2019 IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY, SIGNAL & POWER INTEGRITY

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Specific EMC Requirements for Semiconductor Manufacturing Environment and Review of SEMI E33 and E176 Standards

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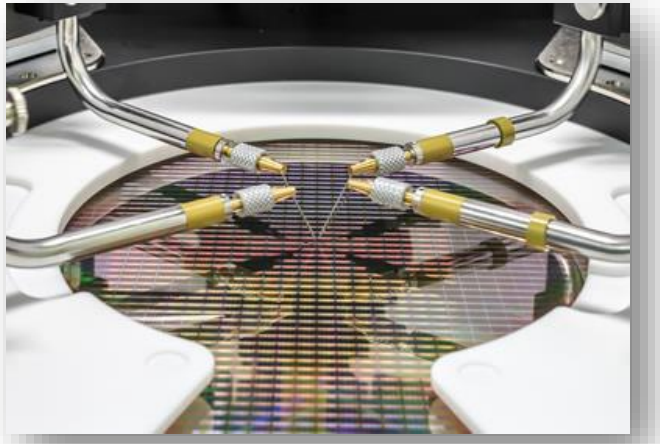


What is So Special About EMC in Semi Manufacturing?

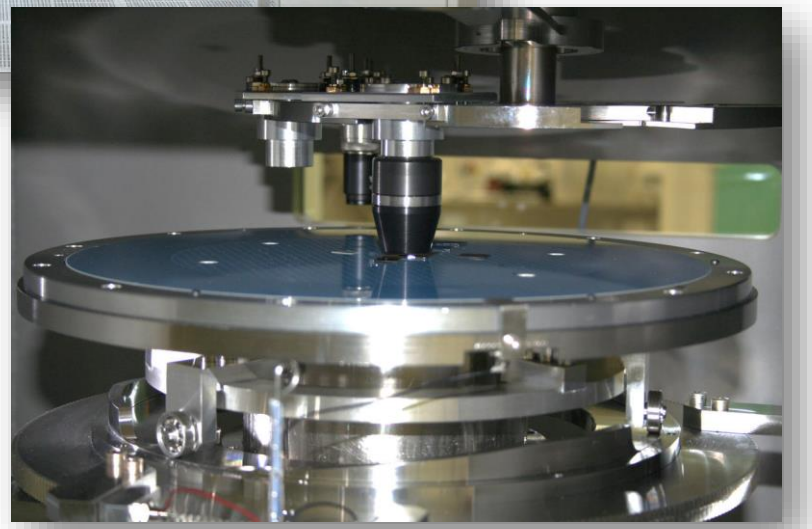
- Devices with increasingly smaller geometry
  - Todays' leading technology is 7 … 10 nm with 3 nm coming up in 2020
  - Tighter tolerances for the process
  - Lower signal levels – test and equipment errors
  - High number of tightly co-located tools in the process
  - Higher sensitivity of the devices to electrical overstress (EOS)
- Cost Issues
  - High levels of EMI cause problems with yield - even 0.5% yield loss is a substantial problem
  - Equipment malfunction: interruption in the process, however short, is unacceptable
  - Latent damages (in the field) caused by EOS are an issue
- Semiconductor industry is more about speed, yield and low cost than about fine EMC details and the precision of EMC measurements

Basic Differences Between "Conventional" EMC and SEMI Requirements

	Conventional EMC Regulations	SEMI Manufacturing Specifics
Purpose	Compliance with Regulations	Improvement in productivity by reduction of EMI
Radiated Emission	10m distance	As close as adjacent equipment (<1m)
	Only external emission	External and internal emission in key areas
	Frequency range 30 MHz and up	Additional VLF and ELF magnetic fields for SEM
Conducted Emission	Short cables, only one product	Complex power and ground network
	Only external emission	External and internal emission in key areas
	50 Ohms termination	Realistic impedance in actual factory
	Frequency 150 kHz to 30 MHz	9 kHz to 30 MHz
All Measurements	Quasi-peak	Most signals are transients: peaks

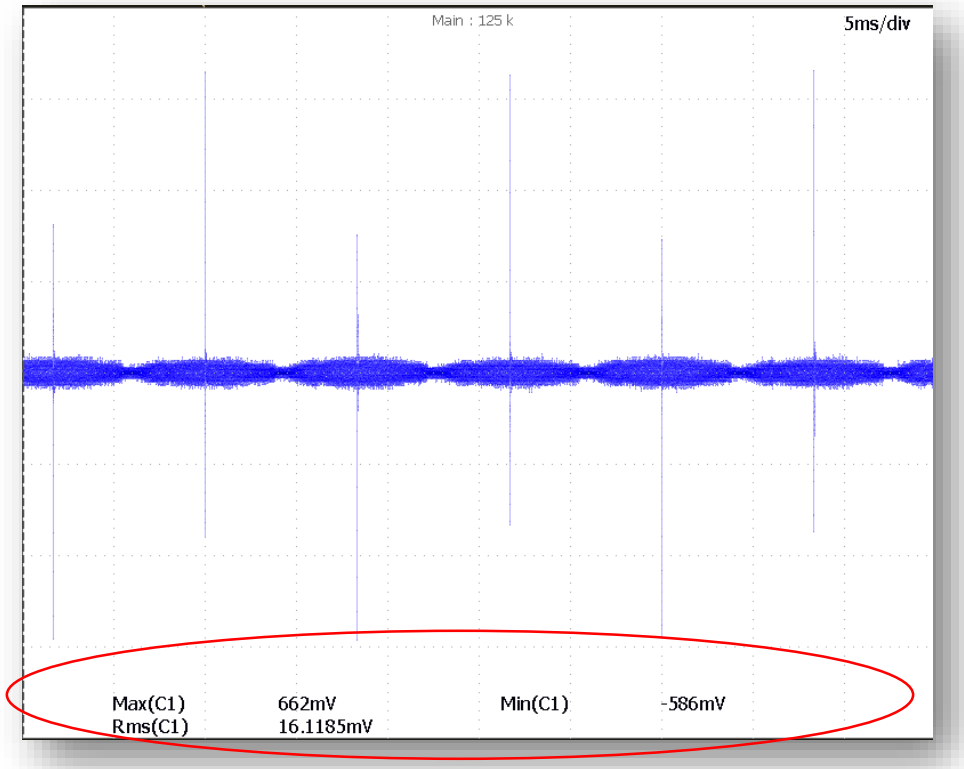
Radiated Emission

- Real estate in a cleanroom is at premium
- Close co-location of equipment improves productivity
- Integrated equipment from several manufacturers
- 10 m distance for radiated emission test is totally irrelevant
- Near field measurements are much more relevant
- Internal emission is important for certain processes inside equipment



Quasi-Peak vs. Peak

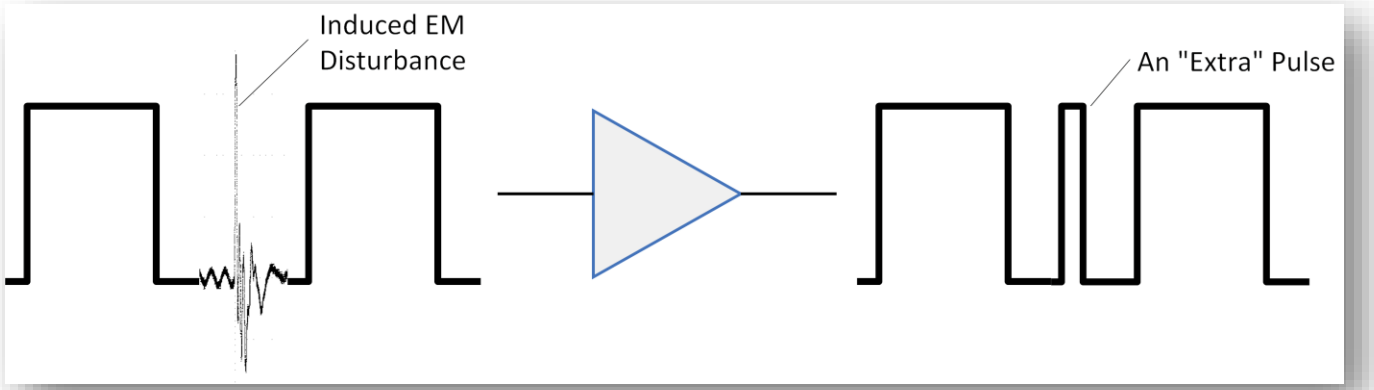
- Component damage and equipment malfunction are mostly caused by transient signals, i.e. short spikes
- Quasi-peak, RMS or average values for are meaningless
- Peak values are most relevant
- Fully EMC-compliant equipment is often a source of strong EMI pollution



+Peak: 662mV
-Peak: -586mV
RMS: 16.12mV

Why Peak Signals Matter

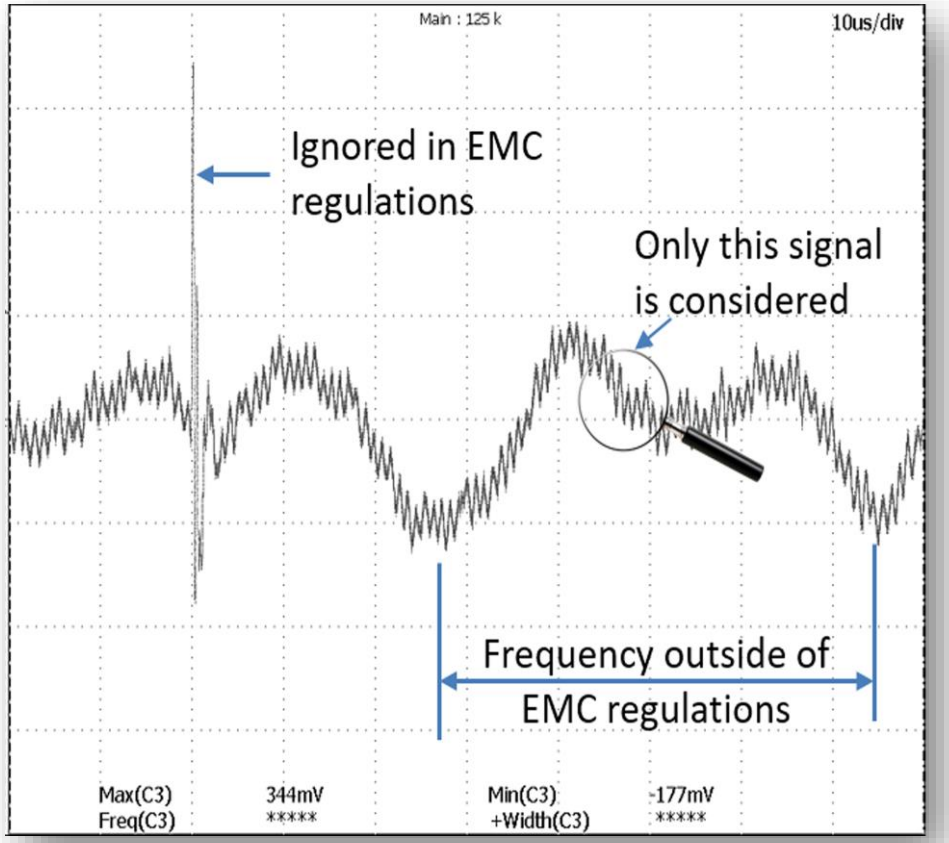
- A spike (radiated or conducted) induces voltage on signal line
- After passing the first logic gate this spike becomes a legitimate logic signal
- Not only now equipment misbehaves, there is no trace of what and why it happened
- High level spikes cause electrical overstress to sensitive devices



Most EMI-caused equipment lockups are intermittent and unreproducible

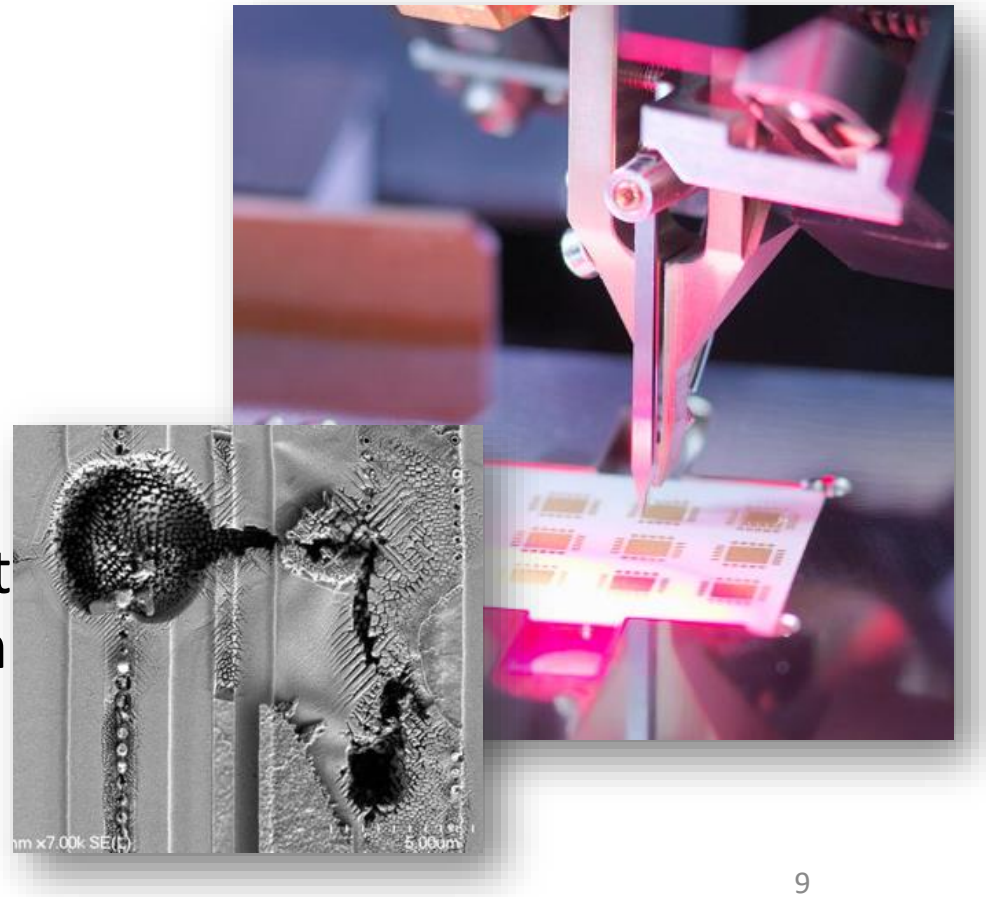
Current EMC Regulations: Specifying the Least Important Parameters

- What is specified in EMC regulations is not sufficient for very practical needs of semiconductor manufacturers
- As seen, what is specified is the least significant signal (conducted emission shown) that is unlikely to cause any problems in a factory, however the signals ignored are the ones of real importance



Electrical Overstress (EOS): Number One Cause of Damage to IC Devices

- Excessive voltages and currents cause EOS
- Voltage of just 0.3V peak can damage devices
- Conducted EMI inside the tools is common cause of EOS
- Often EOS manifests itself as “latent damage” where the devices are not instantly “killed” but are weakened and eventually fail in application – a very expensive failure



SEMI Standards: Enabling Efficient Semiconductor Manufacturing

SEMI has active and large body of Standards' efforts for all aspects of semiconductor manufacturing and handling

SEMI E33: Equipment EMC

- **Guide for Semiconductor Manufacturing Facility Electromagnetic Compatibility**
- Compliance of equipment itself
- Clear division of responsibility for EMI
- ELF and VLF requirements (photolithography)
- EMI Audit
- EMI education

SEMI E176: Facility and Process EMI

- **Guide to Assess and Minimize Electromagnetic Interference (EMI) in a Semiconductor Manufacturing Environment**
- EMI control in the facility
- EMI control in the process
- EMI Audit
- EMI Education

SEMI E33-2017

GUIDE FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT ELECTROMAGNETIC COMPATIBILITY (EMC)

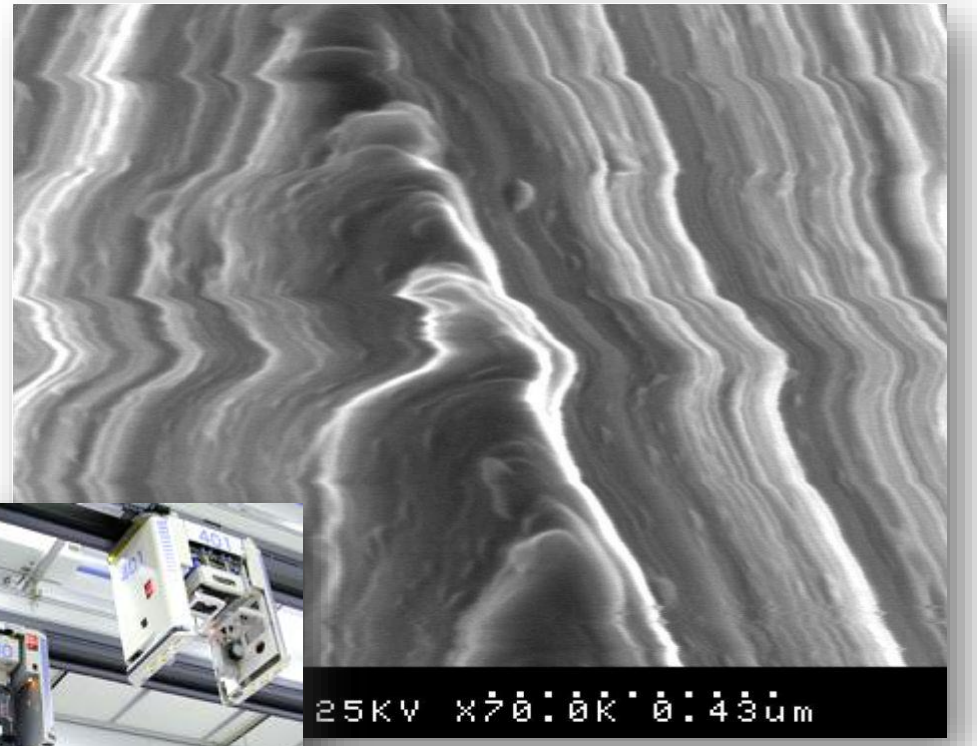
- Basic EMC compliance of equipment
  - European EMC Directive
- Division of responsibilities for EMC-related compliance when equipment is installed, coupled or repaired
  - Removes uncertainty and assigns responsibility for EMC compliance
- Test Method Recommendations
  - Equipment should be tested when fully installed and operational
- ELF/VLF Interference
  - Scanning Electron Microscopes (SEM)
- EMI Audit

SEMI E33: Division of Responsibility for EMC

Item	Responsibility
Semiconductor manufacturing equipment itself	Supplier (equipment manufacturer)
Equipment in combination with other equipment if supplied (i.e., integrated) by one supplier	Supplier (equipment integrator)
Equipment in combination with other equipment if integrated by the user	User
Facility-level electromagnetic environment	User
Equipment installation-related compliance and EMI-performance	Party responsible for installation
Equipment co-location	User
Equipment after repair or maintenance	Party responsible for repair or maintenance
Post-sale additions or modifications made by the supplier that affect EMC compliance	Supplier (semiconductor manufacturing equipment manufacturer or integrator)
Post-sale additions or modifications made by the user that affect EMC compliance	User

ELF and VLF Magnetic Fields

- Extreme and very low frequency magnetic fields (ELF and VLF) distort images in scanning electron microscopes (SEM)
- Frequencies of interest start from sub-Hertz and go up to 3 kHz
- Acceptable limits could be as low as 10nT or 0.1mG
- Even sliding metal chair introduces distortion
- In semiconductor FAB typical problems are caused by overhead transports that are too close to photolithography areas, power transformers, and cables



SEMI E176

GUIDE TO ASSESS AND MINIMIZE ELECTROMAGNETIC INTERFERENCE (EMI) IN A SEMICONDUCTOR MANUFACTURING ENVIRONMENT

- While “regular” EMC regulations address EMI performance of individual equipment, the ultimate goal of semiconductor industry is high productivity and high yield, requiring low levels of EMI in actual use
- There were no EMI regulatory or guidance documents addressing this issue
- SEMI E176 guides semiconductor manufacturers towards the “end result” – low EMI levels in production
- SEMI E176 is a unique document – perhaps IEEE EMC Standards can take it as an example for much-needed guidance for EMI control in actual use

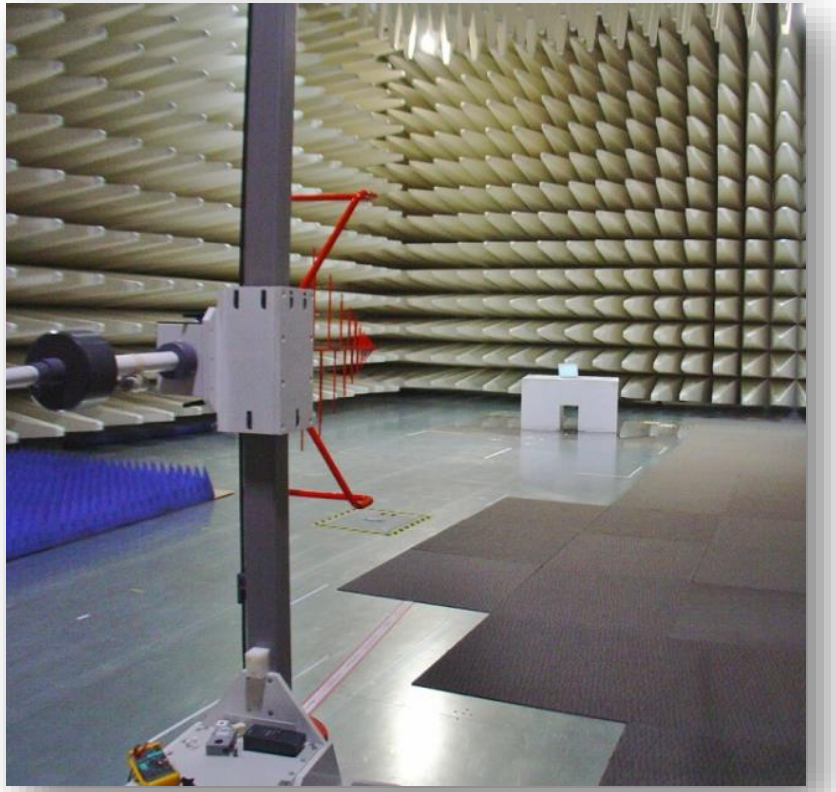
SEMI E176: Finishing the Job

Conventional EMC Regulations

SEMI E176 Standard

Why SEMI E176?

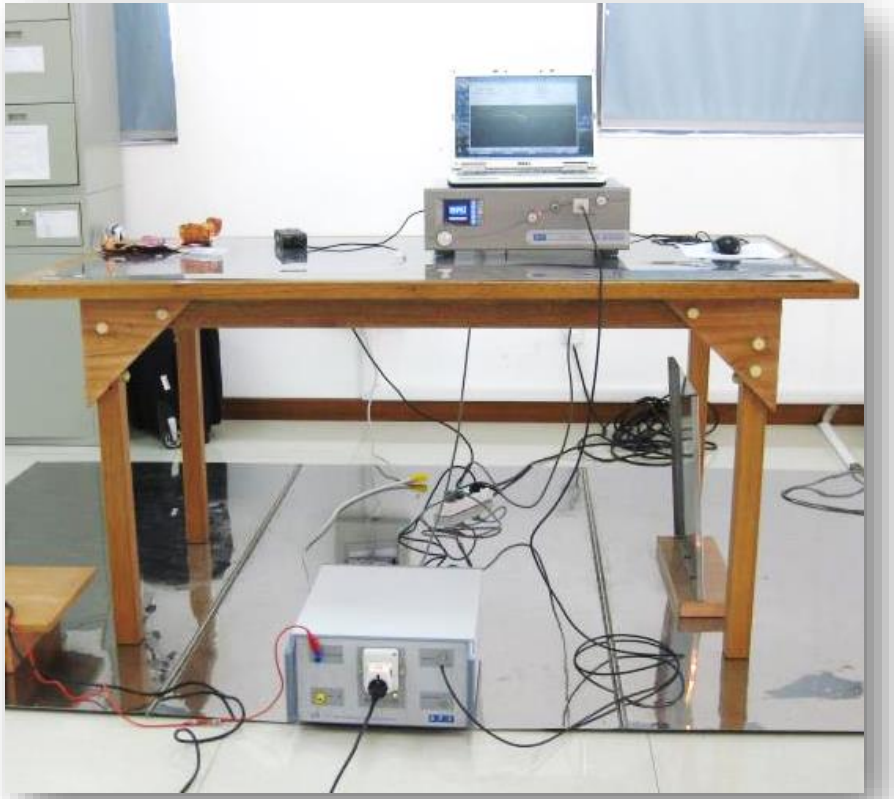
Lab Test



Real-Life Environment

Why SEMI E176?

Lab Test



Real-Life Environment

SEMI E176 Structure

- EMI basics
  - Semiconductor manufacturers are not EMI specialists, nor they want to become ones. This section helps to de-mystify EMI in very basic and practical ways
- Effects of EMI on Equipment, Semiconductors and Communication
  - Guides users to understand the reasons for keeping EMI low
- Sources of EMI in semiconductor manufacturing
  - PWM motors, SMPS, UPS, LED lighting, commutation, etc.
- EMI Measurements
  - Radiated, conducted, peak – practical recommendations
- EMI Survey/Audit
- EMI mitigation
- Recommended EMI levels

SEMI E176: EMI Education

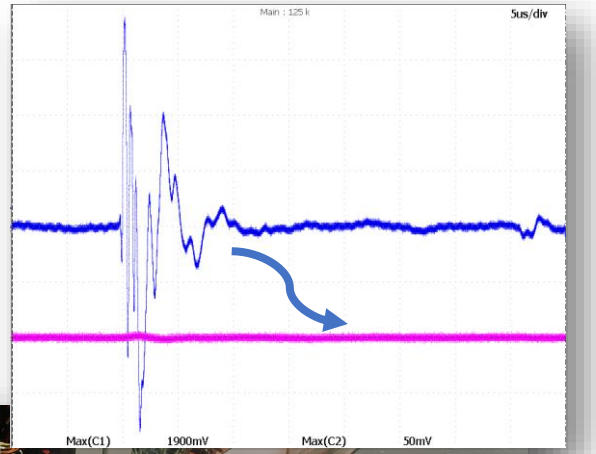
- Main goal is to enable device manufacturers to effectively manage practical aspects of EMI in their process
- Effects of EMI on Equipment, Devices and Communication
  - Explains why it is important to control EMI
- Sources of EMI in semiconductor manufacturing process
  - Puts focus on the worst EMI polluters specific to the process
  - PWM motors, SMPS, LED lighting, UPS, commutation, etc.
- Types of electromagnetic emission
  - Radiated, conducted, continuous, transient

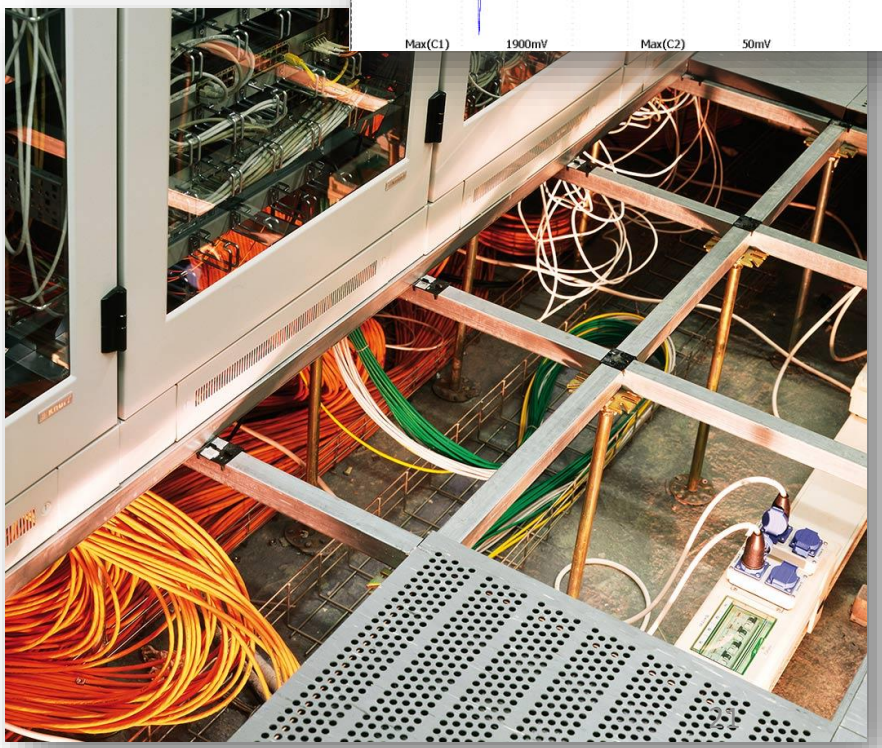
SEMI E176: EMI Measurements

- SEMI E176 focuses on relevance of measurements rather on the “last dB”
- Radiated measurements:
  - Realistic distance - equipment integration and co-location
  - Peak measurements
  - Internal measurements where it matters
- Conducted emission:
  - No LISN needed – we are dealing with real power lines
  - Peak measurements
  - Measurements between different grounded points, including ground current
  - Internal measurements
- E176 provides guidance on minimum specification for commonly-available instruments

SEMI E176: EMI Mitigation

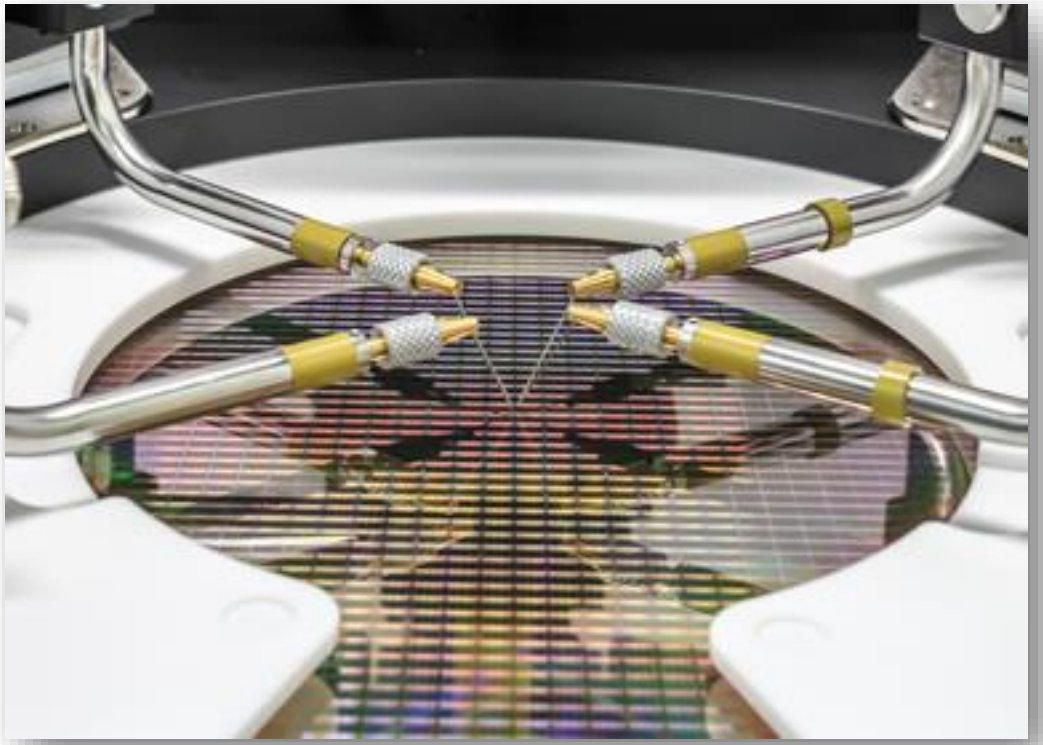
- For results-oriented manufacturing it makes little sense to indicate high levels of EMI without helping to lower them
- Equipment redesign or deep internal modifications are not an option
- Practical common-sense methods with “instant gratification”
  - Mitigation of EMI at the source vs. at the “target”
  - Shielding and filtering
  - Wiring routing
  - Power and ground distribution
  - Maintenance with EMI in mind





SEMI E176: Adding Internal EMI in Key Areas

- Internal EMI is important in key areas where
  - Metal-to-metal contact with sensitive devices (EOS)
  - Test errors
  - Equipment malfunction (wafer sorter misses the slot, etc.)
  - Composite tools (IC handler and IC tester, etc.)
- Both voltages and currents are specified
  - Emphasis on peak values
- Typical processes
  - Wafer level test, wire bonding, IC handling and test, die attach, etc.



SEMI E176: EMI Audits and Surveys

- EMI Audit
  - Verification of EMI levels and other properties as needed in required areas (external and internal)
- EMI Survey
  - Mapping out levels and other relevant properties of EMI, usually with the purpose of equipment placement, relocation, co-location, process changes, etc.
- Both can be performed either internally or externally
- EMI Survey sometimes performed by equipment manufacturer to verify acceptable levels of the facility's conducted and radiated emission for proper operation

SEMI Is Not Alone

IRDS INTERNATIONAL ROADMAP FOR DEVICES AND SYSTEMS™ IEEE

- IRDS: International Roadmap for Devices and Systems
- Under IEEE auspices
- Major semiconductor companies

Table FAC10 Facilities Technology Requirements

Year of Production	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*
DRAM ½ Pitch (nm) (un-contacted Poly) (f) [2]	**28.3**	**26**	**23.8**	**21.9**	**20**	**18.4**	**16.9**	**15.5**	**14.2**	**13**	**11.9**	**10.9**	**10**	**9.2**	**8.4**	**7.7**
Continuous Conducted Emission Limit Allowable Continuous Noise (9kHz - 30MHz) Level (dBuV)	**90**	**90**	**90**	**90**	**90**	**90**	**80**	**80**	**80**	**80**	**70**	**70**	**70**	**70**	**70**	**70**
Transient Conducted Emission Limit Allowable transient signal Level (V) for regular environment	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Transient Conducted Emission Limit Allowable transient signal Level (V) for sensitive environment	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**

Manufacturable solutions exist, and are being optimized
Manufacturable solutions are known
Interim solutions are known
Manufacturable solutions are NOT known

Conclusion

- SEMI EMC Standards are neither rejection of nor a replacement for the existing EMC regulations
- SEMI EMC Standards simply “complete the job” by focusing on the “end result” – low acceptable EMI levels that affect semiconductor manufacturing process and the devices in real-life applications
- Specified acceptable EMI levels are of real relevance to semiconductor manufacturing process and devices
- With SEMI EMC Standards every factory is a living EMI “lab,” paving the way to real reduction of EMI where it matters
- IEEE EMC may open itself to help users in the broader field with similar documents to control EMI in their environment improving productivity and reliability
- Contact author at vkraz@onfilter.com for participation in SEMI EMC Standards