Essentials of

EMC compliance testing

ir. Filip Nauwelaerts
Lab & Quality manager – Laboratoria De Nayer
Laboratorias De Nayer

ISO17025 accredited for

- EMC (Civil, MILSTD, Automotive, R&TTE)
- Electrical Safety (LVD)
- Mechanical shock and vibration
- Climatic reliability
- Antenna Calibration

Notified Body EMC
Notified Body LVD
### EMC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
<th>Level</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emissions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conducted (note 5)</td>
<td>EN55011, EN55022, FCC: Level B</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Radiated (note 5)</td>
<td>EN55011, EN55022, FCC: Level B</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Harmonic Distortion</td>
<td>EN61000-3-2 Class A &amp; MIL-STD-1399 SECTION 300A</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Flicker and Fluctuation</td>
<td>EN61000-3-3</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td><strong>Immunity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrostatic Discharge</td>
<td>EN61000-4-2: Level 2</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Radiated RFI</td>
<td>EN61000-4-4: Level 3 &amp; MIL-STD-461F</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Fast Transients - burst</td>
<td>EN61000-4-4: Level 3</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Input Line Surges</td>
<td>EN61000-4-4: Level 3 &amp; MIL-STD-1399</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Conducted RFI</td>
<td>EN61000-4-8: Level 3 &amp; MIL-STD-461F</td>
<td>Compliant</td>
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</tr>
<tr>
<td>Voltage Dips</td>
<td>EN61000-4-11 &amp; MIL-STD-704</td>
<td>Compliant</td>
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</tr>
</tbody>
</table>

### ENVIRONMENTAL

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions/Description</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature</td>
<td></td>
<td>-55</td>
<td>470</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td></td>
<td>-55</td>
<td>475</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Derating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acoustic Noise</td>
<td></td>
<td>56.5</td>
<td></td>
<td></td>
<td>dBA</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td></td>
<td>5%</td>
<td></td>
<td>95%</td>
<td>%RH</td>
</tr>
<tr>
<td>Shock</td>
<td>3000 Bumps, 10G (18ms) half sine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td>T.Static - MIL-STD-810G</td>
<td>10</td>
<td></td>
<td>500</td>
<td>Hz</td>
</tr>
</tbody>
</table>

### NOTES

1. This product is not intended for use as a stand alone unit and must be installed by qualified personnel.
2. The specifications contained herein are believed to be correct at time of publication and are subject to change without notice.
3. All specifications at nominal input, full load, 25°C unless otherwise stated.
4. When powering inductive or capacitive loads, it is recommended to use a blocking diode on the output.
5. An external filter is required to meet the conducted and radiated emissions requirements for MIL-STD-461F.
Gas container ship
- Specific EMC requirements (e.g. EN60945,..?)
- Varying temperature and air humidity
- Ship turbine vibration levels
- Incident wave shock levels
- Salt mist
- IP

Industrial gas to liquid plant, Qatar
- Specific EMC requirements (e.g. EN61000-6-2/4?)
- High temperature
- Low relative air humidity
- Specific safety requirements
Where do we start..

Time to Market

Req. analysis/modeling → design → prototype → Validation/certification

△ Development cost
Contents

• Some topics on EMC:
  • Context
  • EMCD and CAP
  • How to approach standards

• Reliability and qualification
  • When EMC meets the environment…

• Some things to consider
Electronic devices are operating in each others EM environment due to:
- Physical proximity
- Use of common supply, data cables, …

Functionality of each system may be influenced by mutual interaction

**E.M.C.**

Capability of such systems to:
- Maintain functionality
- Not to cause excessive emission

**REQUIREMENTS**

**IMMUNITY**

**EMISSION**
What is Electromagnetic Compatibility (EMC)?

Interference coupling between systems

RADIATION

CONDUCTION

Typical categorization of EMC phenomena:

- RI (1)
- CI (2)
- RE (3)
- CE (4)
- ...

Nearby system

Test system

RxTx mains

What is Electromagnetic Compatibility (EMC)?
What is Electromagnetic Compatibility (EMC)?

EMC can be quantified

• System compatibility can be measured or tested
  • Testing immunity: cause a known interference → check functionality!
  • Measuring emission: Measure emitted power → compare emission levels with limits

Perform these and other measurements
  • in a controlled environment,
  • without external influence,
  • guaranteeing correct and reproducible results

Which measurements? methods? Limits? Test set-up?

STANDARDS
Formulated by international and European normalization commissions
Are applied in the framework of European directives

EMC directive
What is Electromagnetic Compatibility (EMC)?

EMC directive

- EMC directive 89/336/EEC harmonizes European EMC legislation
  - 3/5/1989: birth
  - 1/1/1992: voluntary
  - 1/1/1996: mandatory

- Essential requirements for products on the European market (Art.5 -> Annex I):
  - limited electromagnetic disturbance by emission
  - adequate level of intrinsic immunity

- EMC = mandatory within European market
  No national differences
  → goal = free market

- CE marking
  Declaration of conformity (DoC)
  - with all relevant European directives
  - complies with essential requirements
  = Responsibility of the supplier
  Market surveillance!
  Sanctioned when proven to be compliant

- Conformity assessment procedure (CAP)
  89/336/EU: until 20 July 2009
  2004/108/EU: starting from 20 July 2007
  2014/30/EU: starting from 20 April 2016
What is Electromagnetic Compatibility (EMC)?

- Harmonized standards cannot be applied for practical reasons
- Group of similar product variants with high level of similarity
- ...

List of NB's: http://ec.europa.eu/enterprise/newapproach/nando/
EMC standards

Standards development

• European EMC standardization: 3 authorized normalization institutes
  - CENELEC
  - CEN
  - ETSI

Electrotechnical products Telecommunication

• collaboration with international organizations
  - IEC
  - ISO
  - ITU

• Compulsory conversion to national legislation by all member states
  = task of the national commission (NC)
  Belgium: BEC  (Netherlands: NEC)

• Transition period:

  - ENXXX ed1.0
  - ENXXX ed2.0

example:
  - EN55022 :2010
  - EN55032:2012
  - EN55032:2015
Hierarchy within EMC standards

- worldwide variety of EMC standards
- apparent poor coherence

How to find your way through the maze?
- products' field of application
- used technologies (e.g. wireless applications)
- part of product family (e.g. railway)

Taxonomy of standards:

- **Product (family) standard**:  
  - products with common characteristics  
  - Specific EMC requirements (levels and limits)  
  - methods: references to Basic standards  
  - Specific product standards have higher priority then product family standard  
  - e.g.: railway rolling stock devices (EN 50121-3-2)

- **Generic standards**:  
  - In case no product (family) standard exists  
  - applicable to products intended for residential or industrial environment  
  - test levels and limits

- **Basic standards**:  
  - referred to by generic and product standards  
  - description of test methods  
  - categorized by physical phenomenon

EMC standards

Hierarchy within EMC standards (2)
Electrostatic discharge between object and EUT

• Electrostatic discharge between object and EUT
  => pulse \( i(t) \) en \( v(t) \)
  => E and H-field

• Level:
  • + en - 4kV, 6kV, 8kV

• Method: IEC61000-4-2
  • EUT on HCP (1M\( \Omega \))

  • ESD pistol

  • contact: contact first, then discharge on conducting surfaces (possibly painted)
  • air: air discharge on isolated surfaces

  • through coupling planes (V en H, 1M\( \Omega \))
EMC assessment - immunity

EN61000-4-3 RI (1)

- EM fields in proximity of the EUT
  - non-intentional radiators
  - intentional radiators (gsm, radio, …)
  - EM fields induce currents inside EUT

- Levels:
  - example EN61000-6-1:
    - 80 MHz – 1GHz, 1.4 – 2GHz , UMTS: 2 – 2,7GHz
    - 3V/m / 1V/m
    - Modulation 80% AM, 1kHz

- Method: IEC61000-4-3
  - known uniform EM field, inside anechoic chamber

  Faraday cage + absorbing material
  - no outside influence
  - no reflections (standing waves)
  - no disturbance of outside world
EMC assessment - immunity

EN61000-4-3 RI (2)

- Test set-up (example)
EMC assessment - immunity

EN61000-4-3 RI (2)

- Field uniformity calibration
  - Verification of deviation in measured field strength for 16 points
EMC assessment - emission

Some example standards:
- EN 55022 – ITE, Radio disturbance characteristics, limits and methods of measurement
  - 30MHz – 1GHz
  - Class A: not domestic
    - less stringent
    - label!
  - Class B: domestic

<p>| Table 5 – Limits for radiated disturbance of class A ITE at a measuring distance of 10 m |
|------------------------------------------|------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Quasi-peak limits dB(μV/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 230</td>
<td>40</td>
</tr>
<tr>
<td>230 to 1,000</td>
<td>47</td>
</tr>
</tbody>
</table>

NOTE 1 The lower limit shall apply at the transition frequency.
NOTE 2 Additional provisions may be required for cases where interference occurs.

<p>| Table 6 – Limits for radiated disturbance of class B ITE at a measuring distance of 10 m |
|------------------------------------------|------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Quasi-peak limits dB(μV/m)</th>
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</thead>
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<td>30 to 230</td>
<td>30</td>
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<td>37</td>
</tr>
</tbody>
</table>

NOTE 1 The lower limit shall apply at the transition frequency.
NOTE 2 Additional provisions may be required for cases where interference occurs.
EMC assessment - emission

RE (2)

1GHz – 6GHz

Class A: not domestic
  • less stringent
  • label!

Class B: domestic

Upper frequency is based on highest internal source of the EUT:
  <108MHz: up to 1GHz
  <500MHz: up to 2GHz
  < 1GHz: up to 5GHz
  >1GHz: up to 5x highest frequency, limited to 6GHz
EMC assessment - emission

RE (3)

• Basic standard references to CISPR16:
  • Measurement instrumentation as defined by CISPR16-1-1 (P_k, Q_p, A_v detector receivers)
  • Measuring antennas as defined by CISPR16-1-4
  • Measuring test site as defined by CISPR16-1-4 (NSA, S_{VSWR})
  • Measuring method as specified by CISPR16-2-3 (setup and methodology)
  • Measurement instrumentation uncertainty considerations as by CISPR16-4-2

Example:
EMC assessment - emission

RE (4)

- Test setup

Table-top equipment

Floor standing equipment
EMC assessment - emission

RE (5)

- Measurement:
  - Azimuth (rotation)
  - Height scan
  - V en H

\[ \text{PEAK} \quad \text{QUASI-PEAK} \]
\[ \text{FREQUENCY [MHz]} \]
\[ \text{EMISSION LEVEL [dBuV/m]} \]

30 100 1000

20

40

60

80

100

EN55022 Class B 10m

7 Dec 2005 14:39:19 SAR Laboratoria De Nayer

Q-PEAK LIMIT

• Measurement:
  - Azimuth (rotation)
  - Height scan
  - V en H

search for max emission

• Verification of results

Initial measurement peak value
peak value \( \leq \) QP limit \( \rightarrow \) Pass
peak value \( > \) QP limit

QP measurement \( \leq \) QP limit \( \rightarrow \) Pass
QP measurement \( > \) QP limit \( \rightarrow \) Fail
EMC assessment - emission

CE (1)

• Limits & method

EN 55022 – ITE, Radio disturbance characteristics, limits and methods of measurement

• 150kHz – 30MHz

• mains (AC en DC) and telecom ports

• mains

Class A:

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Limits dB(μV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quasi-peak</td>
</tr>
<tr>
<td>0.15 to 0.50</td>
<td>79</td>
</tr>
<tr>
<td>0.50 to 30</td>
<td>73</td>
</tr>
</tbody>
</table>

NOTE: The lower limit shall apply at the transition frequency.

Class B:

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Limits dB(μV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quasi-peak</td>
</tr>
<tr>
<td>0.15 to 0.50</td>
<td>66 to 56</td>
</tr>
<tr>
<td>0.50 to 5</td>
<td>56</td>
</tr>
<tr>
<td>5 to 30</td>
<td>60</td>
</tr>
</tbody>
</table>

NOTE 1: The lower limit shall apply at the transition frequencies.
NOTE 2: The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz.
EMC assessment - emission

CE (2)

• Telecommunication ports:
  incl: connection with distributed network (PSTN, DSL, ISDN, ethernet,…)
  excl: connection with subparts of EUT (RS-232, USB,…)

Class A:

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Voltage limits dB (µV)</th>
<th>Current limits dB (µA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quasi-peak</td>
<td>Average</td>
</tr>
<tr>
<td>0,15 to 0,5</td>
<td>97 to 87</td>
<td>84 to 74</td>
</tr>
<tr>
<td>0,5 to 30</td>
<td>87</td>
<td>74</td>
</tr>
</tbody>
</table>

NOTE 1 The limits decrease linearly with the logarithm of the frequency in the range 0,15 MHz to 0,5 MHz.

NOTE 2 The current and voltage disturbance limits are derived for use with an impedance stabilization network (ISN) which presents a common mode (asymmetric mode) impedance of 150 Ω to the telecommunication port under test (conversion factor is $20 \log_{10} 150 / I = 44$ dB).

Class B:

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
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<td></td>
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<tr>
<td>0,15 to 0,5</td>
<td>84 to 74</td>
<td>74 to 64</td>
</tr>
<tr>
<td>0,5 to 30</td>
<td>74</td>
<td>64</td>
</tr>
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EMC assessment - emission

• Measurement:
  • mains: LISN (Line Impedance Stabilization Network)
    • defined impedance (CISPR16 – par.5.1)
    • filtering of external disturbances
  • Telecom ports: coupling network, clamp, I probe, …
    • CISPR22 par 9.5.2
    • application dependent

• Test setup:

![Test setup diagram](image-url)
EMC assessment - emission

CE (4)

- LISN (Line Impedance Stabilization Network)
  - defined impedance (CISPR16 – par.5.1)
  - filtering of main voltage (only mains frequency should pass to EUT)
  - Provides a characteristic mains network impedance for the EUT
  - Transfers the EUT disturbance voltages towards metering equipment
EMC assessment - emission

- Interpretation test results
  - Initially peak
  - Evaluation:

[Flowchart diagram showing decision points for PK, QP, and AVG detectors]

EN55022

PK detector

- Yes: PK < AVG limit?
  - Yes: PK < QP limit?
    - Yes: QP detector
      - Yes: QP < QP limit?
        - Yes: Pass
          - No: Fail
        - No: AVG detector
          - Yes: AVG < AVG limit?
            - Yes: Pass
              - No: Fail
          - No: Fail
      - No: AVG detector
        - Yes: AVG < AVG limit?
          - Yes: Pass
            - No: Fail
        - No: Fail
  - No: Fail
the environment...

... can be harsh
Reliability and qualification

Environmental testing – when?

- development, prototypes

![Failure rate curve](attachment:image.png)

- **Qualification**
  - Normalized environmental parameters (IEC, EN, ISO, MILSTD, ...)
  - Test conditions (i.e. levels) more “realistic”
  - Pass/Fail criteria

- Detection failure mechanisms by applying **extreme test levels**
  - After repair/changes to product, tests are repeated at higher levels until financial or technological limits are reached
  - Improvements are evaluated for meaningfulness
  - Typical High level vibration, fast temperature change, shock, HALT, ...

- Complementary approaches, not substituting each other (e.g. whiskers)
Reliability and qualification

Environmental testing – when?

- Detection early failures by screening (ESS)
- Postproduction test, detection infant mortality
  ⇒ improve reliability of delivered product group
  ( = Reliability acceptance testing)
- Test levels are limited,
  Prevents negative influence on useful lifetime!
- E.g.: Flight models
Combined failure mechanisms

EMC after climatic qualification

1. Corrosion effect on metals due to oxidation

- Rapid simulation: EN60068-2-11 (57): salt mist (cyclic)
  EN60068-2-30: damp heat, cyclic
- Example where CuNi was used instead of Stainless steel, due to delivery issues:
Combined failure mechanisms

EMC after climatic qualification

2. $T^\circ$ and $\%$RH effects on gaskets for EMC shielding

- damp heat, cold storage, etc.
- Deformation and loosening of gaskets

3. $T^\circ$ related deformation effects on enclosures
Combined failure mechanisms

EMC after climatic qualification

Combined effects:
- Equipotential of enclosure changed
- Metal conductivity changed

⇒ Shielding effectiveness changed
  ⇒ Failure on RE
  ⇒ Possible failure on RI
  ⇒ Influence on ESD current path

\[ SE = -20 \cdot \log\left(\frac{E_t}{E_i}\right) \]
Combined failure mechanisms

EMC after climatic qualification

Possible solutions:

- Choice of metal
- Coatings or galvanised steel:
  remark: non-conductive coatings are to be avoided when related to EMI grounding
Combined failure mechanisms

Vibration after Safety qualification

Test sample qualified for environmental testing

Assessment for abnormal conditions (acc. EN60950)
- Single fault conditions (short on 5V DC power in secondary circuit)
- Evaluation: failure; risk of possible heating of power supply due to lacking failsafe system

=> adjusted design: additional PCB with relays, switching off power when single fault conditions are detected

Mechanical qualification repeated:
Mechanical vibration (based on EN60068-2-6)

switching of relays, due to resonance on additional PCB
=> unintentional power-off switching
=> redesign required to meet both specifications!
Combined failure mechanisms

EMC redesign before vibration testing

PCB redesign with additional capacitors after EMC and LVD evaluation
Mechanical qualification repeated:
  => PCB ‘heavier’ in comparison with previous design
  => resonating effect of PCB
  => damage to component

PCB support needs adjustment…
Combined failure mechanisms

Passive filtering with ferrite beads

Additional ferrite beads as passive filters

=> changes force on cable connector ending
=> might introduce loosening of connector due to high density during vibration qualification
EMC assessment

Things to consider

- **Prepare your product datasheet**
  - Power supply and rating?
  - Which interfaces?
    - Signal port (telecom port?)
    - Maximum cable length,
      physical <-> protocol (ISO) ?
  - Maximum fundamental clock frequency?
  - In case of variants: which is the **worst case** sample?
  - specific technologies used? (RED?)

- **Define context of use, multiple (product)standards may apply**

- **Export outside EU?** (FCC, C-Tick, VCCI, …)
  - Differences in mains supply?
  - Different frequency allocation?
  - CB-scheme?

- **Define functional criteria and means to monitor or simulate them**

- **Some immunity tests might be destructive**

- **Specific for LVD assessments:**
  - gather relevant certification documentation of all modules/subassemblies
  - detail information of components with certification documentation of **in-house** developed critical sub assemblies
  - functional description, technical (installation) manual

- **Don’t assume that certified subassemblies will comply after implementation**
Need further information?

www.labodenayer.be