EMC Problems
and their Solutions as Experienced
in the EMC Test Lab

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Abstract
This paper will discuss actual EMC problems encountered in electronic products. The EMC
problems are those encountered in EFT, Surge, ESD, power fail and emissions testing.
This paper will show how to correct these problems using various methods. It will make a
case as to why EMC problems should be considered in the initial design of a product before
it submitted to the EMC test lab. Using these methods will result in a product of higher
quality and lower cost.

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1 Introduction

Experience in solving EMC problems shows that having just one individual EMC expert in a company, is not the optimal solution for an efficient development. EMC knowledge must be supported within the company as broadly as possible. Each coworker must make an important contribution according to his function to develop an EMC compliant product. An awareness of the EMC design of a product with all involved in development and production is the only way to guarantee disturbance resistant products.

From experience, approximately 60% all EMC of problems are avoidable by using proper design techniques. The first EMC considerations must be addressed at the beginning of the Design phase of a product between developers and the technical designer.

Additional costs of later EMC interference elimination on devices are high. Taking into consideration EMC measures is more economical at the beginning of the product development. Delaying the product introduction to the market caused by EMC redesign generates additional costs.

This essay treats the most frequent problems, which occur in an EMC service laboratory. Often there are many common design flaws that reduce immunity of the devices. The developer and technical designer have a large influence in designing a device on the first attempt economically with the necessary immunity. It is important have a basic knowledge of the EMC design failures to be avoided in a successful design. If the EMC design is not considered in the early product design cycle, the use of expensive EMC protection devices will be required as a product is about to go into production because only minor modifications are possible at this late stage.
2 Cases and Subracks

From the standpoint of EMC design, the case has the primary function of shielding. The case functions as a path for discharge to earth, and as a screen for the suppression of internal radiated emissions. A low-inductive ground connection of the individual housing parts is necessary for good EMC behavior. On the market there are a multiplicity of EMC cases, which fulfill the highest requirements for shielding.

2.1 EMC cases

The main difference between EMC cases and standard cases are:
- Special design for RF use
- Closed housing with special RF screening material
- Cover with no holes or holes with an optimum shielding
- Frontplates with special RF shielding
- Attachment with many screws for better RF shielding

**Suggestion**

The RF behavior usually exceeds the shielding requirements of the application. The difference between standard cases and EMC cases is that the EMC case has better RF shielding and fewer holes and slots. Holes in the frontplate for displays, connectors and cables are a source of emissions. Elimination of the source of emissions or screening of components on the printed circuit boards is usually more economical in reducing emissions.

In comparing the EMC housing of different manufacturers, the method used to make the EMC measurements must be understood. Thus the indicated screen absorption values can only be conditionally compared.

**Manufacturer A**

Figure 1: Display of E and H field with information about the case model and the numbers of frontplates

**Manufacturer B**

Figure 2: Information to the test standard
2.2 Subrack and Front Panel

High ground current disturbances are led away over the module carrier to the housing. Therefore, special attention must be given to the construction of the module carrier. The components must be interconnected with low impedance within the module carrier. When assembling the module carrier, a fixed connection with good contacts between the individual sections is important. Material with a conductive surface is preferred to an isolating surface such as an anodized coat.

Often the connection between the thread strip and the subrack is left to chance. With grub screws (s. fig. 3), which penetrate the isolating anodized skin, a perfect connection to the frame is guaranteed.

![Figure 3: Stud bolt for conductive connection between the thread strip and subrack](image)

2.3 Front panel

The frontplates from distributors are often anodically oxidized. The attachment of the front plate is often made with plastic nipple. The front plate does not have a good connection to the frame. During the ESD test, the front plate works as an antenna and radiates the ns impulses directly into electronics. The results are disturbances or failures of the equipment.

![Figure 4: No electrical connection between the front panel and subrack.](image)

**Remedy**

- Rearside of the panels conductive (electro-chemical pickling)
- Screw socket with conductive material (figure 5)
- Using a countersunk screw without screw socket

![Figure 5: Conductive attachment of the front panel](image)
2.3.1 Example: ESD test to front plate

Front plates without electrical connection to the frame, act as an antenna during ESD testing and radiate the impulses directly inside the device. This leads to EMC disturbances.

<table>
<thead>
<tr>
<th>Original design</th>
<th>Front plates with anodized coats. Use of plastic screws for frontplate attachment. No measurable electrical connection between front plate and frame.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result after ESD test</td>
<td>ESD disturbance at test level &lt;2kV</td>
</tr>
<tr>
<td></td>
<td>View an audible flash over between front plate and housing with the consequence that the front plate takes the ESD potential up to the flash over and radiate directly into electronics.</td>
</tr>
<tr>
<td></td>
<td>The impulse field strengths are equal to or larger than military NEMP impulses (50kV/m Trise &lt;10ns).</td>
</tr>
<tr>
<td>EMC Corrective Measure</td>
<td>The anodized coat on the rear side of the front plates is sanded off. This results in a measurable connection from the front plate to the housing.</td>
</tr>
<tr>
<td>Check after the modification</td>
<td>No influence with ESD test</td>
</tr>
<tr>
<td></td>
<td>The front plate can pass the charge directly to the housing and does not radiate in inside the device.</td>
</tr>
</tbody>
</table>

Tips
- For the subrack use material that is electrically conductive on the surface.
- Use front plates with electro-chemical pickling or behind-mill on the rear side. Use conductive plates with a foil on front.
- Define the connection from the thread strip to the tie bar with a grub screw.
- Design the connection between front plate and subrack with conductive material.
- Make a simple check of the electrical connection with an ohmmeter. (* < 0.5 Ω including measuring cables *)
- Contacting possibly with EMI shielding gaskets
3 EMC Design

The design of electrical equipment requires that the design consider EMC behavior. Each functional module of the device must be associated to an interference class (disturbed, normal and calm). Simultaneously, the internal disturbers of the equipment must be verified and eventually they need separate shielding. With the specifications of the position of plugs and control elements the designer has additional information on where to arrange the peripherals in the equipment. (Figure 6)

Now the partitioning of the device follows into the different EMC zones. The dispatching of the functions into the different interference classes will result in an interference-resistant design from an EMC standpoint. As a result of further requirements the definite design arises.

3.1 Example: Design of an EMC Burst generator

Figure 6: EMC zones

Zone I: Disturbed zone
- High voltage rectifier
- Pulse forming burst pulse,
- Decoupling filter to line

Zone II: Normal zone
- Line filter spatially separated
- Line transformer
- Signal filter
- Input knob and display

Zone III: Calm zone
- Control device

Tips for increasing the immunity

- **Mains after entrance** into the device must be **filtered immediately**. Often the mains first pass through the fuses, switches and indicator lights. The mains lines that are not filtered act as an antenna and radiate disturbances into the device inside. Thus the disturbances bypass the filter which becomes ineffective.

- **In and output lines** must be protected by capacitors to ground or inductances (low frequency signals) or must be **screened** (data lines or low level sense signals). Over these lines no disturbances may penetrate neither outward nor arrive into the inside.

- The **conducted emission** is effective to both sides. Therefore a correct filtering contributes substantially to the increase of immunity. The position of the filter at the power input is meaningful only, if the source of the noise causes no larger disturbances inside the equipment.

- Basically **screened** and **unscreened** sections inside a device must be **separated** strictly spatially.
3.2 Example: Replacement of a power supply with another with the CE mark

For the internal voltages a switched power supply unit is selected, where the CE mark is attached already. The using of components with CE mark does not warrant that your equipment fulfills the request of CE mark automatically. The Noise immunity can be very easily reduced by awkward constructions.

Situation

A power supply is replaced by a product with CE Mark. The new power supply is smaller in dimensions and is installed in place of the previous power supply.

The new power supply has another pin allocation. To reduce costs, the mechanical layout was not changed. The mechanical attaching bolts fit in place where the old ones were attached. (Figure 7)

Results of the immunity test:

- **Burst**: Disturbance above 400V
- **Surge**: Flashover at 2000V L-PE

![Figure 7: Original design](image)

Causes:

- **Burst test**: By using the old layout for the mains cable, the mains cable crosses over the low voltage supply cables, whereby the cables touched. The burst impulses are capacitively coupled over to the adjacent lines. With burst pulses of only 400V the 5V and 15V supply voltages were already so disturbed that the device no longer worked properly.

- **Surge test**: The mounting bolt had the same thread and the technical designer did not adapt the length of the screw to the new power supply unit. As a result, the screw rose up inside the power supply, where the distances to a part under voltage became too small. The surge test ended with the flash over at 2000V to the frame and the power supply was damaged.

Modification and results after troubleshooting:

- **Burst**: Network inlet spatially shifted. No interference up to 2500V
- **Surge**: Mounting bolt shortened. No arcing at 4000V L-PE

![Figure 8: Design after troubleshooting](image)
4 Design according to the EMC requirements

Conducted RF disturbances such as burst pulses are generated during switching operations. These are coupled to the signal and mains lines mostly in the common mode. Therefore, the supply lines are predestined to spread the disturbances inside the device. To remove the disturbances, a bypass capacitor must be connected near the rectifier. Otherwise, the disturbance distributes itself over all lines, which forms a coupling capacity with their surface against earth. The immunity is substantially increased by the following this measures:

**Tips**
- Star shaped distribution of the supply to the individual components.
- Capacitor between GND and earth near the rectifier (1...100nF).
- A bypass capacitor at every integrated circuit chip.
- Bypass capacitors for external signal lines to GND.
- Screened control and data cables (screen connects to the frame).
- GND branch line for oscillators and pulling capacitor to the processor GND.

![Figure 9: EMC layout](image-url)
5 Conducted Emissions

5.1 Definition, Origin and Spreading

Radio interferences are all unwanted emissions in the frequency range between 9kHz to over 400GHz. One differentiates between conducted emission and radiated emission.

The elimination of radio interference means to reduce the disturbances under the prescribed limit values. Depending on the application, different standards are used.

Interferences are generated by spark gaps of commutator motors and from fast voltage changes in electronic circuits (phase control rectifiers and digital circuits), as well as from harmonics of oscillators. The high clock rate of electronic devices produce fast slew rates, which produce harmonics in the FM and television band.

In all electronic circuits it is possible that completely unnoticed and unintentional oscillations and resonance’s can arise which generates radio interference. Normally stable circuits can unintentionally be made to oscillate during a layout modification.

The interfering RF spreads over all lines as conducted disturbance. Sometimes the disturbance is radiating and disturbs the radio broadcast. Devices, with only a mains input, can spread the RF over this line and disturb other devices. Therefore a disturbance is possible via the mains even in equipment with a shielded housing.

The measurement of conducted emission is made with two different detectors. These are quasi peak (QP) and average (AVG). Each detector has individual limits.

Narrowband disturbers such as quartz oscillator frequencies give the same results with both detectors. However, wide-band disturbers, such as phase controlled devices produce clearly smaller values when evaluated using the AVG method. Therefore, the AVG limit curves are usually for 10dB below the QP curves.

If the QP measurement result is always below the AVG limit, the AVG measurement is not necessary. The AVG measurement is always less than or equal to the QP measurement.

The conducted emission is measured as voltage interference in the frequency range between 150kHz and 30MHz. The supply lines (AC and DC) are measured with an artificial network and the control or data lines with a probe. The radiated emission above 30MHz is measured in an absorber test chamber or in the field.
5.2 Leakage current

For filtering the radio interference, X- and Y- capacitors as well as inductances are usually used. By using Y-capacitors a leakage current results, which is specified depending upon device class. If no leakage current is specified, then 0.75mA are to be assumed as the limit value. In addition to the leakage current of the Y-capacitors, the specific device leakage current must also be added.

Figure 10a: Example of EMI suppression with X and Y capacitors

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**Table 1: Leakage current of some Y capacitors (V=230V, 50Hz)**

<table>
<thead>
<tr>
<th>Value Y capacitor</th>
<th>1 nF</th>
<th>2.2 nF</th>
<th>3.3 nF</th>
<th>4.7 nF</th>
<th>6.8 nF</th>
<th>10 nF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Y-Capacitor [mA]</td>
<td>0.072</td>
<td>0.159</td>
<td>0.238</td>
<td>0.340</td>
<td>0.491</td>
<td>0.723</td>
</tr>
<tr>
<td>2 Y-Capacitors [mA]</td>
<td>0.144</td>
<td>0.318</td>
<td>0.478</td>
<td>0.679</td>
<td>0.983</td>
<td>1.445</td>
</tr>
</tbody>
</table>

---

**Proposal for application of noise filter elements**

- Reduce the disturbances at their source. A phase control can also disturb an internal microprocessor.
- Use filters in metal housings, where a transition to a screened system exists.
- In a nonprofessional mind, you can think of RF as nebulous noise. A filter can be bypassed by the "fog", if the device shielding is missing.
- Always make sure, that the length of the feed line of the filter capacitors to earth is as short as possible. Each inductance in these connections reduces the filter effect.
- If a line filter with an inductance within the range of 2x10mH does not show any effect, something is wrong. Either the filter is bypassed on other lines or the ferrite of the toroidal core is saturated by asymmetrical impulses.
- Ferrite toroidal cores can be saturated easily. Large asymmetrical impulses such as those in phase control circuits can saturate current-compensated inductances. Use iron powder cores and avoid ferrite cores.
5.3 Process of elimination of radio interference

Generally, we propose that you start EMC measurement first with the conducted emission and then continue with the immunity check. The reasons are:

- The measurement of emissions does not destroy the device under test.
- Modifications for filtering of the radio interference also improve immunity.
- Measuring emissions results also gives information about the immunity behavior.

1. Start with the **measurement of the spectrum** in the original status, to estimate the amount of filter modification required.

2. **Eliminate the interference with X-capacitors** parallel to the line. Rise the value of capacitance up to approx. 0.47\(\mu\)F.

3. **Y-capacitors**
   - If the result with x capacitors is insufficient, continue with Y-capacitors to reduce the asymmetrical part. The value can be increased up to the permissible leakage current.

4. **Use of inductances**, which must be placed mostly in series with the mains. The reason is that the mains impedance is lower.

5. **If this is not successful**, please examine whether the filter elements are bypassed by cross coupling.

6. If the limits are only exceeded **on the higher frequency range**, the design must be examined for radiation. Using **RF inductors** with nickel zinc ferrite material can be a solution for the problem.

7. If the conducted emission to 30MHz is within the limits, you can continue with measurements above 30MHz in the **radiated frequency range**.

8. **As a final check** we propose testing another device from the same production lot so you are sure that the manufacturing process is correct.

To get a rapid overview

X-capacitors have their main effect in the lower frequency range to approx. 1MHz.

Y-capacitors to work over the complete frequency range. Two capacitors with 2.2 nF get better results than a single 4.7nF capacitor. The reason is that smaller self-inductance is obtained from two series elements.

Lines that radiate RF, slots, openings.

Modifications in the layout have also an influence on the EMC behavior.
### 5.4 Systematic overview of radio interference and their remedy

#### 5.4.1 Interference voltage (conducted emission)

<table>
<thead>
<tr>
<th>Symmetrical interference</th>
<th>Frequency range typical &lt; 1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase controlled</td>
<td></td>
</tr>
<tr>
<td><strong>Remedy</strong></td>
<td></td>
</tr>
<tr>
<td>X-capacitors,</td>
<td></td>
</tr>
<tr>
<td>Series inductance with iron powder core</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 11](image1.png)

<table>
<thead>
<tr>
<th>Asymmetrical interference</th>
<th>Frequency &gt; 1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static frequency oscillators, switch power packs, quartz oscillators</td>
<td></td>
</tr>
<tr>
<td><strong>Remedy</strong></td>
<td></td>
</tr>
<tr>
<td>Y-capacitors,</td>
<td></td>
</tr>
<tr>
<td>&lt; 1MHz current compensated inductances with core Mg-Zn</td>
<td></td>
</tr>
<tr>
<td>&gt; 1MHz Ni-Zn core single layer wound</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 12](image2.png)

#### 5.4.2 Radiated Emission

**Predominantly asymmetrical type**

Interference voltage on lines to or from the device
- Mains and signal lines act as antennas
- Radiating (Device size determines the wavelength)

**Remedy:**
- Y-capacitors,
- Current compensated inductances Ni-Zn core single layer wound
- Screening (shielding) of the noise source
- Proper grounding system
- Cable layout
- All components connected to metal and grounds must be contacted with large surfaces.
5.5 Example: Effect of filter elements

As an example, we have a control device working with its maximum load to show the effect of the noise filter. (See Figures 13...15)

**Figure 13 : Original measurement**

Without filtering

The interference exceeds the limit without noise filter elements at 12dBmV. Measurement QP on L and N.

In the drawing the results for L and N are displayed. The measurement on the line L has the highest interference.

**Figure 14 : Filtering with an X2 capacitor**

X2-capacitor, 0.22µF parallel to the mains. The limits are exceeded by 5 dBµV

Measurement QP phase L

Increasing of the value of the x capacitor beyond 0.22µF is insignificant.

**Figure 15 : Filtering with a noise filter**

Line filter model 1A-P (Meteolabor). The limit values QP and AVG are 6 dBµV higher than the interference.

The filter with the combination of the X- and Y capacitors, as well as inductors reduces the internal interference below the class B limits.
5.6 Leakage of noise over the GND Layer

The ground layers must be designed according the following rule: **Areas with RF noise sources must be separated with "bubbles" (blank areas). Disturbances are then grounded directly and this keeps the other areas calm.** (See fig. 16).

The ground area around the oscillator area near the processor is designed as a bubble. The load capacitance of the oscillator is directly connected to the GND pin of the processor. Thus the quartz oscillations are not spread unnecessarily in the circuit.

The ground path from the ground layer to earth must be as short as possible. The individual ground areas conduct directly to the ground capacitor.

![Diagram of ground layer reduction](image-url)

**Figure 16: Reduction of noise via the GND Layer**
Example: Interference of quartz oscillators

In this example, the AVERAGE measurement shows the disturbances are at 18 and 22 MHz (fig. 17). The form of the disturbance suggests clock frequencies of a microprocessor. The disturbances can be eliminated neither with X nor Y capacitors. During the investigation of the boards we recognized, that the GND line of the load capacitances of the oscillator, distributes the disturbances in a star shape on the whole printed circuit board. A modification of the printed circuit board with the connection from the GND of the load capacitances to the microprocessor GND brought an improvement of the measuring results to around 8 dB\textmu V. After this modification, the emissions meet the limits without application of further filter elements. (See figure 18)

Figure 17: Interferences at 18 and 22 MHz

The GND load capacitance spreads the disturbances directly over the whole printed circuit board.

Figure 18: Measurement after modification

Filtering of the quartz resonant circuit by bonding the load capacitances GND according the recommendation in figure 16.

When the correct design is used, the emission drops 4dB\textmu V below the limit.

6 Plugs and cables
Plugs and cables are used to connect the devices to external devices and sensors. They have to pass the signals without additional noise. EMC tests have shown that the type cables and plugs can have an influence on the immunity performance of the product. Investigations of different applications indicate that immunity results can vary by a factor of 2 to 3 times depending upon the types of plugs and cables used in the product.

A large number of plugs and cables on available on the market and they have a lot of different characteristics. Often the manufacturers have an economical standard design and an exclusive product line with increased specifications like military versions or similar types. Often a special EMC set can be ordered for a better shielding.

### Advice on choosing Plugs

- Install the plug housing with a low ohmic contact to the front plate or housing.
- If the plug is soldered on the printed circuit board, make sure that the disturbances do not arrive via the screen inside to the device. They must be shorted to the front plate immediately.
- Grounding connections with "green yellow" wires satisfy most of the electrical safety requirement in the low frequency 60Hz area. \( U = L \frac{di}{dt} \)
- Use plugs that have a conductive area for the cable screen to the plug around the signal conductors.

When using plugs, it is important that interferences are shorted out over the screen directly to the front plate or housing. Pay special attention to a conductive laminar connection to the front plate. Using screened cables, the transition of the cable screen to the plug is very important. (Figure 19).

![Figure 19 Connection Screen - connector a) poor, b) correct](image-url)
6.1 Example: Sub D Connector with screened cable

A. Compound Connector sealing
Description:
The helical screen is soldered over a wired cable connection to the plug housing. In this area the cables are not shielded. A large range of quality exists among various connector manufacturers.

Immunity:
Coupling of the cable jacket current to the signal is possible. To avoid this, filtering at the device input is mandatory.

B. Plastic connector with metalized surface
Description:
The screen contacts the conducting surface. Depending on the design, a defined contact resistance to the housing over the cable pull relief can take place. The signal cables are shielded at every position.

Immunity:
The connection from the housing to the plug is not well defined. Connections with plastic can flow with the time. The quality of the connection from the screen to the plug has large variations. The quality of such a screen connection can also change with time.

C. Connector with metal case
Description:
The cable screen is connected with good contact and is screwed into the housing. The signal cables are always in the shielded area. A leakage current in the range of 100A is shunted via a defined path to the plug housing.

Immunity:
The design of this shielding method provides good results. This design is preferred. The use of plug with metal housings and screened cables is a simple method for producing a good immunity result especially where a modification of the equipment is not possible.

Comparative immunity tests with burst pulses and the capacitive coupling clamp between cables of the type A and C above result in salient differences. A type A cable can cause disturbances at 800V, whereby the same device with a type C cable shows no interference to over 2000V.
6.2 Screened Cables

There is a multiplicity of screened cables available on the market. There are closed, helicoiled, braided, double braided and isolated etc. The following figure 21 shows some examples of screened cables.

![Screened Cables Diagram](image)

Most screened cables consist of a braid screen. A criterion used for evaluation of the screen is the amount of coverage of the screen, where bad values are 60% coverage and good values have 85 to 95% coverage. Good coverage is achieved with as much screen coverage as possible using thin wires. Two pair twisted double screens without isolation performs better than a cable with one screen with 95% coverage.

In special applications, a triaxial cable is used. These have the advantage that the inner coaxial cable is almost completely protected by the second screen. A frequent application is for computer cables used in networks.

Closed screens provide 100% coverage and are suitable also for use with frequencies over 100 MHz.

Helicoiled screens have an overlapping metal area, which is usually not conductive. This reduces the screening effect above 100kHz. With an additional screen layer, the shielding effect can be improved.

The cables can be connected to the reference earth either on one side or on both sides. When connected on one side to GND, the screen attenuates the electrical fields only. Grounding a cable on both sides attenuates both the electric and magnetic fields.

It is important that the signals are separated from the screen in triaxial cables to prevent dangerous ground loops.

Sometimes it is necessary to experiment to find the best method for cable screen grounding. The results depend upon the type of the disturbance and its spectrum, the cable length and other environmental factors as whether on not the double grounding of the screen is favorable.
6.3 Choice of cables

<table>
<thead>
<tr>
<th>Cable</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twisted cables no screen.</td>
<td>Up to approx. 1 MHz.</td>
</tr>
<tr>
<td></td>
<td>Magnetic compensation with twisting. The more turns/m the better (20...60/m).</td>
</tr>
<tr>
<td>Twisted cables with screen grounded on one end.</td>
<td>Up to approx. 1 MHz.</td>
</tr>
<tr>
<td></td>
<td>Magnetic compensation can be achieved by twisting an additional electrical screen.</td>
</tr>
<tr>
<td>Coaxial cable, or triaxial cable.</td>
<td>Up to a couple of 100 MHz.</td>
</tr>
</tbody>
</table>

Figure 24: Sensitivity of some cable layouts

Figure 24 shows the influence of a low frequency (50kHz) interference. The cable is 3cm above the reference ground. All results are related to figure 24a).

- Asymmetrical lines with screen on both side grounded 24c) are less sensitive than with one side grounded as in 24a).
- Lines, which are grounded on one side only, are clearly more insensitive than when they are grounded on both sides.
- The screen must not be used for the signal. Disturbances on the screen influence the signal.
- A screen is an additional interference protection for twist pair cables.
- Depending upon the application, optimal shielding must be determined experimentally.
7 Common interference problems

The following advice allows the engineer to solve interference problems without the use of filter elements. It is always possible to suppress the noise with a standard filter, but not always necessary. The Burst and ESD interference often require layout modifications. This is usually necessary if the disturbance spreads out on the printed circuit boards and no other way to eliminate the disturbance exists.

7.1 Burst Test

<table>
<thead>
<tr>
<th></th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Interference</td>
<td>Interconnection cross over unfiltered lines.</td>
<td>Separate the lines spatially or decouple the lines.</td>
</tr>
<tr>
<td></td>
<td>Disturbance is conducted through the plug to the printed circuit board into the device inside.</td>
<td>Plugs must be grounded at the housing.</td>
</tr>
<tr>
<td></td>
<td>No connection screen – housing.</td>
<td>Connection screen - housings must be connected.</td>
</tr>
<tr>
<td></td>
<td>GND line leads cross over the screen.</td>
<td>Use a single conductor for GND.</td>
</tr>
<tr>
<td></td>
<td>Screen is connected across a pin into the device inside and screwed internally to the housing.</td>
<td>Search for another plug that solves this problem better.</td>
</tr>
</tbody>
</table>

| Internal Interference | Cause: Devices inside equipment cause the disturbance. | Remedy: Bypass capacitor GND to earth eventually with potential equalization resistance (MΩ value). |

7.2 ESD

<table>
<thead>
<tr>
<th></th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interference with reset</td>
<td>Voltage drops during ESD caused by the current pulse (some 10ns).</td>
<td>Bypass capacitor near the disturbed device. RC filter for undervoltage detector.</td>
</tr>
<tr>
<td>Tripping of encoders</td>
<td>Front plate radiates during the test into the device inside.</td>
<td>Conductive connection between housings and front plates.</td>
</tr>
<tr>
<td>Short loss of function</td>
<td>ESD couples over the cable connections.</td>
<td>Use a screened cable with the correct plug.</td>
</tr>
</tbody>
</table>

| Loss of function after ESD to external housing | Reason: Common lines for LCD electronics GND and the LCD frame. | Remedy: - Connect a capacitor approx. 2.2nF between the LCD frame and the housing. - isolate LCD with a glass - Use LCD with two separate lines for GND / frame |

<table>
<thead>
<tr>
<th>LCD Interference</th>
<th>Reason</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reason:</td>
<td>Common lines for LCD electronics GND and the LCD frame.</td>
<td>Remedy: - Connect a capacitor approx. 2.2nF between the LCD frame and the housing. - isolate LCD with a glass - Use LCD with two separate lines for GND / frame</td>
</tr>
</tbody>
</table>
### 7.3 Surge

<table>
<thead>
<tr>
<th>Event</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal discharge in the device</td>
<td>Insulating distance in the device inside too small.</td>
<td>Increase the distances between the components, check the isolation class of the components.</td>
</tr>
<tr>
<td>Destruction of components</td>
<td>Components are the wrong size. Check the dielectric strength of the components.</td>
<td>Coordinate the overvoltage protection between the components and the overvoltage protection. Look for internal resonances between filters and components.</td>
</tr>
<tr>
<td>Interference</td>
<td>coupling the surge pulse.</td>
<td>Separate the lines that contain the surge pulses.</td>
</tr>
</tbody>
</table>

### 7.4 Power Fail

<table>
<thead>
<tr>
<th>Event</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of function</td>
<td>Storage capacitors too small.</td>
<td>Increase the capacitance of the storage capacitor</td>
</tr>
<tr>
<td>Partial loss of function</td>
<td>Uncoordinated behavior, data loss.</td>
<td>Storage capacitor of one dc voltage is too small. Adapt the different dc voltage for a defined &quot;shut down&quot;.</td>
</tr>
</tbody>
</table>