SEMI E176-1017
GUIDE TO ASSESS AND MINIMIZE ELECTROMAGNETIC INTERFERENCE (EMI) IN A SEMICONDUCTOR MANUFACTURING ENVIRONMENT

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1 Purpose

1.1 The purpose of this Guide is to provide guidance for the assessment and minimization of electromagnetic interference (EMI) in a semiconductor manufacturing environment to improve yield, equipment availability, and test results (e.g., testing time, measurement relevance, repeatability, and accuracy).

2 Scope

2.1 This Guide applies to equipment and facilities provided for the purpose of manufacturing semiconductor devices (i.e., equipment in a semiconductor manufacturing environment) not otherwise in the scope of SEMI E33, including all communications and control systems; processing, metrology, inspection, and automation equipment; and information-technology equipment.

2.2 The primary focus of this Guide is on a semiconductor manufacturing environment, but this Guide may also be applied to the facilities and equipment used for manufacturing other related products (e.g., photovoltaics (PVs), flat panel displays [FPDs], disk drives, microelectromechanical systems [MEMS]).

2.2.1 Some terms are specialized to a semiconductor manufacturing environment.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

NOTE 1: Under certain conditions, EMI can impact equipment safety.

3 Limitations

3.1 This Guide does not apply to EMI caused by electrostatic discharges (ESDs) from process-specific charging that may occur to semiconductors in process under manufacture. Refer to SEMI E78 and SEMI E129 for more information.

3.2 This Guide does not apply to manufacturing equipment within the scope of SEMI E33.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E33 — Guide for Semiconductor Manufacturing Equipment Electromagnetic Compatibility (EMC)

SEMI E78 — Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment

SEMI E129 — Guide to Assess and Control Electrostatic Charge in a Semiconductor Manufacturing Facility

4.2 *European Commission (EC) Directives*[1]

Directive 2014/30/EU — Directive 2014/30/EU of the European Parliament and of the Council on the Approximation of the Laws of the Member States Relating to Electromagnetic Compatibility and Repealing Directive 2004/108/EC

[1] European Commission, Rue de la Loi 200/Wetstraat 200, B-1049 Bruxelles/Brussels, Belgium; Telephone: +32.2.299.30.85, Fax: +32.2.296.17.49, http://www.europa.eu.int

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4.3 *IPC Standards*[2]

IPC-A-610F — Acceptability of Electronic Assemblies

4.4 *Other Documents*

ITRS 2.0 — 2015 International Technology Roadmap for Semiconductors (ITRS)[3]

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AC* — alternating current

5.1.2 *CEN* — European Committee for Standardization

5.1.3 *CFL* — compact fluorescent lamp

5.1.4 *CFR* — Code of Federal Regulations

5.1.5 *DC* — direct current

5.1.6 *EC* — European Commission

5.1.7 *ELF* — extremely low frequency

5.1.8 *EMC* — electromagnetic compatibility

5.1.9 *EMF* — electromagnetic field

5.1.10 *EMI* — electromagnetic interference

5.1.11 *EOS* — electrical overstress

5.1.12 *ESD* — electrostatic discharge

5.1.13 *FCC* — Federal Communications Commission

5.1.14 *FFT* — fast Fourier transform

5.1.15 *FPD* — flat panel display

5.1.16 *IC* — integrated circuit

5.1.17 *IEC* — International Electrotechnical Commission

5.1.18 *IEEE* — Institute of Electrical and Electronics Engineers

5.1.19 *IPC* — Association Connecting Electronics Industries

5.1.20 *ITRS* — International Technology Roadmap for Semiconductors

5.1.21 ITU — International Telecommunication Union

5.1.22 *MEMS* — microelectromechanical systems

5.1.23 *OEM* — original equipment manufacturer

5.1.24 *OSHA* — Occupational Safety and Health Administration

5.1.25 *PLC* — power line communication

5.1.26 *RF* — radio frequency

5.1.27 *RFID* — radio frequency identification

[2] Association Connecting Electronics Industries, 3000 Lakeside Drive, 105 N, Bannockburn, IL 60015, USA, Telephone: +1.847.615.7100, Fax: +1.847.615.7105, http://www.ipc.org

[3] Available from https://www.semiconductors.org/main/2015_international_technology_roadmap_for_semiconductors_itrs/

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5.1.28 *RMS* — root mean square

5.1.29 *SEM* — scanning electron microscope

5.1.30 *SMPS* — switched-mode power supply

5.1.31 *UPS* — uninterruptable power supply

5.1.32 *VFD* — variable frequency drive

5.1.33 *VLF* — very low frequency

5.2 *Definitions*

5.2.1 *conducted emission* — electromagnetic signals present on wires, cables, metal parts and other conductors of equipment.

NOTE 2: Conducted emissions are often unintended and undesirable.

5.2.2 *electrical overstress (EOS)* — exposure of a device or circuit to damaging electrical signals other than electrostatic discharge.

5.2.3 *electromagnetic compatibility (EMC)* — the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic interference with other equipment in that environment.

5.2.4 *electromagnetic interference (EMI)* — electromagnetic phenomena that can interrupt, obstruct, or otherwise degrade or limit the effective performance of electrical equipment.

5.2.5 *electrostatic discharge (ESD)* — the rapid spontaneous transfer of electrostatic charge induced by a high electrostatic field. [SEMI E78]

5.2.6 *ELF-sensitive equipment* — equipment with a performance that is adversely affected by extremely low frequency (ELF) electromagnetic fields (EMFs).

NOTE 3: Scanning electron microscopes (SEMs) are typically considered ELF-sensitive equipment.

5.2.7 *EMI Audit* — a process of verifying whether actual EMI characteristics are in compliance with desired EMI limits.

5.2.8 *EMI Survey* — a process of measuring and reporting characteristics of electromagnetic phenomena relevant to an EMI audit.

5.2.9 *EMI event* — an occurrence of electromagnetic interference (EMI) that may also include electromagnetic emission from electrostatic discharge (ESD) events. [SEMI E33]

5.2.10 *EMI-sensitive equipment* — any equipment with performance that is adversely affected by electromagnetic interference (EMI) present in the semiconductor manufacturing environment. [SEMI E33]

5.2.11 *enclosure* — the physical boundary of the equipment through which electromagnetic fields (EMFs) may radiate or upon which they may impinge.

5.2.12 *ESD event* — an occurrence of electrostatic discharge (ESD).

5.2.13 *extremely low frequency* (*ELF*) — the spectrum range less than 3 kHz. [SEMI E33]

NOTE 4: Sources differ on the limits of ELF. For example, the United States (U.S.) Occupational Safety and Health Administration (OSHA) defines it as a frequency of 1to 300 Hertz and the International Telecommunication Union (ITU) defines it as a frequency of 3 to 30 Hertz.

NOTE 5: The 60 Hertz mains frequency in the U.S., parts of Japan, and Taiwan, and the 50 Hertz mains frequency in most of Asia and in Europe are typically considered a type of ELF EMF.

5.2.14 *port* — a particular interface (e.g., ground port) of the specified equipment with the external electromagnetic environment.

5.2.15 *power line communication (PLC)* — a communication technology for sending data over power cables.

5.2.16 *radiated emission* — electromagnetic field (EMF) emanating from equipment.

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5.2.17 *supplier* — party that provides equipment to, and directly communicates with, the user. A supplier may be a manufacturer, an equipment distributor, or an equipment representative. See also the definition for user. [SEMI S2]

5.2.18 *user* — party that acquires equipment for the purpose of using it to manufacture semiconductors. See also the definition for supplier. [SEMI S2]

5.2.19 *very low frequency* (*VLF)* — the spectrum range from 3 kHz and 30 kHz. [SEMI E33]

5.3 *Symbols*

5.3.1 *cm* — centimeter

5.3.2 *dBμV* — decibel-microvolt

5.3.3 *ft.* — foot

5.3.4 *GHz* — gigahertz

5.3.5 *GS* — gigasamples

5.3.6 *Hz* — hertz

5.3.7 *kHz* — kilohertz

5.3.8 *m* — meter

5.3.9 *μm* — micrometer or micron

5.3.10 *MS* — megasamples

5.3.11 *nm* — nanometer

5.3.12 *Ω* — ohm

5.3.13 *s* — second

5.3.14 *V* — volt

6 Basics of EMI in a Semiconductor Manufacturing Environment

6.1 *Radiated and Conducted Emission*

6.1.1 Radiated emissions are electromagnetic signals radiated by changing voltages and currents present in cables, wires, and metal structures. Radiated emissions may have one dominant component—either electric or magnetic—in the 'near field' and both components at a predetermined ratio in the 'far field'. For a discussion on near and far fields, see SEMI E33 Related Information 2. Notably, any radiated emission creates a complementary conducted emission since any electric or magnetic field causes voltage or current in affected conductors.

6.1.2 Conducted emissions are electrical signals in cables, wires, and metal structures. Notably, any conducted emission creates a complementary radiated emission since any voltage or current causes an electric or magnetic field accordingly.

6.2 Any electrical or electronic equipment in the normal course of its operation generates electromagnetic fields (EMFs) in the form of radiated emissions and conducted emissions on cables, wires, and metal parts. Some radiated emissions might be intentional such as wireless networks, mobile phones, radio frequency (RF) generators, and RF identification (RFID) readers and some conducted emissions might be intentional such as line frequency or power line communication (PLC) systems. However radiated emissions might also cause undesirable signals in cables, wires, and equipment circuits and conducted emissions might cause undesirable radiated emissions or 'ringing' and other EMI events in conductors. Under certain circumstances these signals can adversely affect one or all of the following:

6.2.1 Normal operation of equipment,

6.2.2 Time-to-test and measurement results in test equipment, and

6.2.3 Electronic communications both wired and wireless.

6.3 *Sensitive Devices* — Sensitive devices are often defined by permanent physical damage to them as well as interference with their operation caused by EMI. In many cases, the magnitude of electrical noise (i.e., undesired

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electrical signals) is not the only influencing factor. Various properties of electrical noise may have a different effect. Sometimes a relatively weak interference with the properties within the equipment vulnerability range can cause more problems than a much stronger signal with different properties. Among such properties are (in no particular order of significance):

6.3.1 Frequency, or pulse repetition rate, of the signal if it is periodic;

6.3.2 Spectrum of the signal if it is comprised of multiple frequencies;

6.3.3 Peak amplitude values, both maximum and minimum values;

6.3.4 Pulse width in case of a pulsed signal;

6.3.5 Pulse rise and fall times;

6.3.6 Modulation properties of the signal; and

6.3.7 Ringing (i.e., oscillation) of the signal.

7 Propagation of Electrical Noise

7.1 *Radiated Emission*

7.1.1 Radiated EMFs propagate through the air. Generally speaking, the field strength diminishes with distance from the source. Metal surfaces of equipment may attenuate the field, but they also can reflect the field providing unexpected resonant peaks. Propagation of electric and magnetic fields has unusual behavior close to the source, in the near field. For a discussion of EMF behavior in the near and far fields, see SEMI E33 Related Information 2.

7.1.2 Due to relatively rapid attenuation of radiated emission with distance, the only relevant impact an emission can cause is usually within a short distance from its origin. The exception to this rule of thumb is emissions at particular frequencies (intentional or accidental), which might interfere with wireless communications. Wireless communications are generally weak signals and can easily be disrupted by other emissions.

7.1.3 The radiated electric field from a circuit greatly depends on the properties of the conductor that forms the radiating antenna, specifically the antenna factor (the efficiency of the antenna vs. the frequency of the radiation) and antenna gain (the directional properties of the antenna). Since the majority of radiated EMI is unintentional (except interference from intentional transmitters, such as wireless networks, etc.), most antennae are also unintentional, and they can have peaks of efficiency at random frequencies that might not obviously match the spectrum of the originating electrical signal. In general, the shorter the antenna, the higher in frequency is its efficiency peak. As a result, a complex electrical signal comprised of a broad spectrum may cause significant radiated emissions only at certain frequencies, not in the entire spectrum of the originating signal.

7.2 *Conducted Emission*

7.2.1 Conducted emissions such as electrical 'noise,' in the form of voltages and currents on wires and cables (mainly on power lines and ground), can travel much farther with less attenuation than radiated emission over the same distance since most of the energy is not being spread in a wide angle (as in the case of radiated emissions).

7.2.2 Power and ground wires are the most common conduit of conducted emissions in the facility since they connect the entire facility together. Since power lines and ground connect all of the equipment in a semiconductor manufacturing environment, electrical noise originated in one location is capable of propagating too many pieces of equipment.

7.2.3 Particular properties of long wires (e.g., distributed inductance and capacitance, associated resonance frequencies) may substantially alter the waveform of the original signal.

7.2.3.1 While the originating signal may have a broad spectrum due to the sharp rise and fall times of transient pulses, the signal after even a short run of wires loses a significant portion of its high-frequency content. Most of the EMI signals of any significance on power lines and ground are confined within 1 to 2 MHz

7.2.3.2 Self-resonances in power lines and ground often result in ringing (i.e., oscillations) on these resonant frequencies in response to sharp transients such as square waves. This ringing has little commonality to the originating signal spectrum. The typical signature of such 'phantom' signals is diminishing ringing artifacts.

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