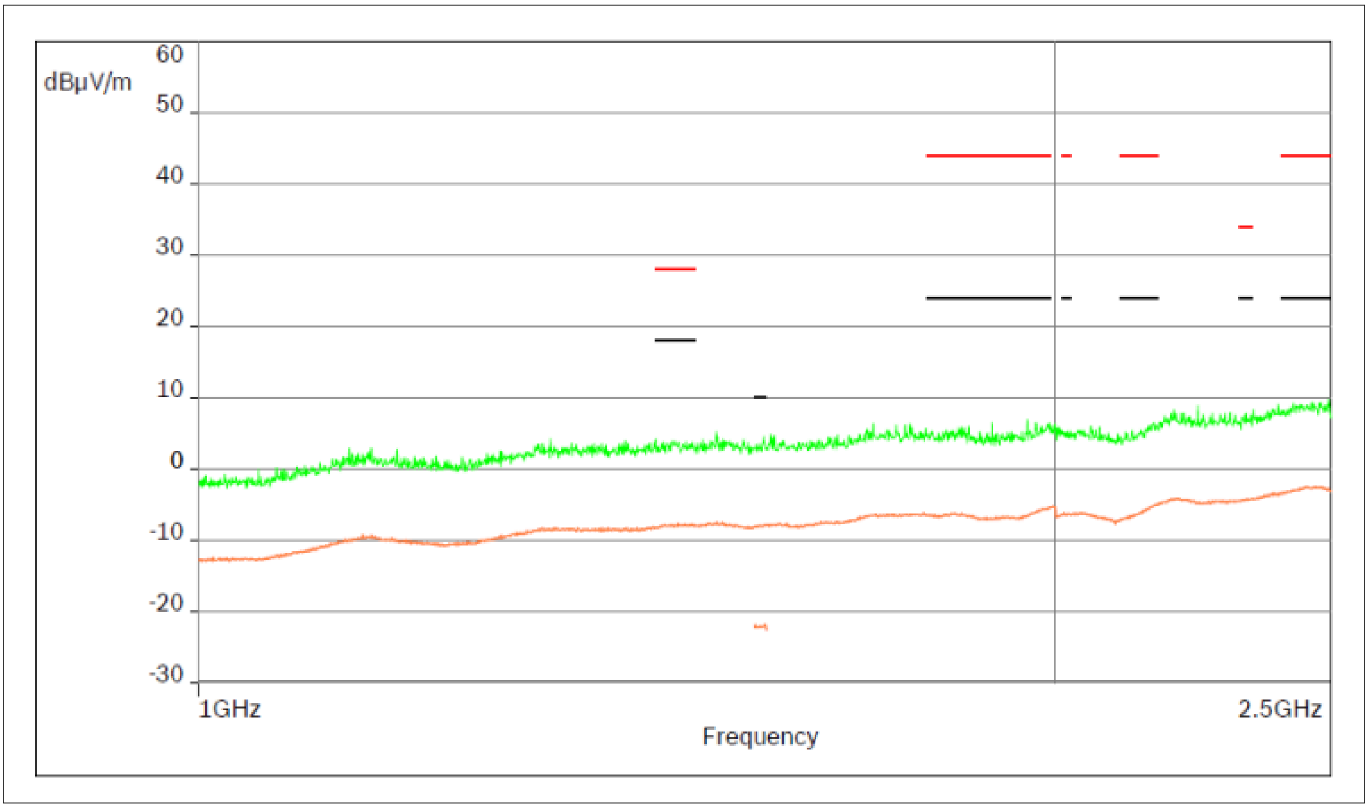

Figure 9 **Radiated emission range from 1 GHz to 2.5 GHz - Horn antenna at DUT, vertical direction**

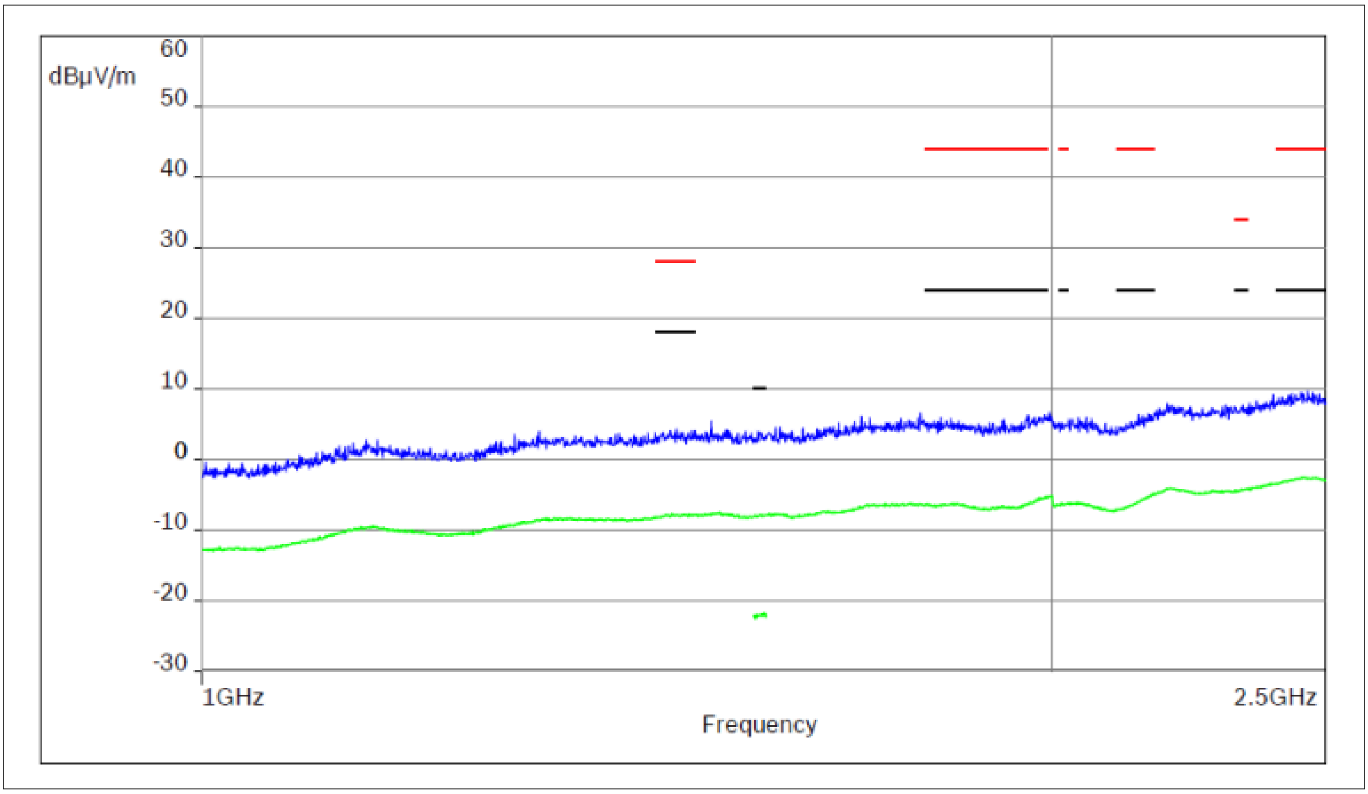

Figure 10 Radiated emission range from 1 GHz to 2.5 GHz - Horn antenna at DUT, horizontal direction

Table 4 Radiation immunity test cases

Frequency range	Modulation type	Antenna polarization	Field strength	Step size
80 MHz to 400 MHz	AM	Vertical	100 V/m	5% step
80 MHz to 400 MHz	AM	Horizontal	100 V/m	5% step
1 GHz to 2 GHz	CW	Vertical	100 V/m	2% step
1 GHz to 2 GHz	CW	Horizontal	100 V/m	2% step

The radiated immunity test passed the ISO 11452-2 standard, no any false touches are observed in the CAPSENSE™ buttons during the radiated immunity testing.

7 Summary

Electromagnetic emissions and susceptibility are system-level concerns that require careful design to ensure electromagnetic compatibility (EMC). This application note highlights the key generic design considerations to help manage both radiated and conducted emissions, which relate to unwanted electromagnetic energy a device may generate, as well as susceptibility, which refers to its ability to withstand external interference. Standardized test methods for evaluating emissions and immunity are also outlined, providing a foundation for achieving compliance and reliable performance in real-world operating environments.

8 Design references

Designing for EMC considerations is an important and exhaustively published topic. Following are the author's recommendations:

- Henry Ott, Noise Reduction Techniques in Electronic Systems, 2nd Edition. John Wiley & Sons
- David Terrell and R. Kenneth Keenan, Digital Design for Interference Specifications: A Practical Handbook for EMI Suppression. Newnes
- William D. Kimmel and Daryl D. Gerke, Electromagnetic Compatibility in Medical Equipment: A Guide for Designers and Installers. IEEE Press

References

[1] AN79953 – Getting Started with PSOC™ 4
[2] AN57821 – PSOC™ 3, PSOC™ 4, and PSOC™ 5LP mixed signal circuit board layout considerations
[3] AN80994 – PSOC™ 3, PSOC™ 4, and PSOC™ 5LP EMC best practices and recommendations

Revision history

Document revision	Date	Description of changes
**	2025-10-29	Initial release

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