CMS electronics coordination Electrical Safety Issues

Slides may be found at

http://home.cern.ch/~szoncso/EMC/ElSafetyExperiments/Welcome.html

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Electrical safety (and compatibility)

Floating screens are dangerous.

Some connection with earth is necessary against fire hazard (high impedance connection is sufficient)

Detector ELV & LV (decree 88/1056/EEC)

Circuit earthing is NOT A PREREQUISITE. Study your case, and apply the set of rules listed before.
Floating (insulated) LV networks must use earth impedance/ground fault interlocks
and earthing of metallic structures to the PE provided. There is no difference in the protective measures between FELV and LV. Floating structures inside experiment are capacitive couplers. Earthing via high impedance is required.

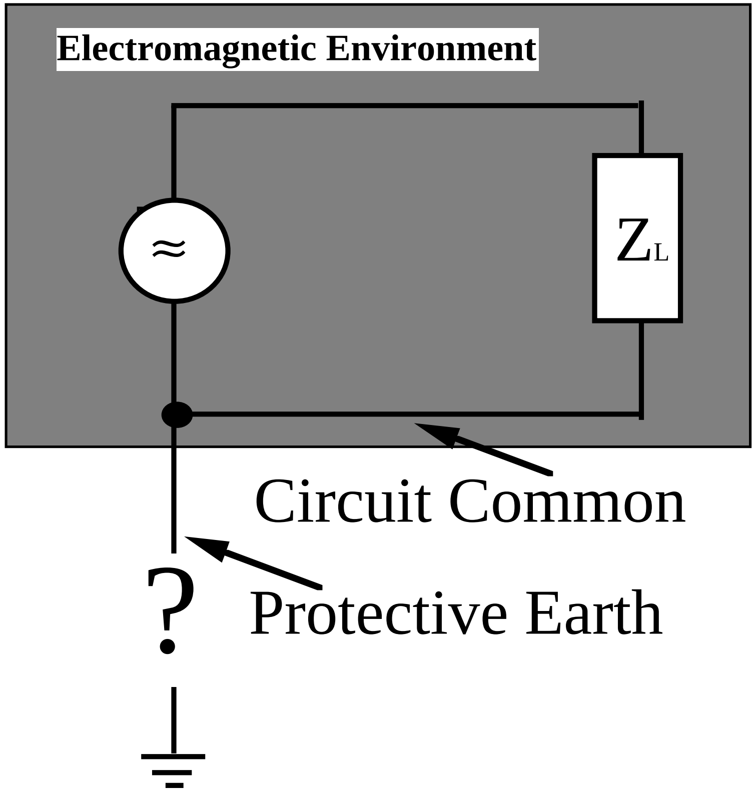
Interlocks

Fail safe interlock systems must be provided for all systems that cannot be fused. Additional requirements stem from the use of cooled cabling or other technical parameters. Slow control systems therefore play a key role for safety.

Electromagnetic Compatibility

CERN is obliged by the decree 89/336/EEC to keep emission levels towards the environment to certain values. Inside the detector these levels may be entirely different. It is up to the detector engineering staff to ensure compatibility. However, we strongly recommend that all electronics be designed for low emission and, hence, low noise susceptibility. As practically all equipment is near-field exposed to neighbouring equipment it would be extremely wise to limit both radiated and conducted emissions. EN 55011 (ISM) and EN 50081 (industrial electronics) may be used for the RF-interference levels. Conducted emission and general guidelines may be found in IEC-1000. In any case, DC power cables may never be routed on different paths for incoming and outgoing lead. Leads should be twisted. The few circuits relevant for safety must comply, one by one, with the legal immunity rules or bear he "EC" mark, the latter completed by the declaration of compliance and written instructions..

Circuit Common and Protective Earth



NO CIRCUIT NEEDS TO BE EARTHED IN ORDER TO WORK.
Therefore, changing earth connections because of interference shifts the problem elsewhere.

Protective Earth:
No current under normal operating conditions. The protective earth can be removed, the circuit will continue to function but without any potential reference. Protective Earth only keeps (free) potentials of equipment at equal levels.

Circuit common:
Common conductor that is part of one or more circuits. Cannot be removed.

Circuits susceptible to common earth interference are badly designed. The earth connection should be used solely for potential reference or safety. Please distinguish common conductor interference, common earth interference and Protective Earth contamination. There is confusion when talking about distinct types of interference. Overlapping wording mixes up common and earth connections. Scientifically speaking there is an overlap between screens connected to earth and earth connections as such. For noise handling purposes the earthed screen is a vital element. The earth connection for safety reasons should not alter noise performance. The circuit common is necessary for equipment supply and interconnection. It is a potential source for common conductor interference.

Extra Low Voltage according to IEC 364

Extra Low Voltage domain (ELV)
AC: ≤ 50 V DC: ≤ 120 V

Safe Extra Low Voltage (SELV)
First condition: All active parts are separated from all other installations by double or reinforced insulation (e.g. transformers VDE 0551/EN 60742).
Second condition: All active parts are insulated from earth.
Third condition: All active parts are insulated from the earth conductor of other installations (same insulation quality as in first condition).

Protected Extra Low Voltage (PELV)
First condition: All active parts are separated from all other installations by double or reinforced insulation.

Functional Extra Low Voltage (FELV)
Everything in this voltage range that is neither SELV nor PELV

Smooth direct current is defined having a maximum ripple of 10% RMS with the peak value not exceeding 15% of the RMS value.
For all other direct currents the values of the tensions for alternating current must be used.
During normal exploitation of equipment or of a part thereof the actual value of the tension may exceed the nominal value by 10% without provoking a reclassification of the installation. Equipment for electrical traction may exceed the nominal value of tension by 20%.

Low Voltage (LVa, BTa)

Low Voltage domain "a" (LVa, BTa)
AC: 50 V < U ≤ 500 V DC: 120 V < U ≤ 750 V

Any supply

Life wires: Connection with earth required. Insulated systems are possible (described on slide 57)

Cases, metallic structures: Connection with earth required

Separation from other circuits equivalent to single insulation
Decree 88-1056: Protection against direct contact required
Protection against indirect contact required (at CERN: scheme TN)

All connectors must be made such that interchange with other installations becomes impossible

Scheme TN: The secondary star point of the distribution transformer is earthed. From this point there are two distinct lines into the installation itself. One carries the retrun current and is called "neutral" or "N", the other one does not carry any operational current and is called "Protective Earth" or "PE". All metallic structures are connected to the PE. That is why the PE is brought down from the surface into the pits using high cross-section earth cables. This is the experiment earth. The often claimed "quiet earth" does not exist. If an earth mesh separated from the general PE is giving less noise in a particular circuit the same effect can be had using a PE connection across some impedance, be it resistive or combined resistive/inductive. You then allow standing voltages without provoking currents on cable screens. Stray currents on cable screens are the main source of the common-to-differential conversion effect.

Insulated Low Voltage (IT) (IEC-364)

Low Voltage and Extra Low Voltage domain (LV/ELV)
AC: ≤ 500 V DC: ≤ 750 V

Life wires: **No** connection with earth allowed

Cases, metallic structures: Connection with earth required

Separation from other circuits equivalent to single insulation (2kV)

Decree 88-1056: Protection against direct contact required
Protection against indirect contact through standardized circuit interlocking when earth impedance is too low (earth fault) or when potential of circuits gets too high (static charge-up)

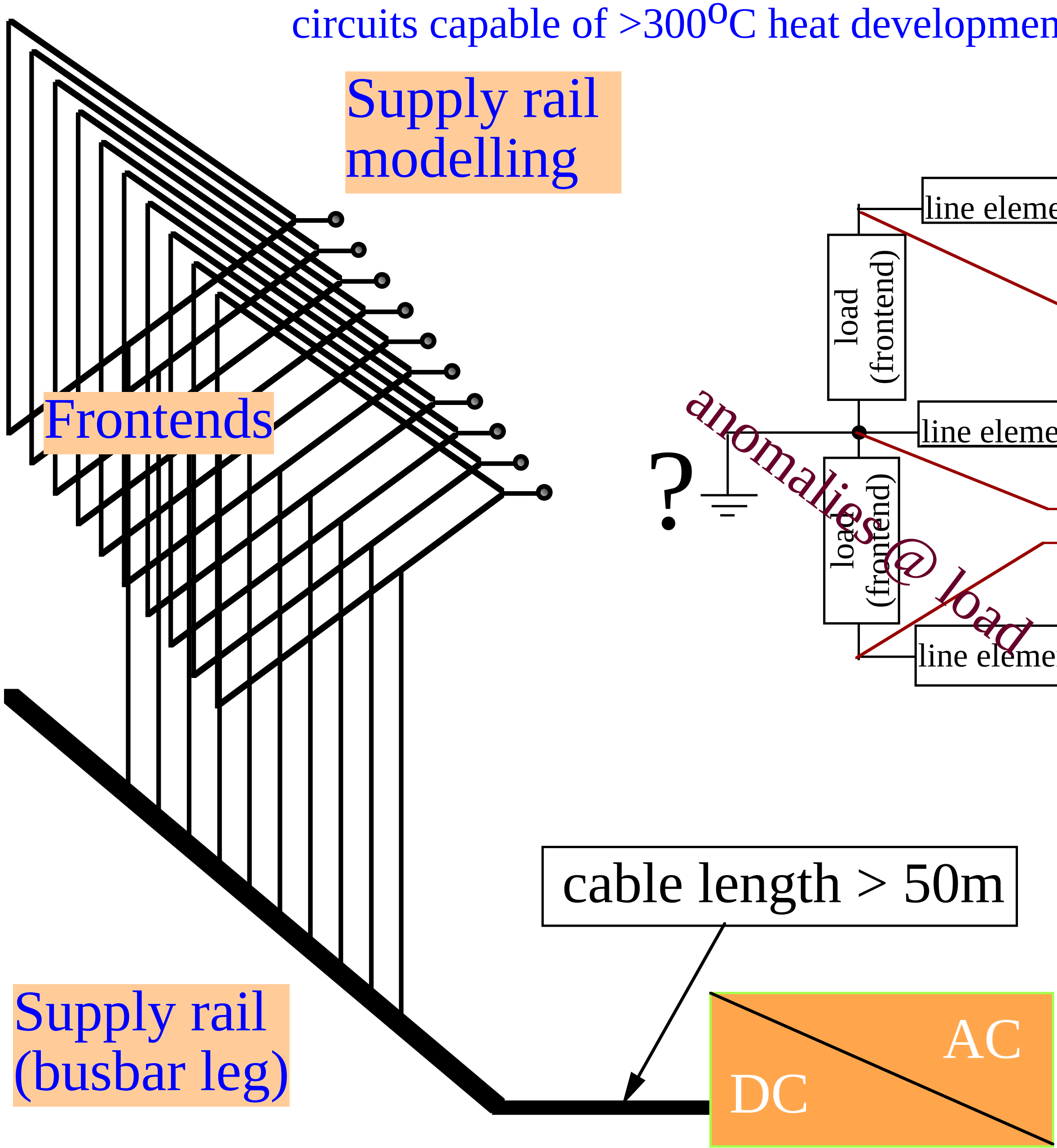
All connectors must be made such that interchange with other installations becomes impossible

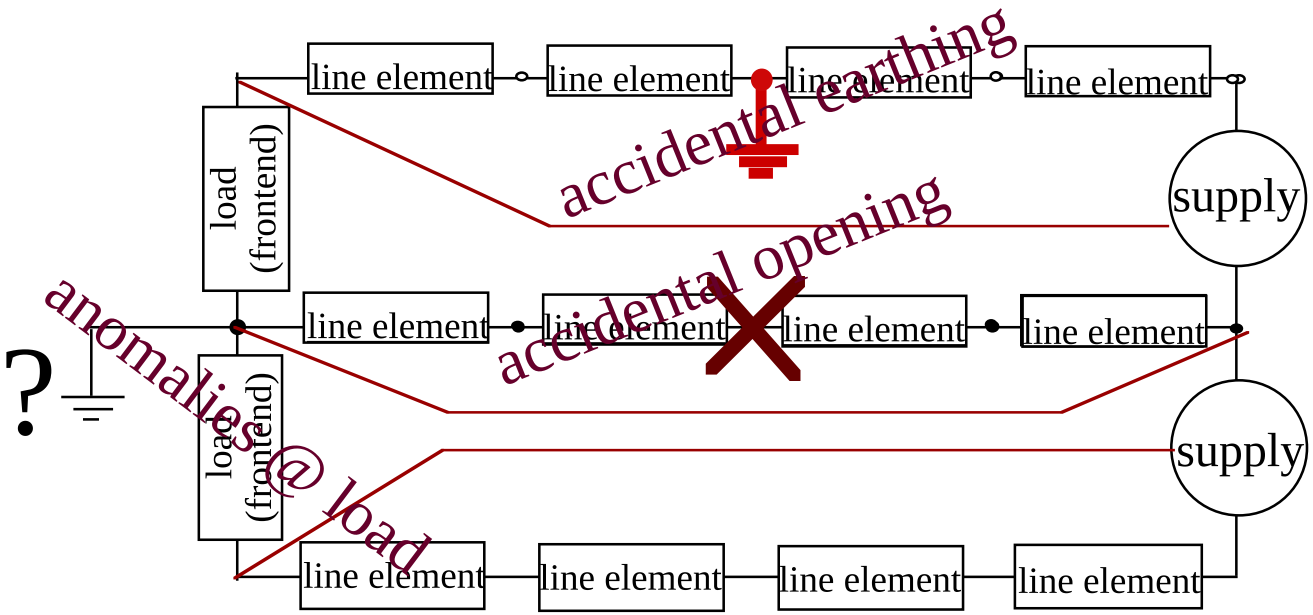
Insulated low voltage power supplies are therefore permitted. However, it should be made clear that the earthing brought into play by the detector circuits effectively determine the earth impedance and hence the short circuit current. This current, seen across the detector installation in case of an earth fault, must not be capable of destroying or setting ablaze the dector installation. In case this condition cannot be met a differential circuit breaker or its electronic equivalent must be employed. The latter condition becomes more complex to fulfill when a circuit needs more than one voltage. It is strongly recommended not to use multiple voltage power supplies using a common return.

ELV supply to frontends - protection problem

see also: fire prevention for circuits > 60 W

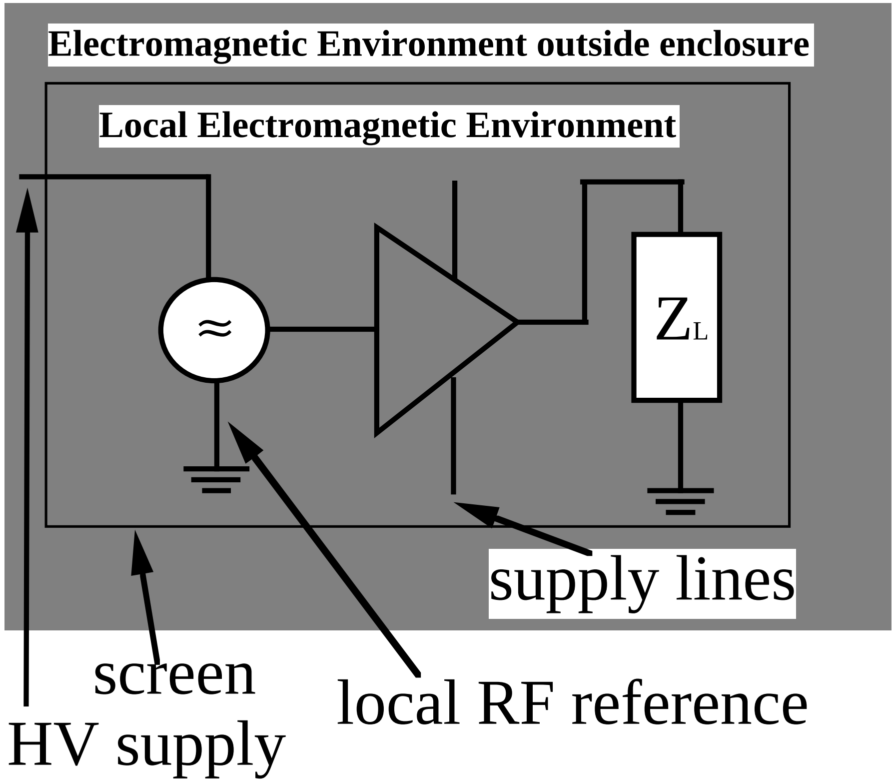
circuits capable of >300^{o}C heat development





Busbars should exhibit an inherently low impedance. Peak demands should be met by a moderate energy storage capability. The low impedance path must be kept low on the connection between busbar and supplied device. It is generally difficult to operate remote busbars buried inside a detector while keeping a low source impedance for connected devices. Dynamic modelling or measurements against peak demands must be done. LHC-experiments will depend heavily on the busbar quality because no power converters may be located inside the detectors. DC will be brought in on high-power DC-rails. System compatibility must be worked out - either we tolerate higher supply voltage ripple by taking appropriate measures onboard our electronics or we keep ripple low by imposing tight standards for busbars. In either case the system aspect will need considerable attention. All possible fault scenarios must be assessed for fire and fault prevention.

Earth budget of frontend electronics



Known RF-parameters of frontend electronics
(parameters depend solely on design and may vary widely)

1) Screening effectiveness (closed screens are independent of local RF-reference)
   80 dB for perfect thin-foil screen without penetration above 100 kHz
   in general extremely degraded to as little as 10 dB by penetrating cabling
2) Supply voltage ripple feedthrough
   40 dB for good design
3) Capacitive coupling
   directly proportional to capacitances. Bad partly open screens act as equipotential plane. Screens need direct path to local RF-reference.
4) Filter attenuation (filters on supply lines, HV-lines, threshold distribution)
   According to design.

NO CIRCUIT NEEDS TO BE EARTHED IN ORDER TO WORK.

Therefore, changing far-reaching earth connections because of interference shifts the problem elsewhere. It is not a solution.

Low Frequency Effects:

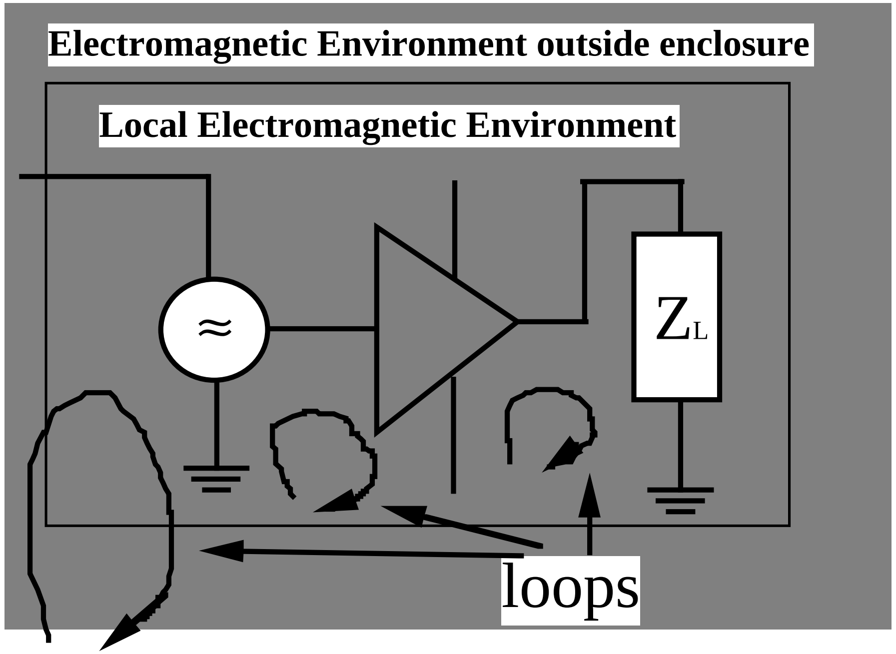
Circuits need to be able to work inside a few µT extra low frequency field.
Systems need to be able to tolerate, without degradation of performance, a few mV of Extra Low Frequency potential difference.

High Frequency Effects:

Local RF-potential reference must be as perfect as possible. Injection and emission of RF must be kept at the lowest possible level.

PCB (and detector) design are of primary importance. Use test pulses and/or high counting rates to determine RF-leakage. Use RF-sniffing or good receivers and antennas for determination. Concentrate work on frequency bands where observed emissions are considered too high. Emission levels are, by reciprocity, a direct measurement of your own susceptibility. Please bear in mind that emissions are disturbing your own neighbouring electronics as well as the neighbouring detector. Emissions may be radiated or conducted or capacitively coupled.

Tolerating ExtraLowFrequency Fields (≤100 kHz)



Known LF-parameters of frontend electronics

(parameters depend on loop surface and circuit design)

1) Screening
   Impossible. Flux deviation possible but prohibitive in LHC environment.
2) Supply voltage ripple & pickup
   Twisted supply lines cancel pickup. This limits exposure to ELF.
   Low frequency ripple must be treated separately from rf-ripple caused mainly by digital circuits.
3) Inductive coupling
   Primary source of ELF. Creates standing voltages. Voltages should not be allowed to be the origin of ELF-currents flowing in circuits or PCB's.
4) Filter attenuation (filters on supply lines, HV-lines, threshold distribution)
   Virtually no attenuation for ELF ripple or pickup. RF-ripple disappears.
5) Deviation of ELF currents to earth
   Should be avoided by all means
6) Artificial low impedance loops for ELF field cancellation
   Widely used in TV's, video monitors and power lines.
   Cancels greater part of ELF by creating an opposite field.

ALL CIRCUITs are exposed to ELF.

Induced voltages should not provoke currents.

Low Frequency Effects:

ELF is POWERFUL and cannot be screened. However, it may be deviated by ferromagnetic material.
ELF-currents are the consequence of induced ELF voltages across low impedance interconnections. Asymmetric design inevitably helps common-to-differential conversion.

ELF Recommendations:

Use either symmetric design or cut ELF path or reduce loop surface
Avoid base line shifting - it changes capacitances and hence coupling.

Large PCBs (and detectors) exposed to ELF fields must be designed for tolerating small ELF potential differences. Large PCB's that are supposed to have a single RF potential reference (which in itself is a contradiction - see also PCI bridges etc.) must be cut into smaller areas using capacitors between areas. Capacitors should be capable of providing low impedance RF-paths while effectiveley cutting ELF currents. Circuits for medium to high speed may want to use more than one capacitor per bridge in order to avoid the effect of capacitor internal resonances.