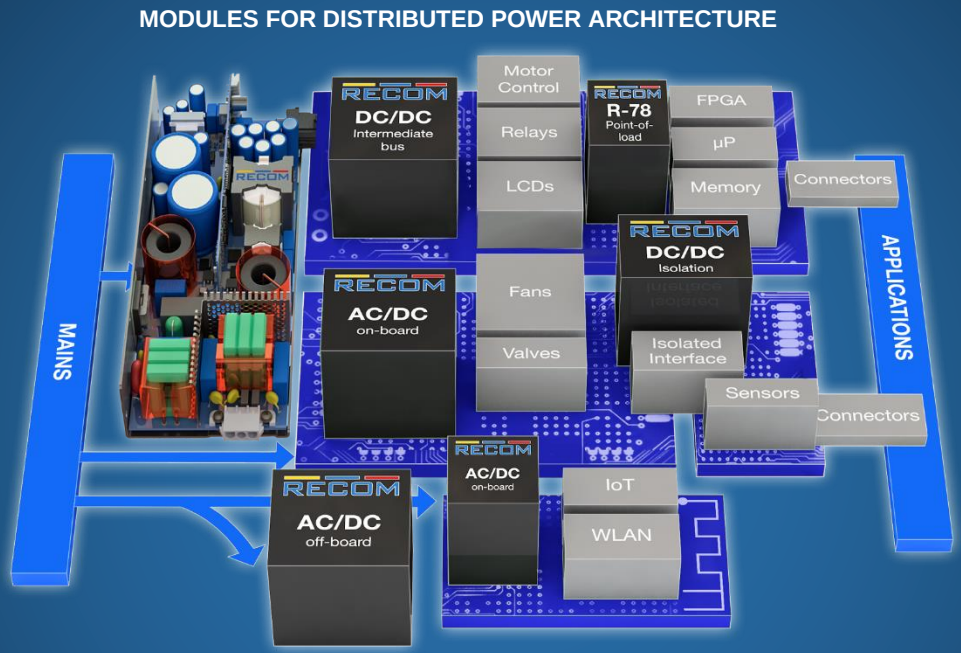
Safety and Compliance Committee
Immunity Testing of SMPS
November 30, 2021

Safety and Compliance Committee

- Meets once per month for 1 hour
- Safety and Compliance Database
  - Tracks changes in major industry compliance issues including materials, EMI-RFI, CISPR, etc.
  - E-mail alerts sent to anyone subscribed to the Safety and Compliance database, membership list is constantly growing
- Members share regular email blasts with articles of interest
- Monthly articles for How 2 Power, special section “Power Supply Safety and Compliance”
- Continued educational webinars

Bio – Josefine Lametschwandtner

- BS in Science with an emphasis on Electronics and Technology from FH Joanneum
- Lead EMC Engineer for RECOM Power
  - Joined in 2014
  - Previous experience with GE Medical Systems
- EMC filter development and testing
- Customer consulting around all EMC issues
- Organizes the RECOM EMC Seminar
- Tri-lingual (German, English, Spanish)



Immunity Testing of SMPS

Josefine Lametschwandtner, BSc

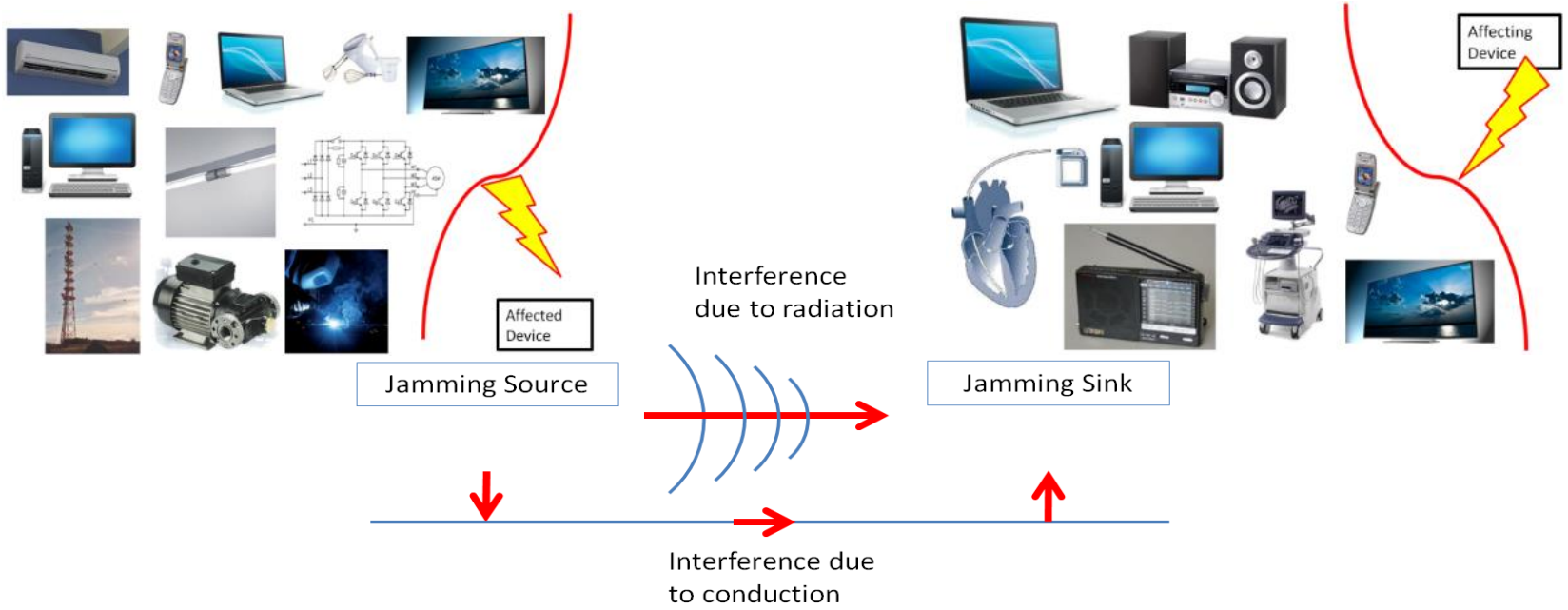
EMC-Webinar, 30th November 2021

RECOM
WE POWER YOUR PRODUCTS

Topics

- Susceptibility to interference
- Overview of tests
  - Transients
  - High frequency
  - General supply network
- Overview

General Principle



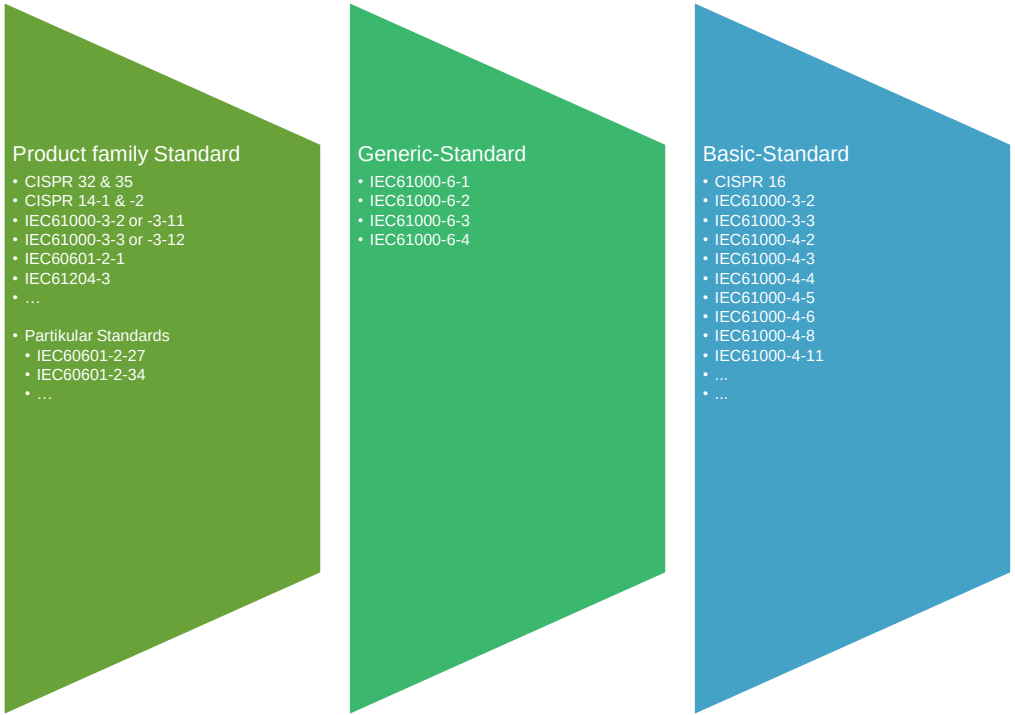
EU Directive 2014/30/EU

Electromagnetic compatibility according to the Directive 2014/30/EU means:

the ability of equipment to function satisfactory in its electromagnetic environment without introduction intolerable electromagnetic disturbances to other equipment in that environment.

Interconnections between different types of standards

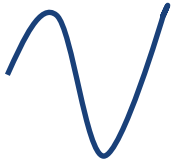
- Product family Standards
  - Particular Standards
- Generic Standards
- Basic Standards



Overview: SMPS under stress

Transients

AC-Supply (Stability & Fields)



High Frequency

Basic Standards - Immunity; 61000-4-x

- ESD (61000-4-2)
- Surge (61000-4-5)
- Burst (61000-4-4)

} Transients

- HF-induced disturbances (61000-4-6)
- E-Field (61000-4-3)

} High Frequency

- Power frequency magnetic field (61000-4-8)
- Voltage Dips, Variations and Interruptions (61000-4-11)

} Power net

Evaluation of Test Results

- Criteria A
  - Normal performance within limits specified by the Manufacturer, requestor or purchaser (e.g. tolerances)
- Criteria B
  - Temporary loss of function or degradation of performance which ceases after the disturbance ceases and from which the equipment under test recovers its normal performance, without operator intervention.
- Criteria C
  - Temporary loss of function or degradation of performance, the correction of which requires operator intervention
- Criteria D
  - Loss of function or degradation of performance which is not recoverable, due to damage to hardware or software, or loss of data.

Transients

Types of transients
- ESD
- Burst
- Surge

Intermittent and therefore hardly tangible
- Transients – fast
- Usually not permanent

Coping with voltage overshoot
- Valve
- Short circuit
- Energy conversion by discharge

ESD – Phenomena & Test Pulse

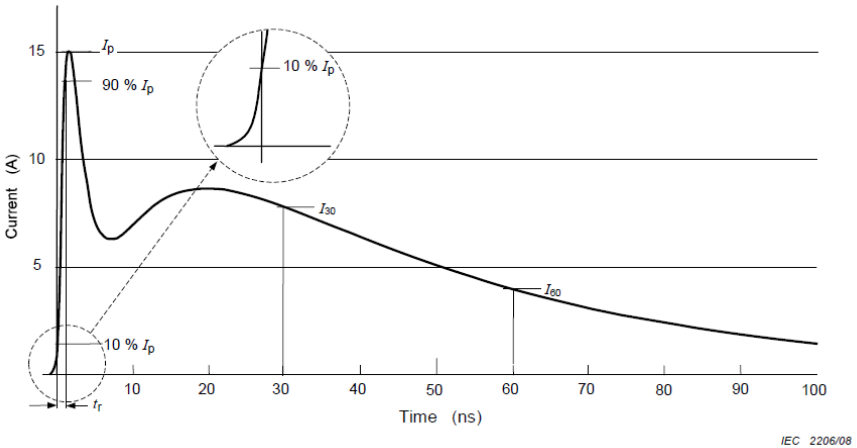


Fig.: Test pulse – ESD [01]

Short Profile:

- Very fast
- Low energy
- Repetition rate of 1 second
- Impact over field and current

ESD – Test Setup

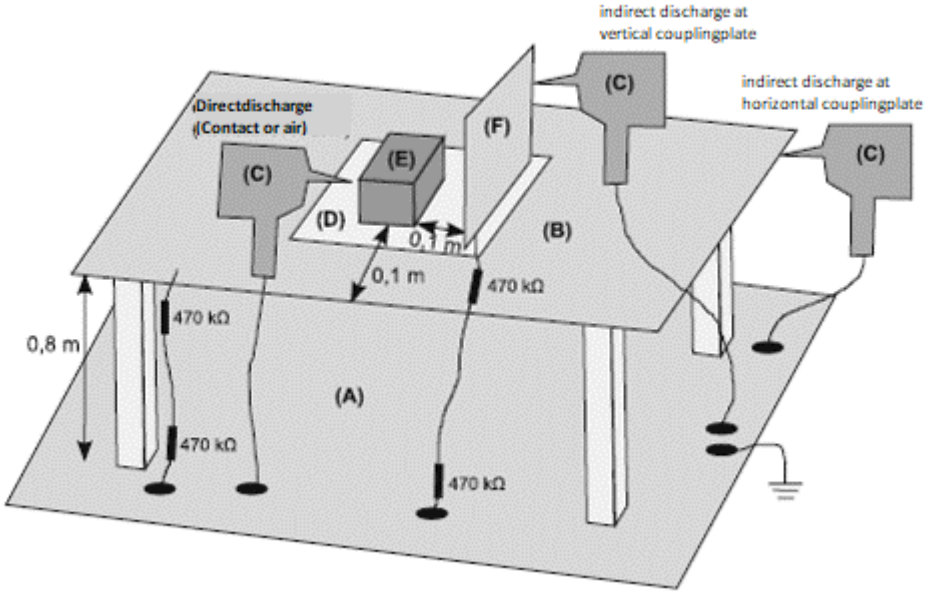


Fig.: Test setup – ESD [02]

Direct contact discharge
At all conductive touchable parts of the EUT

Indirect contact discharge
At vertical and horizontal Coupling plates

Air discharge
At all non-conductive parts of the EUT

Impacts of ESD
Damage or Malfunction

- Damage of „fragile“ Connections (Bonds)
- Damage of pn-junction of transistors
- Crosstalk
  - Triggering the Reset signal
  - Corruption of Data packets

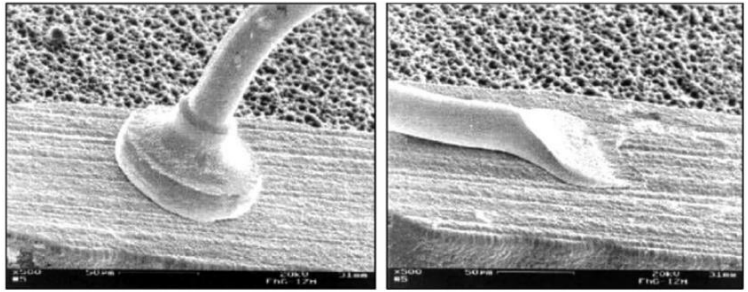


Fig.: Bond connection can be damaged [03]

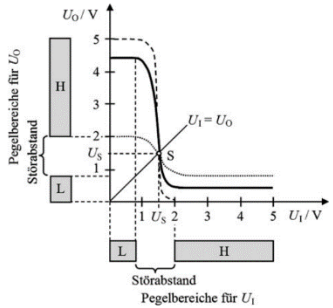
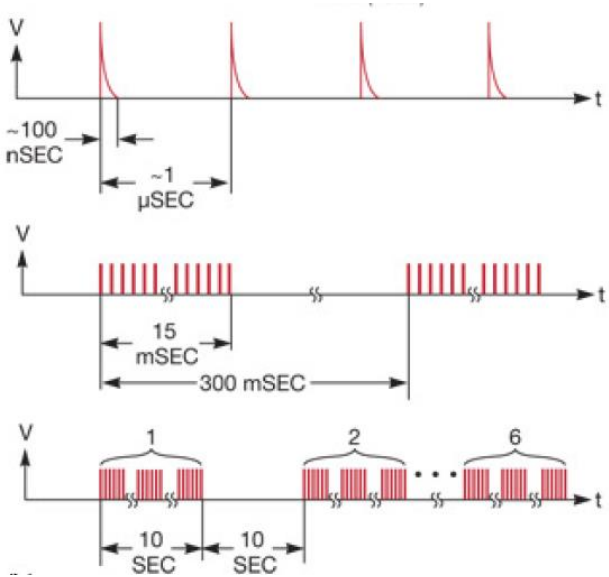


Fig.: Wrong signal due to Crosstalk [03]

ESD – Mitigations

- Low impedance bypass for ESD-events
  - Strong enough to withstand an ESD-event
  - Fast enough to be effective within ns-range
- N-Well-Resistor in Chip-Design
- Diodes
- Software
  - Monitor and repeat sent packets

Burst – Phenomena & Test Pulse



Single Pulse

Pulse packet (Burst)

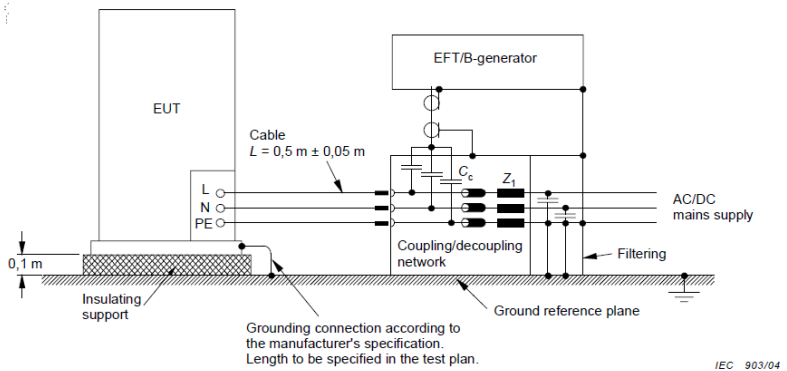
Burst packet

Fig.: Test pulse – Burst [04]

Short Profile:

- Very fast
- Low energy of the single pulses;
- Repetition frequency 100kHz / 5kHz
- Impact over field and current

Burst – Test Setup



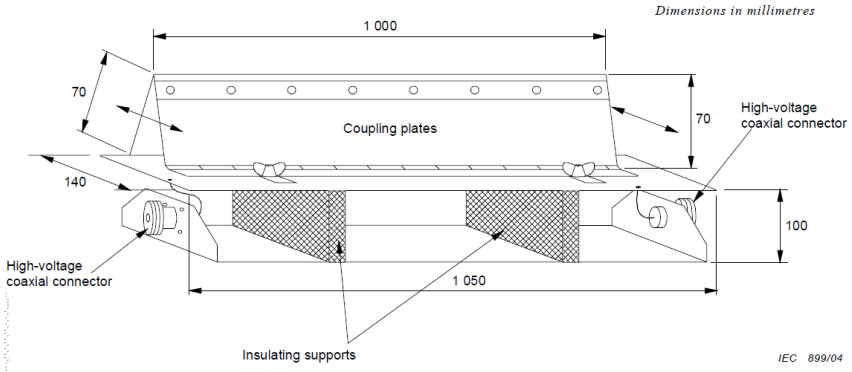
Components

PE	protective earth
N	neutral
L	phase
Z_1	decoupling inductive
C_c	coupling capacitor

NOTE 1 DC terminals can be treated in a similar way.

NOTE 2 Signal and power cables between the CDN and EUT can be up to 1 m in length if so specified in product or product family standards.

Fig.: Test setup – Burst [05]



Warning The distance of the coupling section to all other conductive constructions except to the cable under test and the ground plane shall be more than 0,5 m.

Fig.: Test equipment – Burst [05]

Burst – Phenomenon & Test Pulse

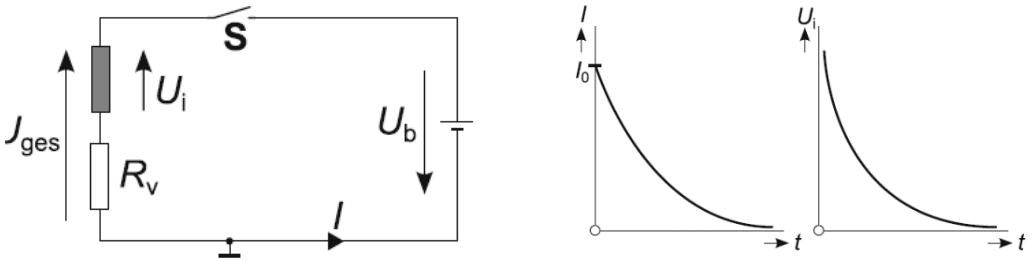


Fig.: Phenomenon – Burst [02]

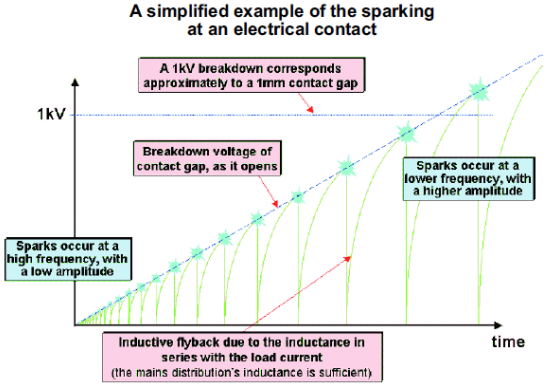


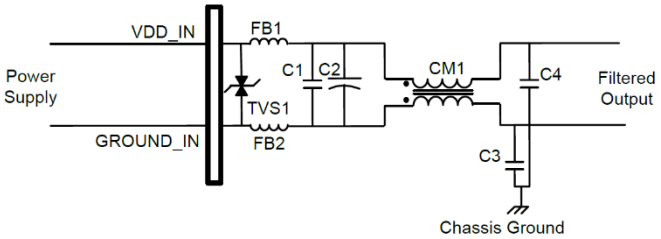
Fig.: Phenomenon – Burst [06]

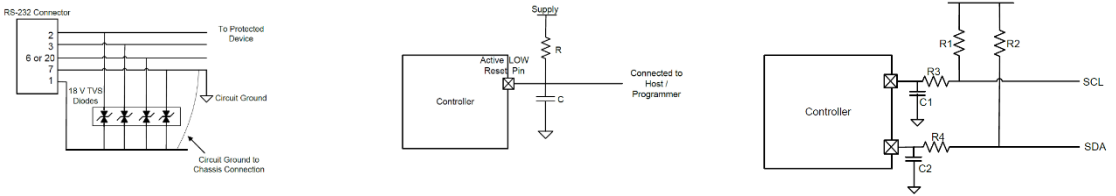
Burst – Mitigation

Filter:
- Power supply
- Data lines
- Communication lines

Floor plan:
- Zones

Reduction of parasitic Capacitance





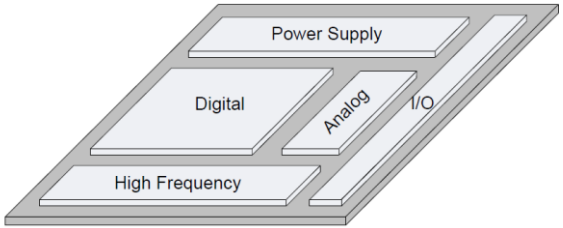


Fig.: Beispiele für Maßnahmen gegen Störungen durch Burst [07]

Surge Phenomenon & Test Pulse

open circuit

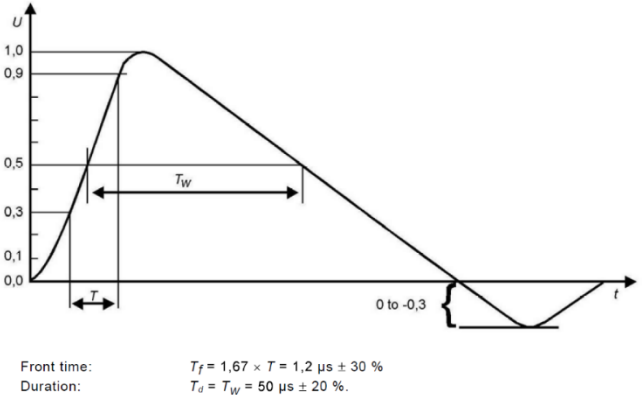
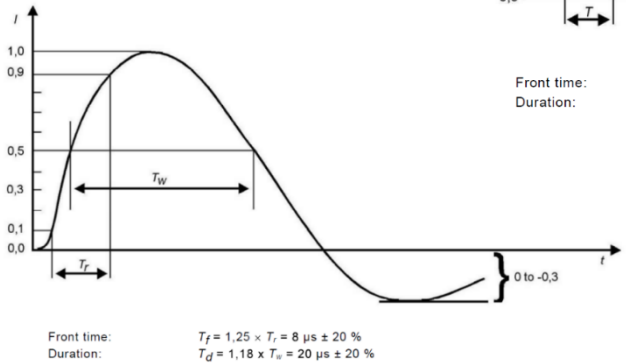


Fig.: Test pulse – Surge [08]



short circuit

Fig.: Test pulse – Surge [08]

Short Profile:

- Quite slow
- High in energy
- Repetition frequency: 60s
- Impact due to current

Surge – Test Setup

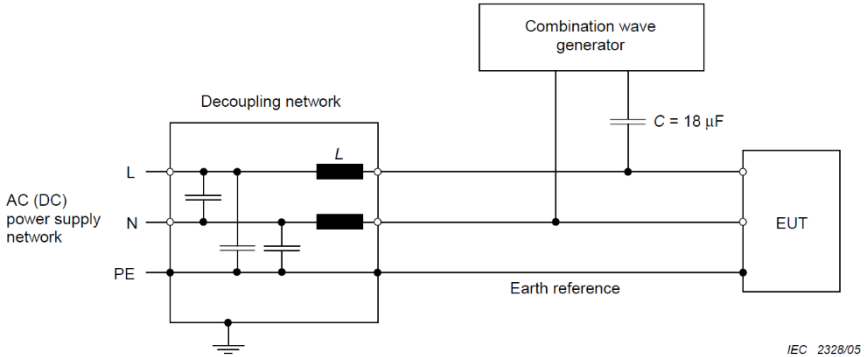


Fig.: Test setup – Surge [08]

Line-to-line – differential mode

Line-to-ground – common mode

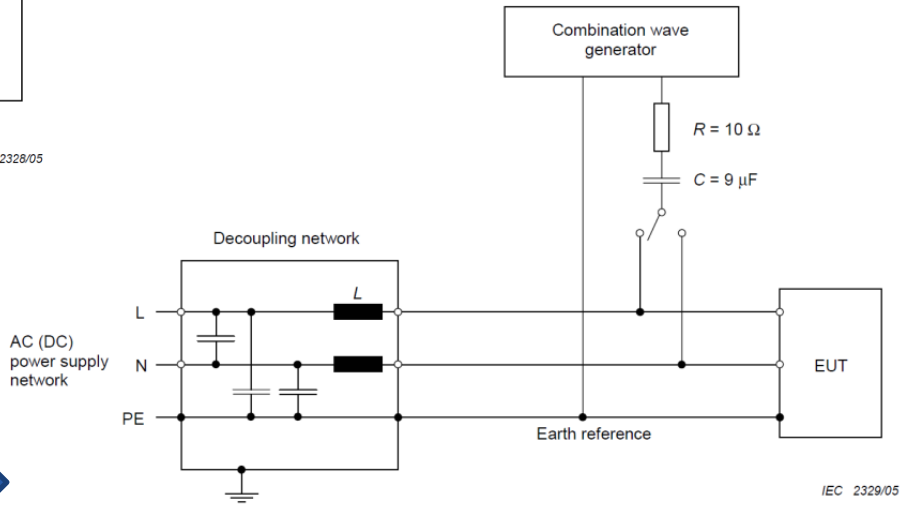


Fig.: Test setup – Surge [08]

Surge – Mitigation

- Series resistor
- Spark gap
- Gas discharge valve
- Multilayer Varistor (MLV)
  - Low series resistor
  - Low response time (below 1ns)
  - Working Voltage up to 60V
- MOV
  - High current rating
- TVS
  - Low Clamping voltage
  - Fast
- Ferrite Beads
  - Suppression of HF-Signals
  - Low current rating

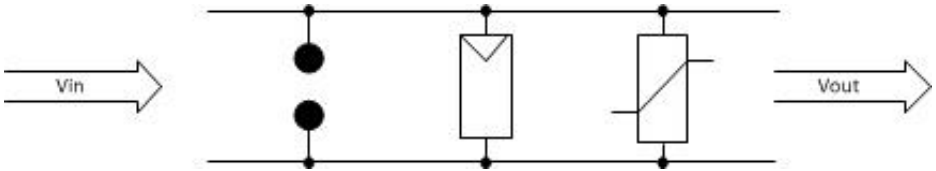


Fig.: Structure of different elements

High Frequency Noise & Disturbances

Types of high frequency noise:
- via lines
- via field

Type of disturbances:
- Induction of high frequency
- Permanent noise & disturbance

Reduce impact by:
- HF-Short circuit
- Shielding
- Damping

RF-Field – Phenomena & Test Signal

Table I.1 – Mobile and portable units

System name Parameters	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC
Transmitter frequency	890 MHz to 915 MHz	1,71 GHz to 1,784 GHz	1,88 GHz to 1,96 GHz	864 MHz to 868 MHz	940 MHz to 956 MHz and 1,429 GHz to 1,453 GHz	1,895 GHz to 1,918 GHz	825 MHz to 845 MHz
Modulation type	TDMA	TDMA	TDMA/ TDD	FDMA/ TDD	TDMA	TDMA/ TDD	TDMA
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz
Duty cycle	1:8	1:8	1:24 (also 1:48 and 1:12)	1:12	1:3	1:8	1:3
Maximum ERP	0,8 W; 2 W; 5 W; 8 W; 20 W	0,25 W; 1 W; 4 W	0,25 W	<10 mW	0,8 W; 2 W	10 mW	<6 W
Secondary modulation	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	None	None	None	None	None
Geographical area	Worldwide	Worldwide	Europe	Europe	Japan	Japan	USA
NOTE – CT-3 is considered to be covered by DECT.							

Table I.2 – Base stations

System name Parameters	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC
Transmitter frequency	935 MHz to 960 MHz	1,805 GHz to 1,88 GHz	1,88 GHz to 1,96 GHz	864 MHz to 868 MHz	810 MHz to 826 MHz and 1,477 GHz to 1,501 GHz	1,895 GHz to 1,918 GHz	870 MHz to 890 MHz
Modulation type	TDMA	TDMA	TDMA/ TDD	FDMA/ TDD	TDMA	TDMA/ TDD	TDMA
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz
Duty cycle	1:8 to 8:8	1:8 to 8:8	1:2	1:2	1:3 to 3:3	1:8	1:3 to 3:3
Maximum ERP	2,5 W to 320 W	2,5 W to 200 W	0,25 W	0,25 W	1 W to 96 W	10 mW to 500 mW	500 W
Secondary modulation	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	None	None	None	None	None
Geographical area	Worldwide	Worldwide	Europe	Europe	Japan	Japan	USA
NOTE – CT-3 is considered to be covered by DECT.							

Fig.: potential jamming sources[09]

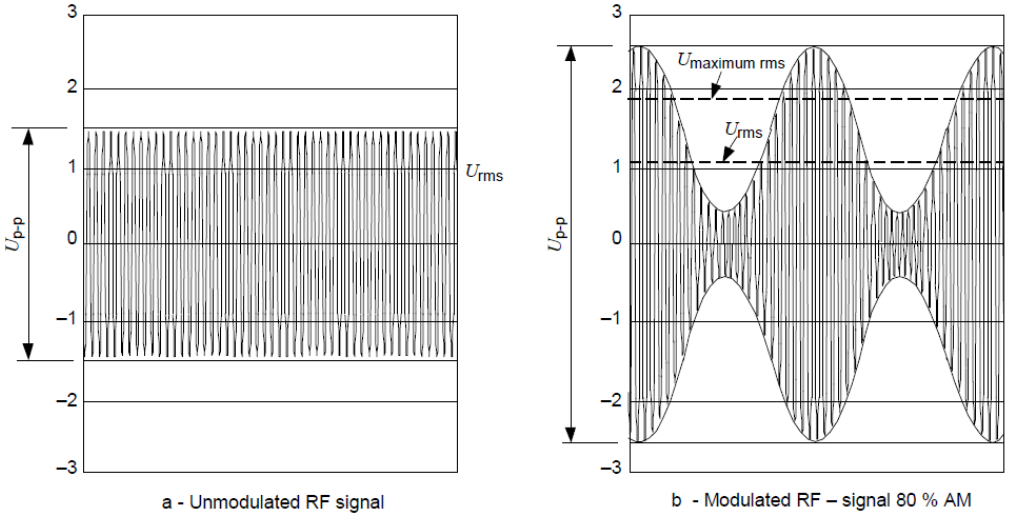


Fig.: Test Signal – RF-Field [09]

RF-Field – Test Setup

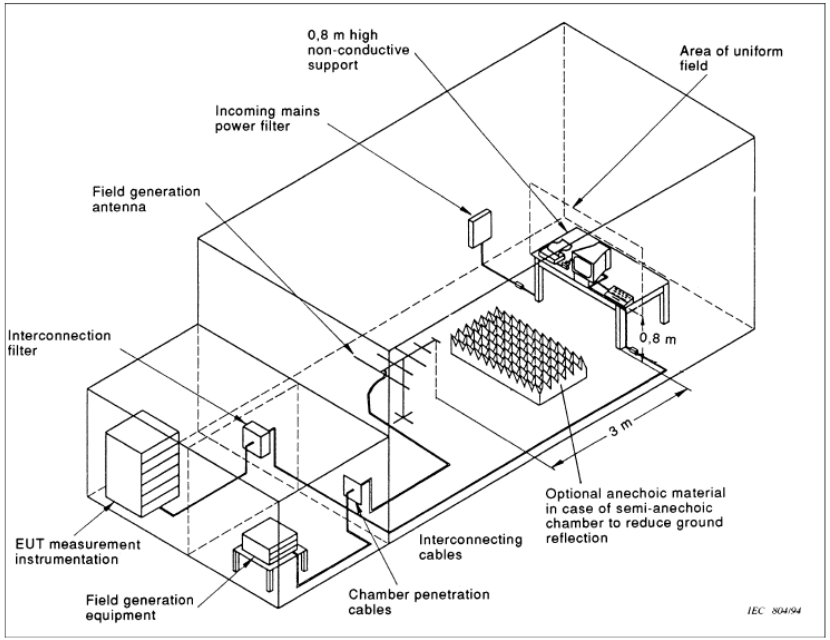
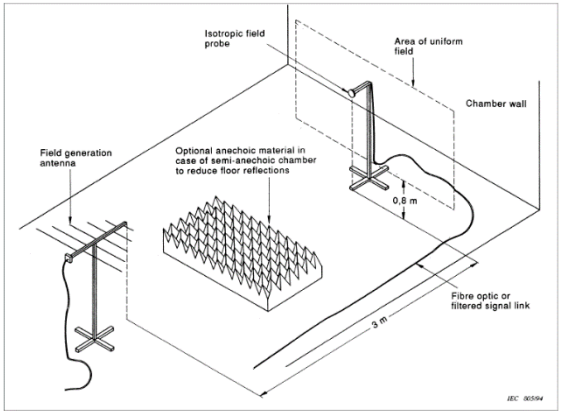


Fig.: Test Setup – RF-Field [09]



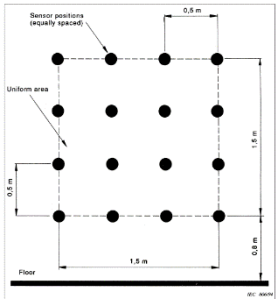


Fig.: Calibration Setup– RF-Field [09]

RF-Field – Mitigation

- Shielding
- Filter
- Connection to PE
- Usually each remedial action set to reduce emission is also effective for susceptability of a system.

HF-Induced Disturbances – Phenomena & Test Signal

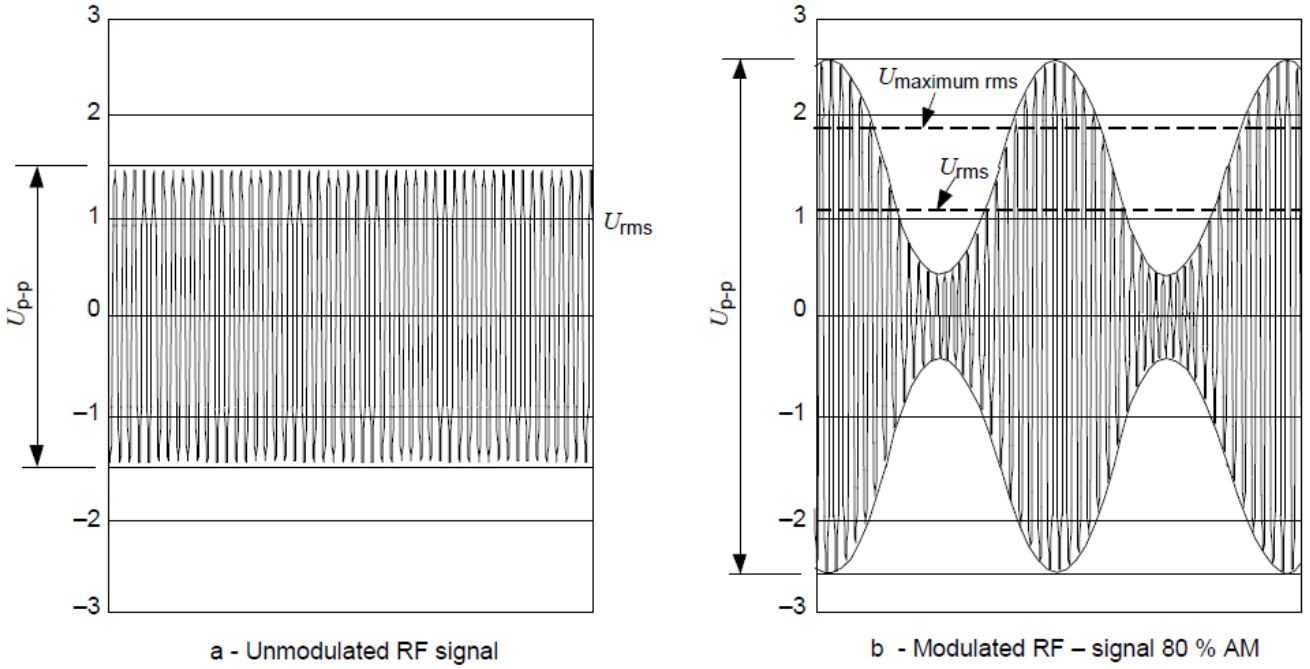
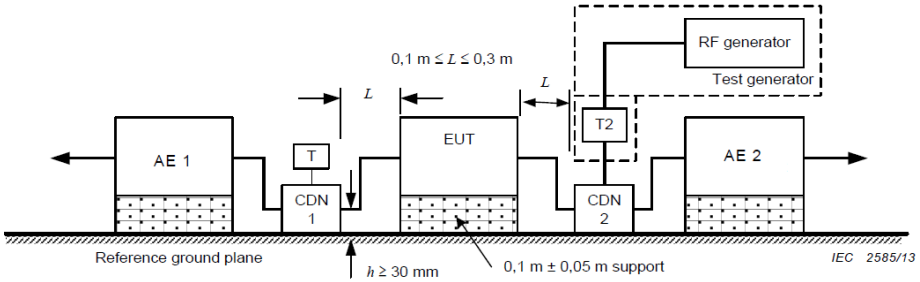
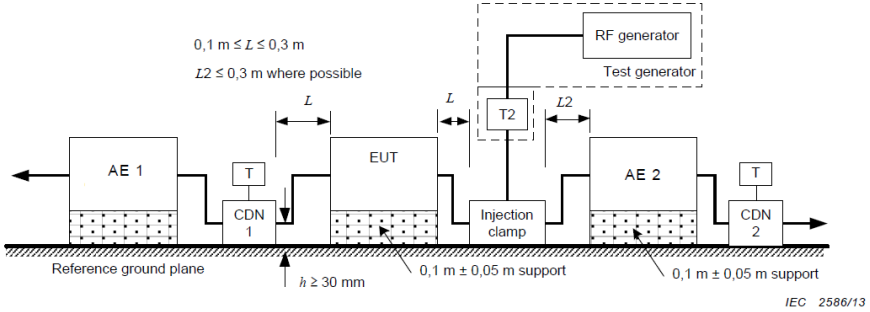


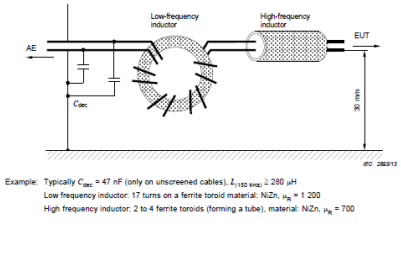
Fig.: Test Signal – HF-induced disturbances [10]

HF-Induced Disturbances – Test Setup



Line type	Examples	CDN type
Power supply (a.c. and d.c.) and earth connection	AC mains, d.c. in industrial installations, earth connection	CDN-Mx (see Figure D.2)
Screened cables	Coaxial cables, cables used for LAN and USB connections, cables for audio systems	CDN-Sx (see Figure D.1)
Unscreened balanced lines	ISDN lines, telephone lines	CDN-Tx (see Figures D.4, D.5, D.7 and Annex H)
Unscreened unbalanced lines	Any line not belonging to other groups	CDN-AFx or CDN-Mx (see Figures D.3 and D.6)





Example: Typically C_{dec} = 47 nF (only on unscreened cables), $L_{150\ kHz}$ ≥ 280 µH
Low frequency inductor: 17 turns on a ferrite toroid material: NiZn, μ_R = 1 200
High frequency inductor: 2 to 4 ferrite toroids (forming a tube), material: NiZn, μ_R = 700

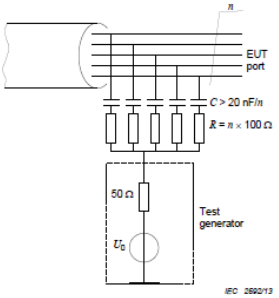


Fig.: Test setup & equipment– HF-induced disturbances [10]

HF-Induced Disturbances – Mitigation

- Filter
- Connection to PE
- Shielding
- Usually each remedial action set to reduce emission is also effective for susceptability of a system.

Disturbances Related to Main Power Grid

Types of disturbances related to main power grid:

- H-Field
- Voltage dips, interruptions and variations

Type of interruption:

- Voltage Drop
- Coupling of 50Hz/60Hz-H-Field

Reduce impact by:

- Buffer by capacitor (vs. Safety)
- Shielding
- Use of components that are not sensitive to magnetic fields

Power Frequency Magnetic Fields – Phenomena & Test Field

- H-Field due to current – 50Hz/60Hz
- Coupling of these fields into EUT

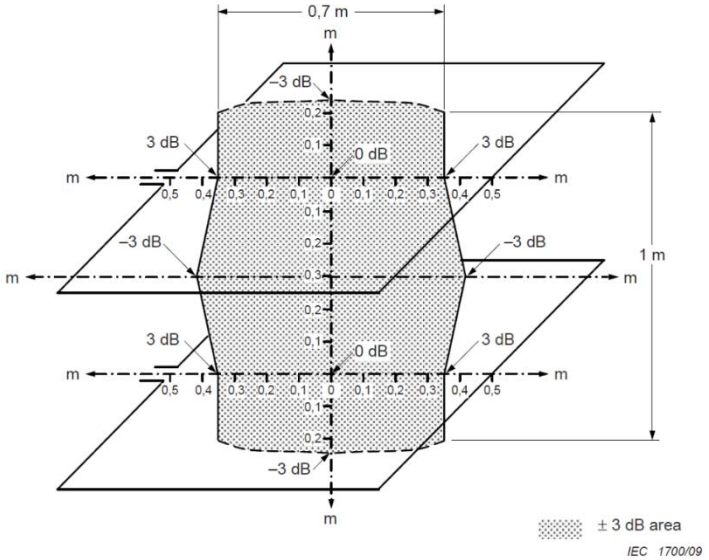


Fig.: Test area – Power frequency magnetic field [11]

Power Frequency Magnetic Field – Mitigation

- Special Environment
- Shielding for H-Field
- Use of components that are not sensitive to magnetic fields

Voltage Dips, Interruptions and Variations – Phenomena & Test Signal

Simulates:

- Unstable power grid
- Variations in supply voltage
- Short interruptions

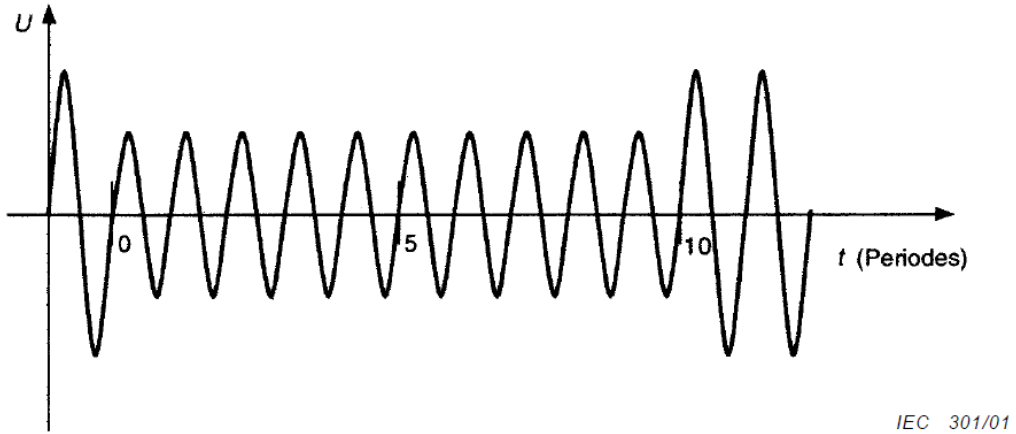


Fig.: Test Signal – Voltage dips, interruptions and variations [12]

Disruptions in Power Grid - Mitigation

- Capacitors:
  - Attention: EMC vs. Safety
- UPS (Uninterruptible Power Supply)
- Shutdown in a defined state

Overview: Stressors for SMPS

- Transients:
  - Input Lines – protective elements
  - Field – Shielding, Short circuit
- HF-Disruptions:
  - Power- & Data lines – Filter
  - Field – Shielding
- Disruptions caused by the power grid:
  - Lines – Buffer, Attention: Safety
  - H-Field – Special environment, special shielding

Conclusion

- EMC tests simulate real phenomena and they have to lead reproducable results, wherever they are performed.
- It is very likely, that a reduction in emission also could lead to a increase in susceptibility.
- SMPS are also at the forefront when it comes to immunity.

Sources

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4. Understanding Noise Spreading-Techniques and their Effects in Switch-Mode Power Applications
   John Rice, Dirk Gehrke and Mike Segal; http://www.smps.us/Unitrode.html

5. IEC61000-4-4

Sources

6. Handbook on EN61000-4-4; Keith Armstrong ; REO UK LTD

7. AN80994; Design Considerations for EFT Immunity
   Shruti Hanumanthaiah, Srinivas NVNS, Cypress

8. IEC61000-4-5

9. IEC61000-4-3

11. IEC 61000-4-6

Sources

11. IEC 61000-4-8

12. IEC 61000-4-11

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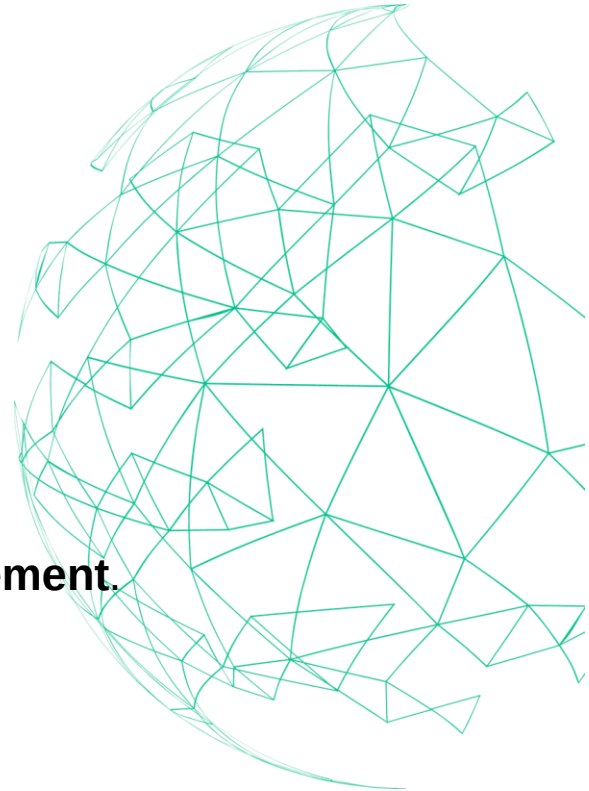
Q & A

Thank You

Please take the survey

We appreciate any ideas or suggestions for improvement.



Upcoming PSMA Events of Interest

- **APEC in-person Safety and Compliance Meeting (March 2022)**
- **Visit the PSMA website for more information**

Webinar Presented by

PSMA

Thank You and hope you have enjoyed the webinar

“Wisdom is not a product of schooling but of the lifelong attempt to acquire it.” – Albert Einstein

Check to see if your company is a member, there is a lot more available to PSMA member companies

If not a member, membership is very low cost for the benefits to you and your company as a whole.

As a member you become part of a team with over 100 companies
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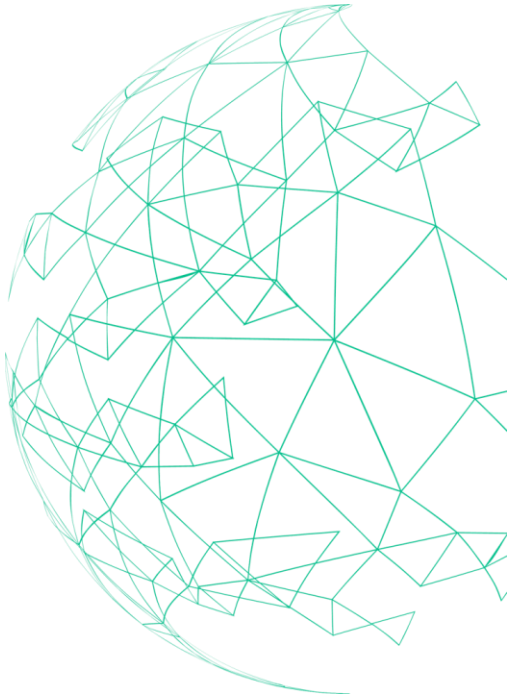

"Individual commitment to a group effort--that is what makes a team work, a company work, a society work, a civilization work." --Vince Lombardi