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EMI Filtering in the Robotics and Automation Industry—an Overview

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Introduction

Robotics is a rapidly expanding field revolutionizing various industries. Electromagnetic compatibility (EMC) is a critical consideration in the design and operation of robotics and automation systems. EMC refers to the ability of a system to function correctly in the presence of electromagnetic interference (EMI), which can come from a variety of sources such as radio frequency transmitters, electrical equipment, and lightning. EMI can disrupt the operation of a system by causing errors in electronic signals or damaging components. Ensuring EMC is essential for the reliability and safety of robotics and automation systems.

Types of Robotics and Automation

There are many different types of robotics and automation that are used in various industries.

- **Industrial robotics.** These are used in manufacturing settings to perform tasks such as welding, painting, and assembly. They are often large and expensive, but they can operate continuously and are highly precise.
- **Service robotics.** These are used in settings such as hospitals, hotels, and homes to perform tasks such as cleaning, delivering items, and assisting with healthcare. They are often smaller and less expensive than industrial robots.
- **Military robotics.** These are used in military operations to perform tasks such as bomb disposal, surveillance, and transportation. They are often designed to operate in hazardous environments.
- **Agricultural robotics.** These are used in the farming industry to perform tasks such as planting, spraying pesticides, and harvesting crops. They can help increase efficiency and reduce the need for manual labor.
- **Automated manufacturing systems.** These are used in manufacturing settings to perform tasks such as assembly, inspection, and packaging. They often involve the use of conveyor belts, robots, and other automated equipment.
- **Robotic surgery.** These are used in the farming industry to perform tasks such as planting, spraying pesticides, and harvesting crops. They can help increase efficiency and reduce the need for manual labor.

Applicable EMC Directives and Standards for Robotics and Automation

The European Union (EU) has several directives and standards related to electromagnetic compatibility (EMC) that are applicable to robotics and automation applications.

EU directives which are EMC related for robotics and automation are:

- The EMC Directive 2014/30/EU: This directive sets out the essential requirements for the EMC of electrical and electronic equipment in the EU [1]. It applies to a wide range of products, including robots and automated systems.

- The Machinery Directive 2006/42/EC: The Machinery Directive is a European Union (EU) directive that sets out the essential health and safety requirements for the design and construction of machinery [2].

The EMCD applies to machinery that contains electrical or electronic parts that may generate or be affected by electromagnetic disturbance. The EMC Directive (EMCD) covers aspects of electromagnetic compatibility related to the functioning of machinery. However, the Machinery Directive (MD) covers the immunity of machinery with respect to safety-related electromagnetic disturbance, whether transmitted by radiation or by wire.

The presumption of conformity is a fundamental principle of the European Union's technical harmonization and standardization. In order to facilitate the free movement of goods within the European Union, products must meet essential requirements, which are set out in relevant EU directives (e.g. the EMCD or the MD). Harmonized standards are one of the means of demonstrating conformity with these essential requirements.

The European Commission maintains a list of harmonized standards for electromagnetic compatibility (EMC) that are published in the Official Journal of the European Union (OJEU). You can find the current list of harmonized EMC standards on the European Commission's website about harmonized EMC standards [3].

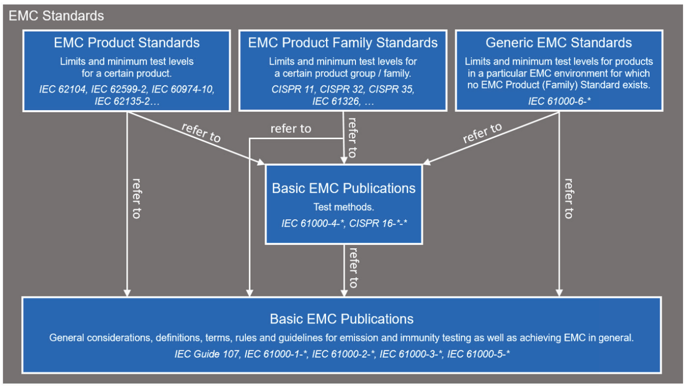

Figure 1: EMC product standards, EMC product family standards, generic EMC standards and basic EMC publications and how they interact [4].

The most challenging part is to find the applicable EMC standards for your product. There are no universal applicable EMC standards for robotics and automation devices and installations. Instead, different EMC standards are defined for specific product (families): laboratory automation (EN 61326-1), household (EN 55014-x), building automation (EN 50491-5-x), etc. In case no specific EMC product standard or EMC product family standard is defined, the generic EMC standards are applied (see Figure 1):

- EN 61000-6-1 (immunity for residential, commercial, and light-industrial environments)

- EN 61000-6-2 (immunity for industrial environments)

- EN 61000-6-3 (emission for equipment in residential environments)

- EN 61000-6-4 (emission for industrial environments)

- EN 61000-6-8 (emission for professional equipment in commercial and light-industrial locations)

Design for EMC

Design for EMC means that EMC is considered early during product development, not just at the end of a project. If you test your product for EMC just shortly before the product is to be launched, project delays and budget overruns result. This is true for every industry, not just robotics and automation.

Here some essential points regarding EMC and product development:

- **EMC concept.** You need to define an EMC concept at the very beginning of the development project (before the first hardware is designed). This EMC concept should especially define points like grounding, shielding, filtering.
- **Iterative testing.** It is recommended to test the EMC performance (emission, immunity) at different product development iterations. There are typically four iterations in hardware development projects: breadboard, prototype, pilot, series. It is good practice to do pre-compliance testing (testing in-house or at a not fully accredited compliance lab) at the prototype stage and fully compliant EMC testing at the later project stages (pilot, series).

EMC Issues in Robotics and Automation

There are several challenges related to EMC in the robotics and automation industry. Electromagnetic interference (EMI) can disrupt the operation of electronic devices, including robots and automated systems. This can lead to errors, malfunctions, and even safety hazards.

A robotics system that incorporates motors, sensors, displays, and wireless communication can be susceptible to a variety of electromagnetic compatibility (EMC) issues. These issues can arise from both internal and external sources of electromagnetic interference (EMI) and can impact the performance and reliability of the system.

Some examples of EMC issues that can occur in a robotics system include:

1. Electrostatic discharge (ESD).
This occurs when a static charge built up on an object or a person (user) is discharged, causing a sudden current flow that can damage or interfere with electronic components.

2. Electromagnetic interference (EMI).
This is a broad term that describes unwanted electrical signal that can interfere with the operation of a device or system. EMI can be caused by various sources, such as motors, power supplies, and radio frequency (RF) transmitters.

3. Electromagnetic emissions.
Unwanted conducted or radiated emissions of a robotics system from various sources like motors, voltage converters (DC/DC, AC/DC), high-frequency communication protocols (HDMI) are a big challenge for electronic design engineers.

4. Radio frequency interference (RFI).
This is a type of EMI that occurs in the frequency range used for wireless communication. RFI can interfere with the operation of wireless sensors or communication systems, causing signal loss or degradation.

5. High-voltage transients (EFTs, surge).
Electrical fast transients (EFTs) and high energy pulse transients (surge) can occur at the power supply pins of the robotic system and potentially degrade the performance of the robotic system or even damage it.

EMI Filters for Robotics and Automation

EMI filters can be incorporated into the design in a number of ways, such as being integrated into the circuit boards or being added as separate components. By properly incorporating EMI filters into the design of a robot, the risk of disruptions and malfunctions can be significantly reduced.

ESD filters

ESD pulses are short in duration (see Figure 2) and therefore of low energy (<20mJ). Typical ESD filter components are:

- **Capacitors.** A capacitor in combination with the serial inductance and resistance of a wire, can serve as ESD protection device.
- **Varistors.** Varistors are voltage-dependent resistors (VDRs), and they are typically used as overvoltage protection devices against bursts (EFTs) and surges. However, they can also be used as ESD protection devices.
- **TVS diode.** Transient-voltage-suppression diodes (TVS diodes) are typically used as overvoltage protection devices against ESD pulses, bursts (EFTs), and surges (if the current through the diode is limited). TVS diodes have the advantage over capacitors and varistors, that they result in a smaller capacitance for the electrical signal and TVS diodes are therefore well suited for ESD protection of high-speed signal interfaces (e.g., USB, HDMI).

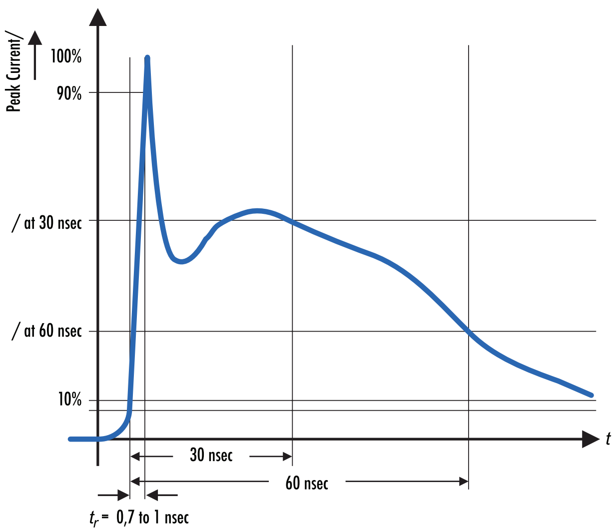

Figure 2: ESD transient pulse [5].

ESD filter components should be placed close to the source (e.g., directly at the point where a cable enters a system or connects to a printed circuit board PCB), so that an ESD pulse is filtered before it can destroy any sensitive electronic microcontroller or thereafter.

Conducted emissions filters

Unintended electromagnetic conducted emissions, e.g., caused by digital electronics or motors, are typically filtered with ferrites, inductors, and capacitors. When using AC mains power-line filters (100VAC to 250VAC), the following properties – besides the filter attenuation – are also important:

- **Safety.** AC mains power filters require capacitors with a sufficient safety rating because a failure of a mains power filter capacitor could result either in fire (short circuit of an X-capacitor) or in electric shock (short circuit of a Y-capacitor). Widely accepted EMC and safety standards for AC mains power filters and filter capacitors are:
- International: IEC 60939-3 (applies to passive filter units for electromagnetic interference suppression for which safety tests are appropriate) and IEC 60384-14 (applies to capacitors and resistor-capacitor combinations intended to be connected to AC mains).
- USA: UL 1283 (UL Standard for Safety Electromagnetic Interference Filters) and UL 1414 (UL Standard for Safety Capacitors and Suppressors for Radio-and Television-Type Appliances) and UL 60939-3 (applies to passive filter units for electromagnetic interference suppression for which safety tests are appropriate).
- Canada: CAN/CSA C22.2 No. 8-13 (applies to filters intended for suppressing electromagnetic interference in, or with, apparatus and machines that are to be connected to an ac supply) and CAN/CSA E384-14-95 (applies to capacitors and resistor-capacitor combinations intended to be connected to AC mains).
- China: GB/T 15287 (applies to equipment and machine connected to the power grid used for radio interference suppression filters), GB/T 15288 (applies to GB/T 15287 included in the complete filter units for radio interference suppression) and GB/T 14472 (applies to capacitors and resistor-capacitor combinations intended to be connected to AC mains).

- **Leakage current to earth.** The leakage current to earth must not exceed certain limits. One example would be the highest requirements for earth leakage current to be met by medical equipment, where according to IEC 60601-1 the leakage current must not exceed 500uA under normal conditions.

Radiated emissions filters
Unintended electromagnetic radiated emissions, e.g., caused by cables inside a robotic system, are typically caused by common-mode currents. Common-mode currents can be most effectively filtered with one of these filter components:

- **Common-mode chokes.** A common-mode choke consists of two coils wound around a common ferromagnetic core (sometimes even more than two coils). The differential signal current flows through one coil and back through the second one. Common-mode chokes in EMC are primarily used to block common-mode currents and, therefore, to eliminate unintended radiated electromagnetic emissions.

- **Cable mount (snap) ferrite beads.** Cable mount snap ferrite beads are wrapped around a cable, wire, or a group of conductors. They can be flexibly installed and are usually used to lower radiated emissions by suppressing common-mode currents.

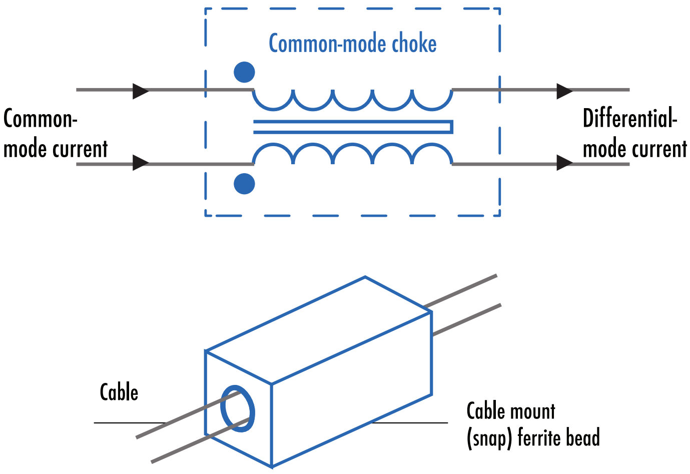

Figure 3: Top: Common-mode choke symbol [4]. Bottom: Cable mount snap ferrite bead.

High-voltage transient filters
Robotic systems are often used in places with harsh electromagnetic environments like densely packed industrial factory plants. In such an environment, high-voltage transients from switching inductive loads can occur quite frequently. That is why filters for high-voltage transient signals are unavoidable and indispensable. Typical high-voltage transient filter components are:

- **TVS Diodes.** TVS diodes are limited in their power handling capabilities. However, they are fast and low-cost devices.

- **Varistors.** Metal oxide (MOV) varistors are cost effective solutions for protecting electronics from high-power surge pulses. However, they degrade after several pulses.

- **Gas discharge tubes.** Gas discharge tubes have a large power handling capability and a low capacitance. Therefore, they are often used as surge protection for antennas and telecom data lines. However, gas discharge tubes are rather expensive and have a high breakdown voltage.

Conclusion

Robotics and automation are revolutionizing various industries, but they can generate electromagnetic interference (EMI) that could affect nearby electronic devices and on the other hand, they can be a victim of EMI. EMC filters are essential components to minimize EMI and ensure reliable operation of electronic systems in the presence of robots and automation and vice versa.

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Headquarters, Global Innovation and Development

Switzerland
Schaffner Group
Industrie Nord
Nordstrasse 11 e
4542 Luterbach
P + 41 32 681 66 26
info@schaffner.com

Sales and Application Centers

China
Schaffner EMC Ltd. Shanghai
T20 - 3 C No 565 Chuangye Road
Pudong district 201201
P + 86 21 38 139 500
cschina@schaffner.com

Finland
Schaffner Oy
Sauvonrinne 19 H
08500 Lohja
P + 358 50 468 72 84
finlandsales@schaffner.com

France
Schaffner EMC S.A.S.
16 - 20 Rue Louis Rameau
95875 Bezons
P + 33 1 34 34 30 60
francesales@schaffner.com

Germany
Schaffner Deutschland GmbH
Schoemperlenstrasse 12 B
76185 Karlsruhe
P + 49 721 56 910
germanysales@schaffner.com

India
Schaffner India Pvt. Ltd
Regus World Trade Centre
WtC 22nd Floor Unit No 2238
Brigade Gateway Campus 26 / 1
Dr. Rajkumar Road
Malleshwaram (W)
560055 Bangalore
P + 91 80 679 35 355
indiasales@schaffner.com

Italy
Schaffner EMC S.r.l.
Via Ticino 30
20900 Monza (MB)
P + 39 039 21 41 070
italysales@schaffner.com

Japan
Schaffner EMC K.K.
Taiju - Seimei Sangenjaya Bldg.
1 - 32 - 12 Kamiuma Setagaya-ku
154 - 0011 Tokyo
P + 81 3 57 12 36 50
japansales@schaffner.com

Singapore
Schaffner EMC Pte Ltd.
05 - 09 Kg Ubi
Ind. Estate 408705
P + 65 63 77 32 83
singaporesales@schaffner.com

Spain
Schaffner EMC España
Calle Caléndula 93 Miniparc III
Edificio El Soto de Moraleja
Alcobendas 28109 Madrid
P + 34 917 912 900
spainsales@schaffner.com

Sweden
Schaffner EMC AB
Östermalmstorg 1
114 42 Stockholm
P + 46 8 50 50 2425
swedensales@schaffner.com

Switzerland
Schaffner EMV AG
Industrie Nord
Nordstrasse 11 e
4542 Luterbach
P + 41 32 681 66 88
P + 41 32 681 66 26
switzerlandsales@schaffner.com

Taiwan
Schaffner EMV Ltd.
20 Floor - 2 No 97 Section 1
XinTai 5th Road
22175 XiZhi District
New Taipei City 22175
P + 886 2 2697 55 00
taiwansales@schaffner.com

Thailand
Schaffner EMC Co. Ltd.
Northern Region Industrial
Estate 67 Moo 4 Tambon
Ban Klang Amphur Muang
P.O. Box 14 51000 Lamphun
P + 66 53 58 11 04
thailandsales@schaffner.com

United Kingdom
Schaffner Ltd.
1 Oakmede Place Binfield
RG42 4JF Berkshire
P + 44 118 977 00 70
uksales@schaffner.com

USA
Schaffner EMC Inc.
52 Mayfield Avenue
Edison New Jersey
P + 1 732 225 95 33
usasales@schaffner.com

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Schaffner Group
Nordstrasse 11e
4542 Luterbach
Switzerland
P + 41 32 681 66 26
info@schaffner.com

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