Laws and Standards II
EMC

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EMC - Electromagnatic compatibility

- The ability of electrical and electronic systems to operate without interfering with other systems (emission).
- The ability of such systems to operate as intended within a specified electromagnetic environment (immunity).

Examples on electromagnetic phenomena that may interfere

- Supply voltage interruptions, dips, surges and fluctuations
- Transient overvoltages on supply, signal and control lines
- Radio frequency fields, both pulsed (radar) and continuous, coupled directly into equipment or onto its connected cables
- Electrostatic discharge (ESD) from a charged object or person
- Low frequency magnetic or electric fields

Disturbances on the mains supply

- **Voltage variations**, 230 V ±10%.
- **Voltage fluctuations**, Ex: Starting a vacuum cleaner.
- **Voltage interruptions.** Faults on power distribution systems are normally clearedquickly and automatically but result in short voltage dips.
- **Waveform distorsion**, non-linear loads.
- **Transients and surges**, switching of inductive loads, lightning strikes.

Generic emission limits

Emission, generic

Residential, commercial and light industry EN 61000-6-3:2001			
	Frequency range	**Limit**	**Comment**
Complete apparatus	30 - 230 MHz 230 - 1000 MHz	30 dBuV/m (10 m) 37 dBuV/m (10 m)	EN 55022 class B
AC-power supply	0 - 2 kHz	flicker and harmonics	EN 61000-3-2,3
	0,15 - 0,5 MHz 0,5 - 5 MHz 5 - 30 MHz	66-56/56-46 dBuV 56/46 dBuV 60/50 dBuV	EN 55022 class B Quasi peak/average
	0,15 - 30 MHz	clicks	EN 55014

Industry EN 61000-6-4:2001			
	Frequency range	**Limit**	**Comment**
Complete apparatus	30 - 230 MHz 230 - 1000 MHz	40 dBuV/m (10 m) 47 dBuV/m (10 m)	EN 55011
AC-power supply	0 - 2 kHz	flicker and harmonics	EN 61000-3-2,3
	0,15 - 0,5 MHz 0,5 - 5 MHz 5 - 30 MHz	79/66 dBuV 73/60 dBuV 73/60 dBuV	EN 55011 Quasi peak/average
	0,15 - 30 MHz	clicks	EN 55014

Generic immunity limits

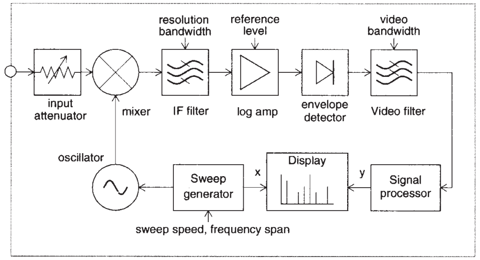
Immunity, generic

Residential, commercial and light industry EN 61000-6-1:2001			
	Phenomenon	**Test specification**	**Comment**
Complete apparatus	Electromagnetic RF-fields	80 - 1000 MHz 3 V/m	EN 61000-4-3
	Electrostatic discharge (ESD)	4 kV contact 8 kV airgap	EN61000-4-2
All cables and prot earth	Conducted RF	0,15 - 80 MHz 3V 1 kHz, 80% AM	EN61000-4-6
Signal and control cables	Fast transients	0,5 kV	EN61000-4-4
AC-power supply in/out	Fast transients	1 kV	EN61000-4-4
	Surge	1 resp. 2 kV	EN61000-4-5
	Voltage dips		EN61000-4-11
DC-power supply in/out	Fast transients	0,5 kV	EN61000-4-4
	Surge	0,5 kV	EN61000-4-5

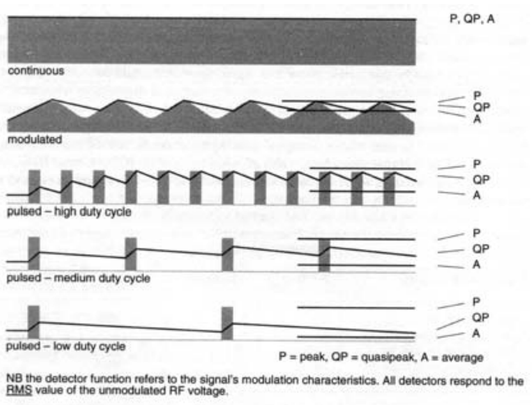
Industry EN 61000-6-2:2001			
	Phenomenon	**Test specification**	**Comment**
Complete apparatus	Electromagnetic RF-fields	80 - 1000 MHz 10 (3) V/m 1 kHz, 80% AM	EN 61000-4-3 Level varies with frequency
	Electrostatic discharge (ESD)	4 kV contact 8 kV airgap	EN61000-4-2
All cables and prot earth	Conducted RF	0,15 - 80 MHz 10 (3) V 1 kHz, 80% AM	EN61000-4-6 Level varies with frequency
Signal and control cables	Fast transients	1 kV	EN61000-4-4
	Surge	1 kV	EN61000-4-5
AC-power supply in/out	Fast transients	2 kV	EN61000-4-4
	Surge	1 resp. 2 kV	EN61000-4-5
	Voltage dips		EN61000-4-11
DC-power supply in/out	Fast transients	2 kV	EN61000-4-4
	Surge	0,5 kV	EN61000-4-5

Emission measurements

The spectrum analyzer

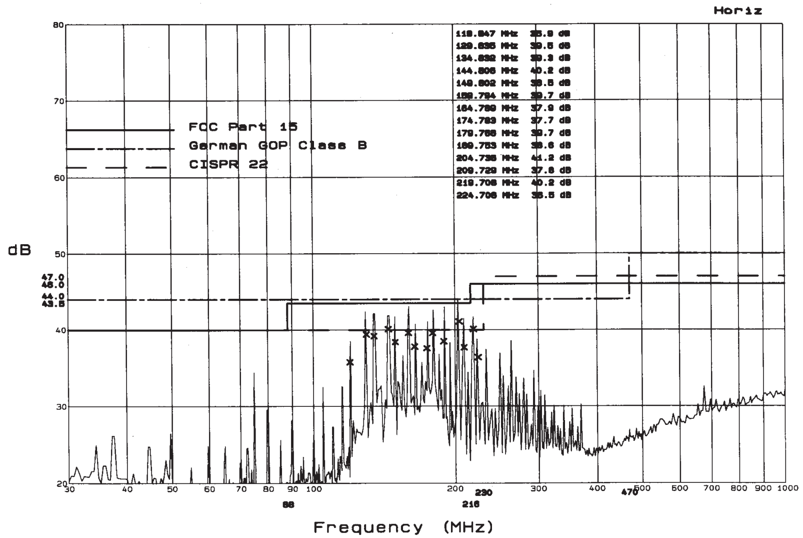


Quasi-peak, Peak and Average detector



Emission measurements

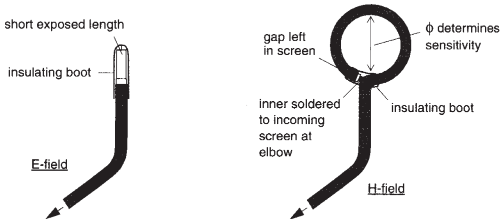
Readout



(b)

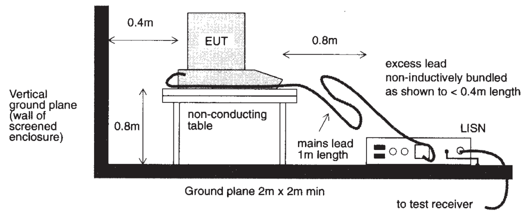
Emission measurements

Near field probes



Emission measurements

Conducted emissions



LISN - Line Impedance Stabilisation Network

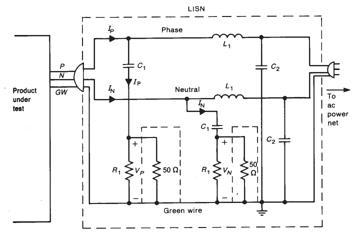
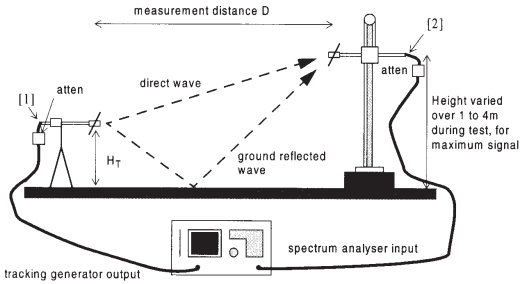


FIGURE 2.15 The line impedance stabilization network (LISN) for the measurement of conducted emissions.

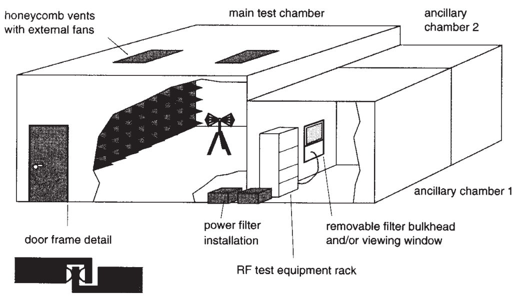
Emission measurements

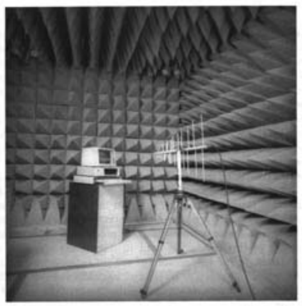
Radiated emissions

Open air measurements



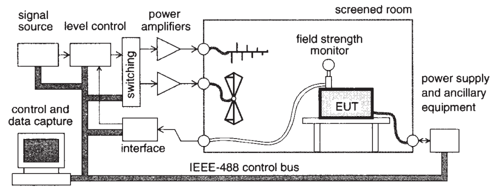
Shielded, attenuated test chamber



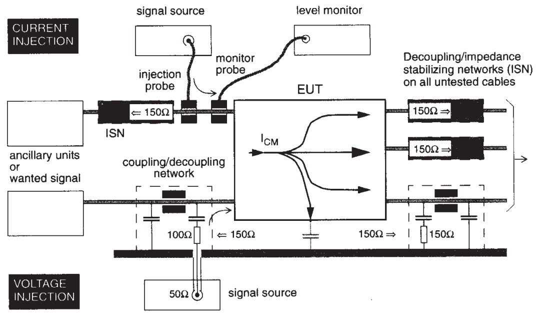


Immunity measurements

Radiated immunity

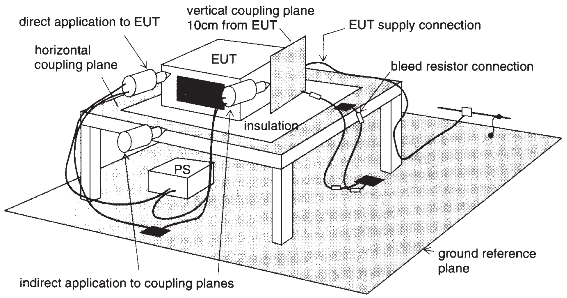


Conducted immunity

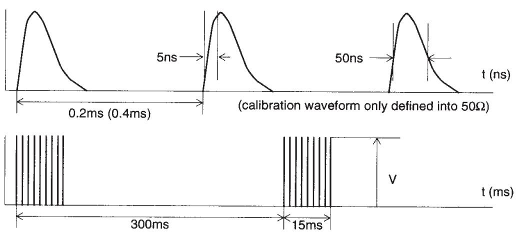


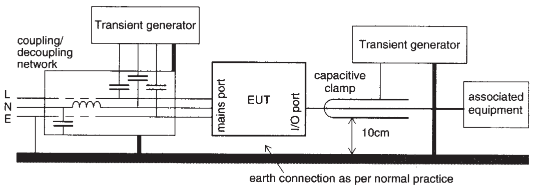
Immunity measurements

ESD



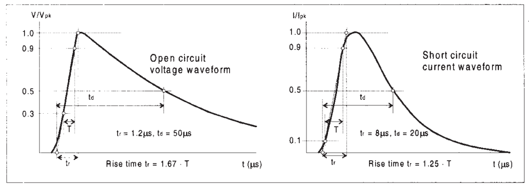
Fast transients

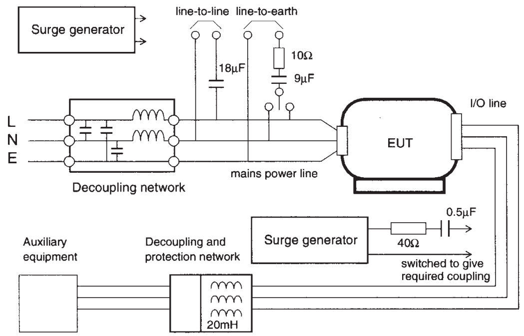




Immunity measurements

Surge





Coupling mechanisms

Coupling paths

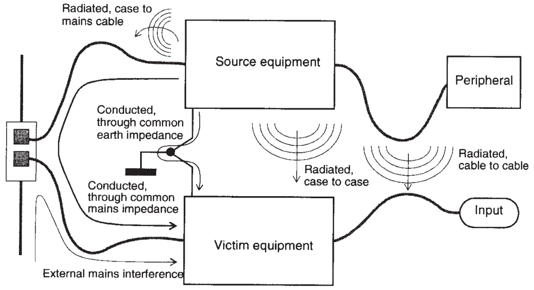
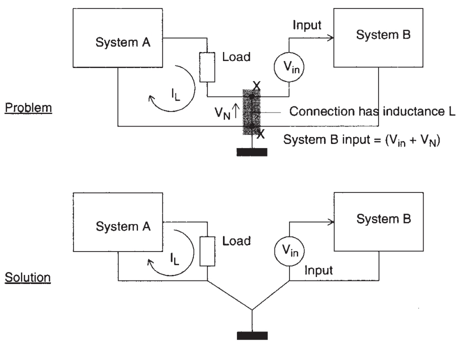


Figure 5.1 Coupling paths

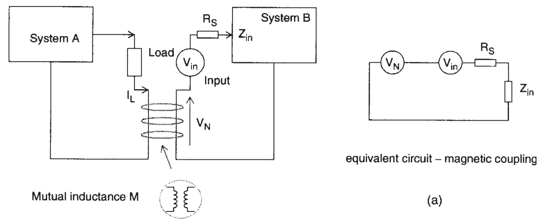
Common impedance coupling



$$V_N = -L \cdot dI_L/dt \; (+ R \cdot I_L)$$

Coupling mechanisms

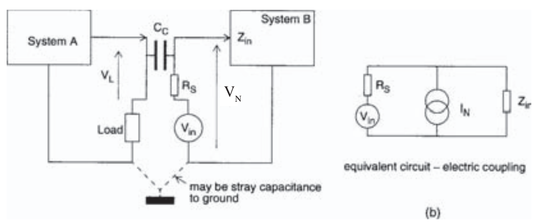
Inductive coupling



$$V_N = -M \cdot dI_L/dt$$

M - Mutual inductance

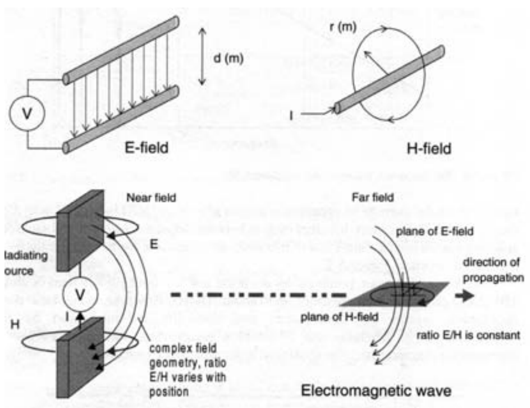
Capacitive coupling



$$V_N \approx C_C \cdot dV_L/dt \cdot Z_{in}//R_S$$

Coupling mechanisms

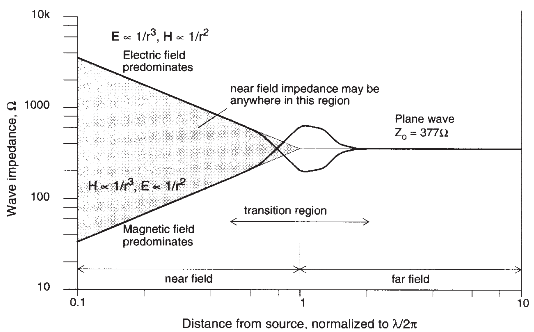
Radiated coupling



Wave impedance

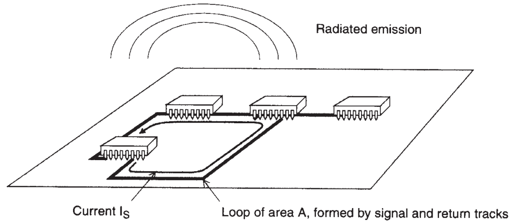
$$Z_W = E/H$$

$$Z_0 = (\mu_0/\varepsilon_0)^{0.5} = 120\pi \approx 377\Omega$$

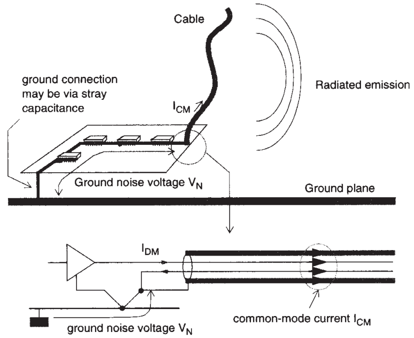


PCB radiation

Differential mode radiation

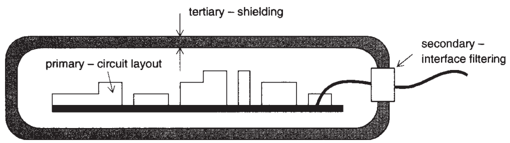


Common mode radiation

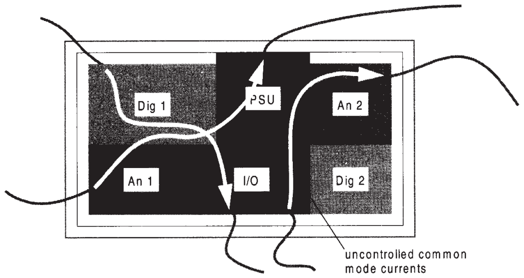


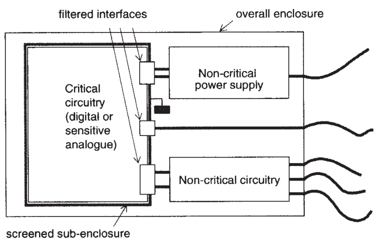
Layout and grounding

EMC control measures



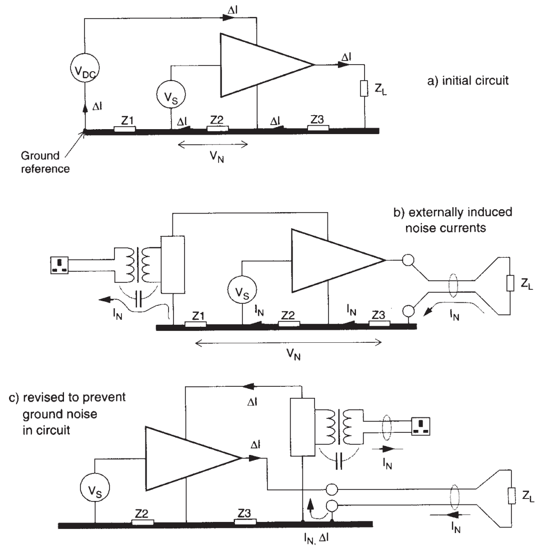
System partitioning





Layout and grounding

Grounding example

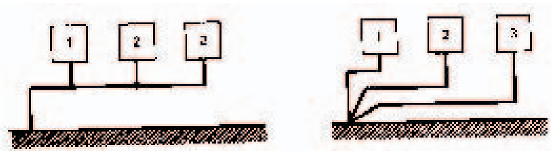


Layout and grounding

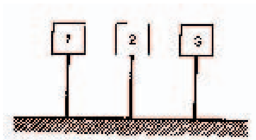
Signal ground

- **Low impedance** path for the return current

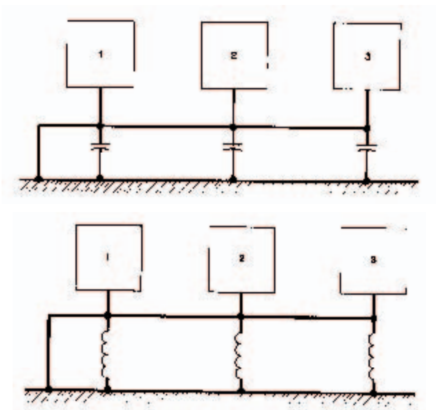
Single point ground, < 1 MHz



Multi point ground, > 10 MHz

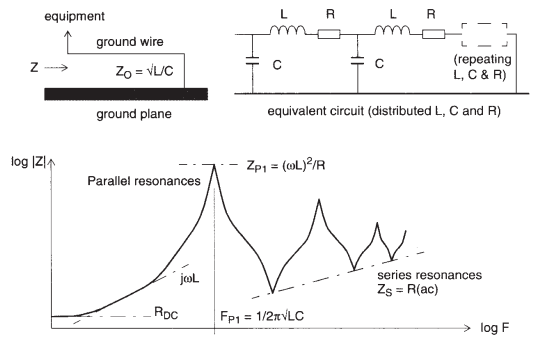


Hybrid ground



Layout and grounding

Impedance of long ground wires



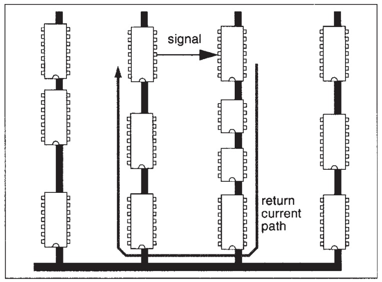
Grounding principles

- All conductors have a finite impedance which increases with frequency
- Two physically separate ground points are not at the same potential unless no current flows between them
- At high frequencies there is no such thing as a single point ground

Layout and grounding

PCB layout

Undesired comb structure



- High impedance return path (high inductance)
- Differential mode radiation!

Ground plane

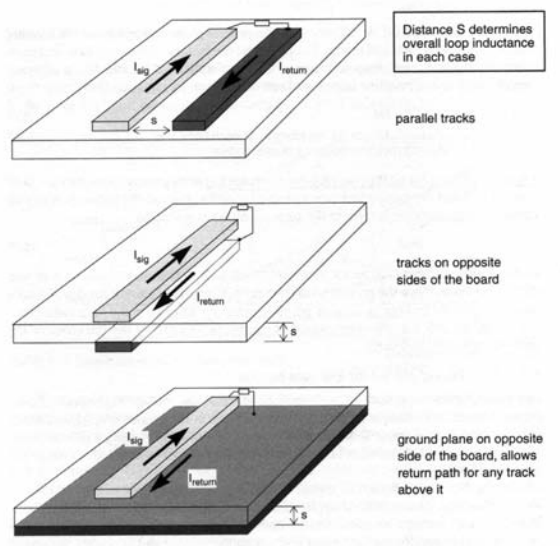
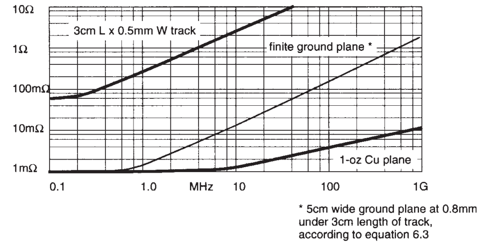


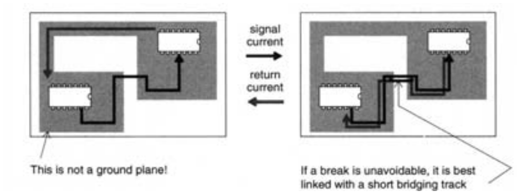
Figure 6.12 Return current paths

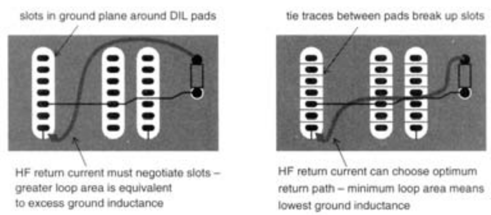
Layout and grounding

Ground plane - track impedance



Ground plane breaks





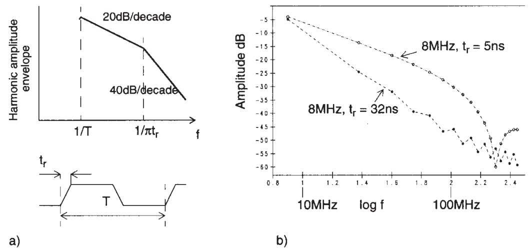
Layout and grounding

Grounding rules

- Identify the circuits of high di/dt (for emissions) - clocks, bus buffers/drivers, high-power oscillators
- Identify sensitive circuits (for susceptibility) - low-level analogue, fast digital data
- Minimize their ground inductance by -
  - Minimizing the length and enclosed area
  - Implementing a ground plane
  - Keeping critical circuits away from the edge of the plane
- Ensure that internal and external ground noise cannot couple out of or into the system: incorporate a clean interface ground
- Partition the syatem to control common mode current flow between sections
- Create, maintain and enforce a ground map

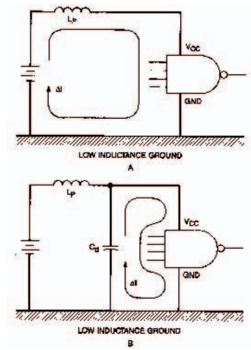
Digital circuits

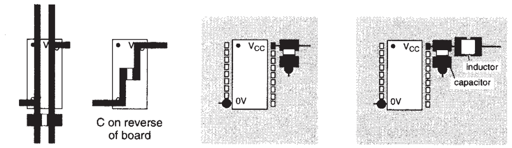
Pulse signal spectrum



- Do not choose faster logic circuits than necessary

Decoupling of supply voltage



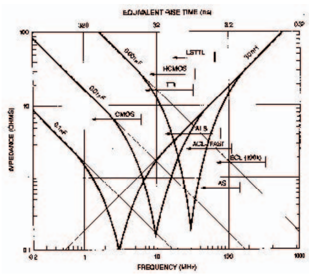


a) adequate b) improved c) on ground plane d) as c) with series L

Digital circuits

Decoupling capacitors

- Must be able to handle fast current transients
- Ceramic capacitor is normally suitable
- Resonance frequency!
- Do not use too large capacitors

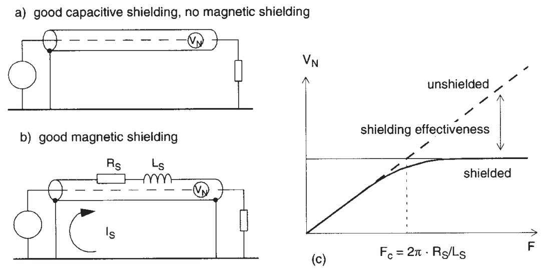


Decoupling recommendations, typical values

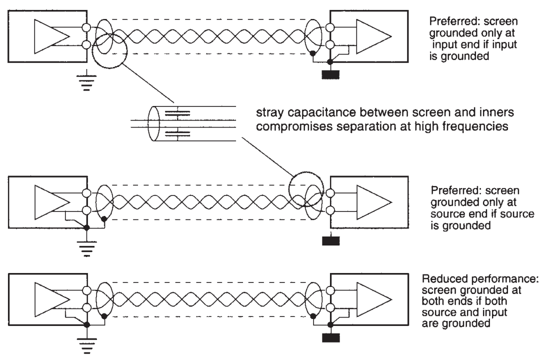
- One 22μF bulk capacitor (tantalum or electrolyte) per board at the power supply input
- One 1 μF tantalum capacitor per 10 packages of SSI/MSI logic or memory
- One 1 μF tantalum capacitor per 2-3 LSI packages
- One 22 nF ceramic or polyester capacitor for each octal bus buffer/driver IC or for each MSI/LSI package
- one 22 nF ceramic or polyester capacitor per 4 packages of SSI logic

Cable screens

Low frequencies - electric - magnetic field shielding

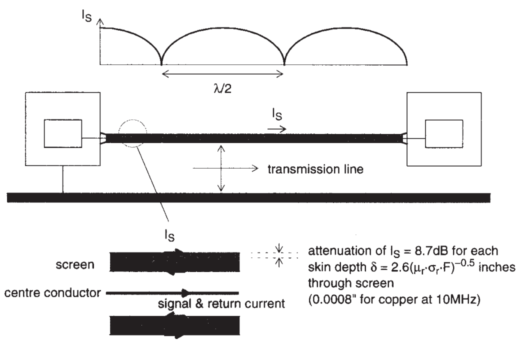


Grounding of cable screens at low frequencies

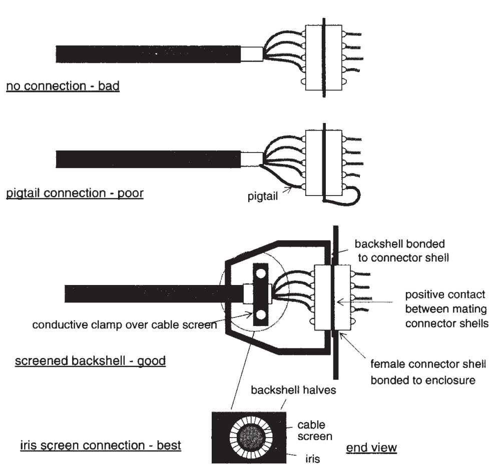


Cable screens

Cable screens at high frequencies

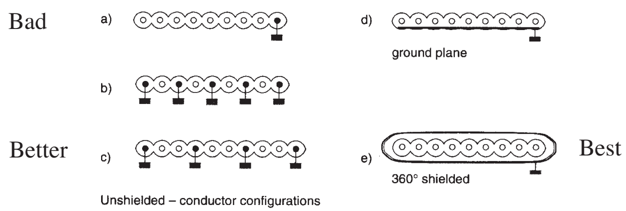


Goood and bad connections



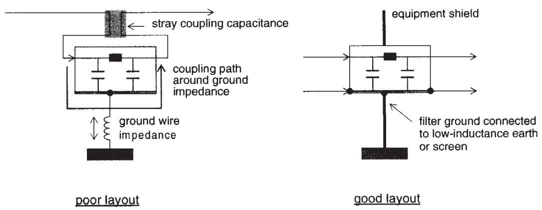
Cable screens

Ribbon cables

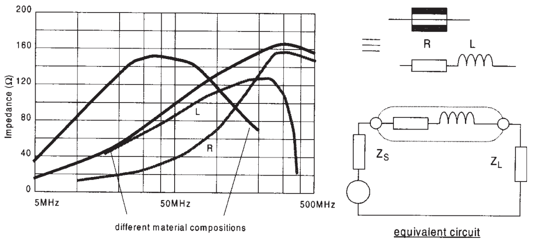


Filtering

Layout



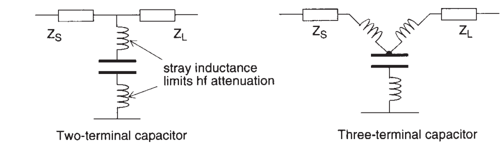
Ferrites



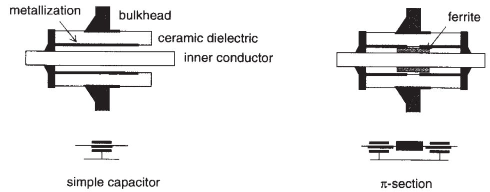
- Longer is better than thicker
- Get maximum amount of material in the chosen volume

Filtering

Three-terminal capacitor

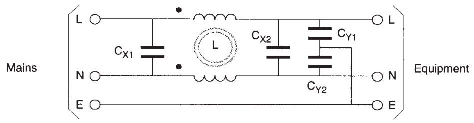


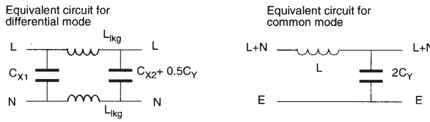
Feed-through capacitor



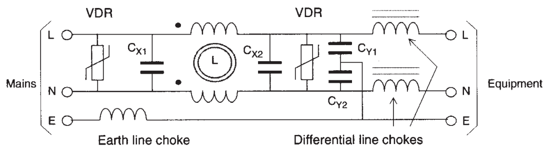
Filtering

Mains filter





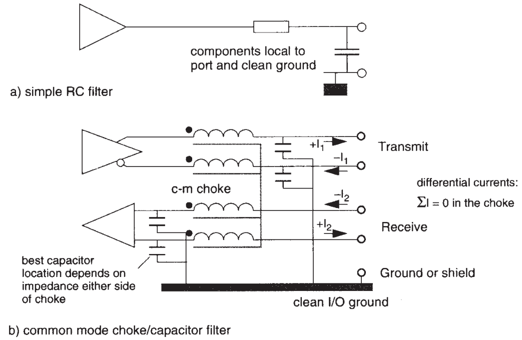
Improved mains filter



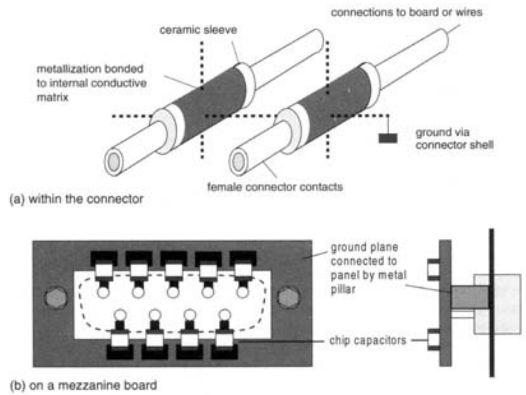
- VDR - Voltage Dependent Resistor - capture transients
- C_{X1} and C_{X2} 0.1 μF - 0.47 μF
- All components in the mains must comply to specific safety requirements.

Filtering

I/O filtering



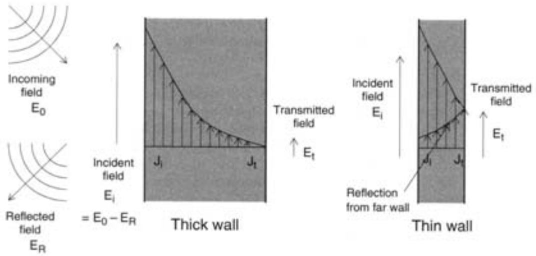
Connector pins

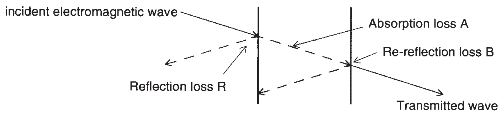


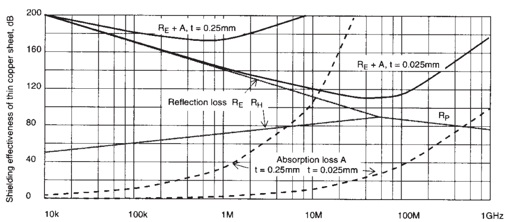
Shielding

Shielding effectiveness

- Conductive material, Cu, Al, ..
- SE (dB) = Reflection loss (dB) + Absorption loss (dB)
  (- korrection term for multiple reflections within shield, dB)





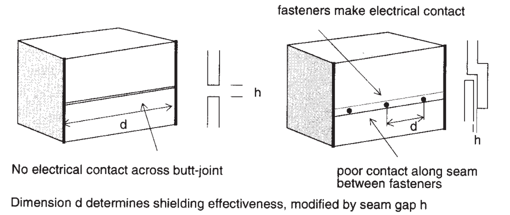


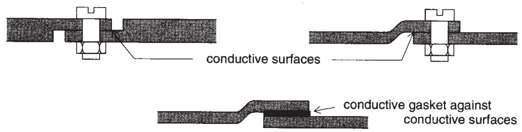
Remember!

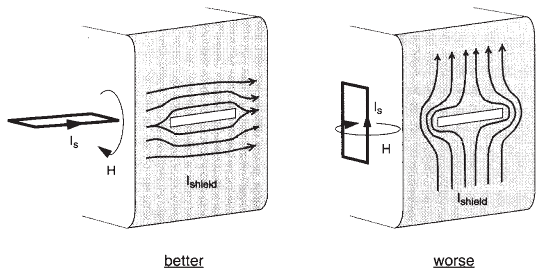
- Low frequency magnetic fields are impossible to shield with just a conductive material
- A high-permeability material like mu-metal may be used to protect from LF magnetic fields by concentrating them to the bulk of the material

Shielding

Joints and openings

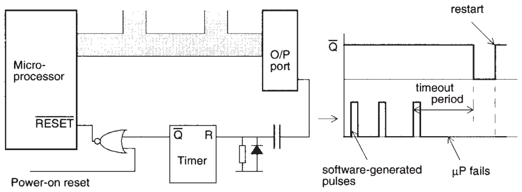




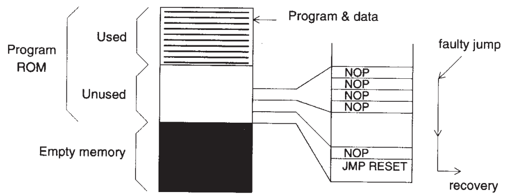


Software

Watchdog

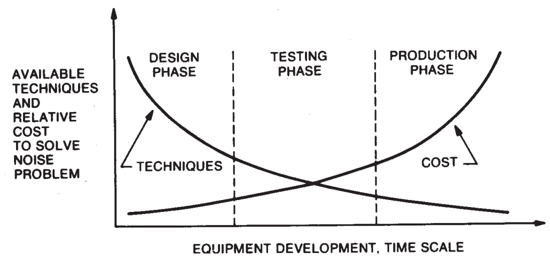


Unused memory



EMC management

When to start



Immediately!

Litterature

- Williams, Tim, EMC for product designers, Newnes 2001.
- Ott, Henry, Noise reduction techniques in electronic systems, Wiley 1988.