EMC

ELECTROMAGNETIC COMPATIBILITY

EUROTHERM CONTROLS

Installation guide

CONTENTS

Eurotherm Controls would like to acknowledge
the assistance of M. Alain Charoy of AEMC
in the preparation of this booklet.

1 - Electromagnetic compatibility

Definition:

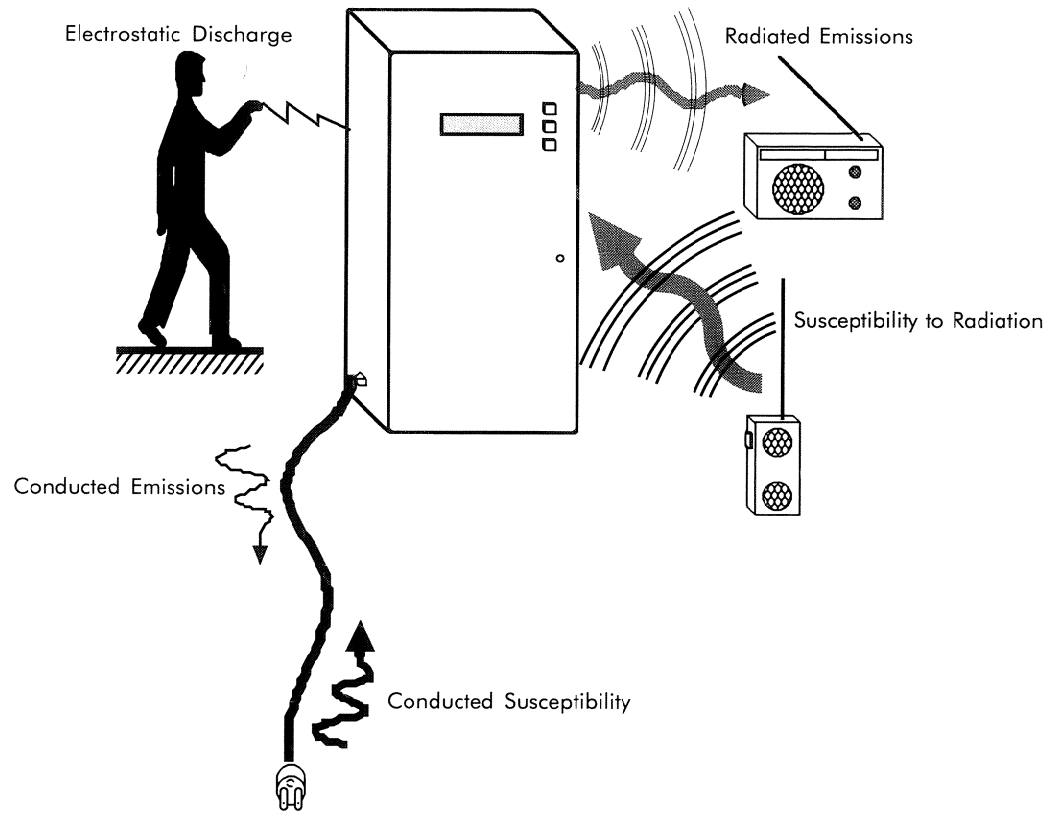
The ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment.

The magnitude of the electromagnetic susceptibility and generation may be qualified by the definition of different environments.

Electronic equipment can encounter two types of problem on site. Firstly equipment can generate interference in two ways, either conducted emissions or airborne emissions. Secondly it can be susceptible to airborne interference from neighbouring equipment and also susceptible to line borne interference from external sources.

This manual is intended to indicate best practice regarding the installation of Eurotherm Controls equipment to minimise potential EMC problems. The purpose of this document is not to give a theoretical view of EMC, but to give a practical guide on best wiring practice in order to limit electromagnetic interference. The main terms used in this manual are defined in an appendix.

The words 'earth' and 'ground' have tended in the English language to be used interchangeably. Thoughout this document, in the interests of clarity the word 'ground' has been used to indicate the metal body or bodies of a piece of equipment. Where safety considerations arise the term 'safety earth' has been used to describe a connection used for this purpose.



II - Earths and grounds

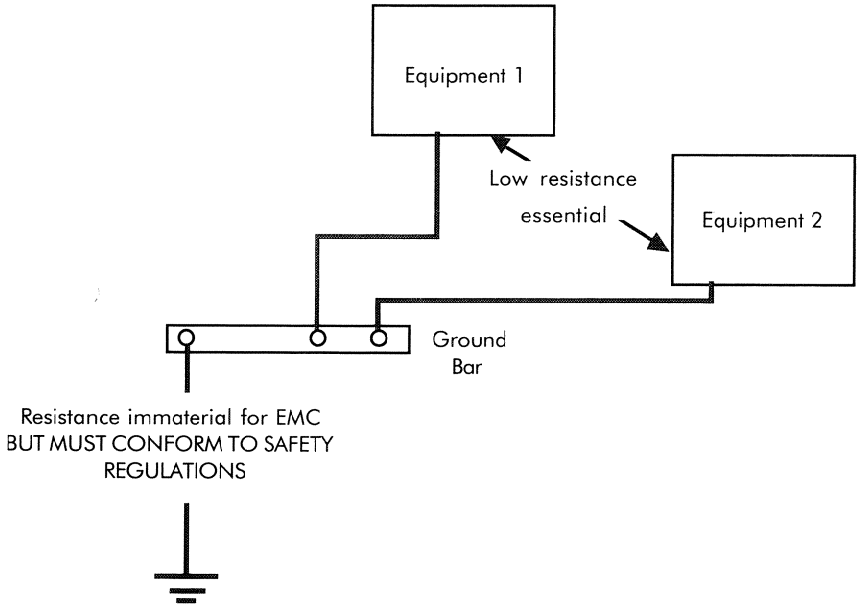
Increasingly, electronic equipment is being interconnected to form integrated systems. Satisfactory operation of the equipment depends directly on the potential difference between the ground references of the equipment.

The concept of equipotential is very important in EMC, and has to be effective over the entire frequency range covered by the regulations.

II - 1 Earthing

The quality of an earth connection is assessed by the resistance to a distant, true high quality earth connection.

From the EMC point of view the resistance of the earth connection is of little importance in comparison with ensuring that all parts of the equipment are at the same potential.



IMPORTANT NOTE

For safe operation of some equipment a good safety earth connection is mandatory.

II - 2 Grounding

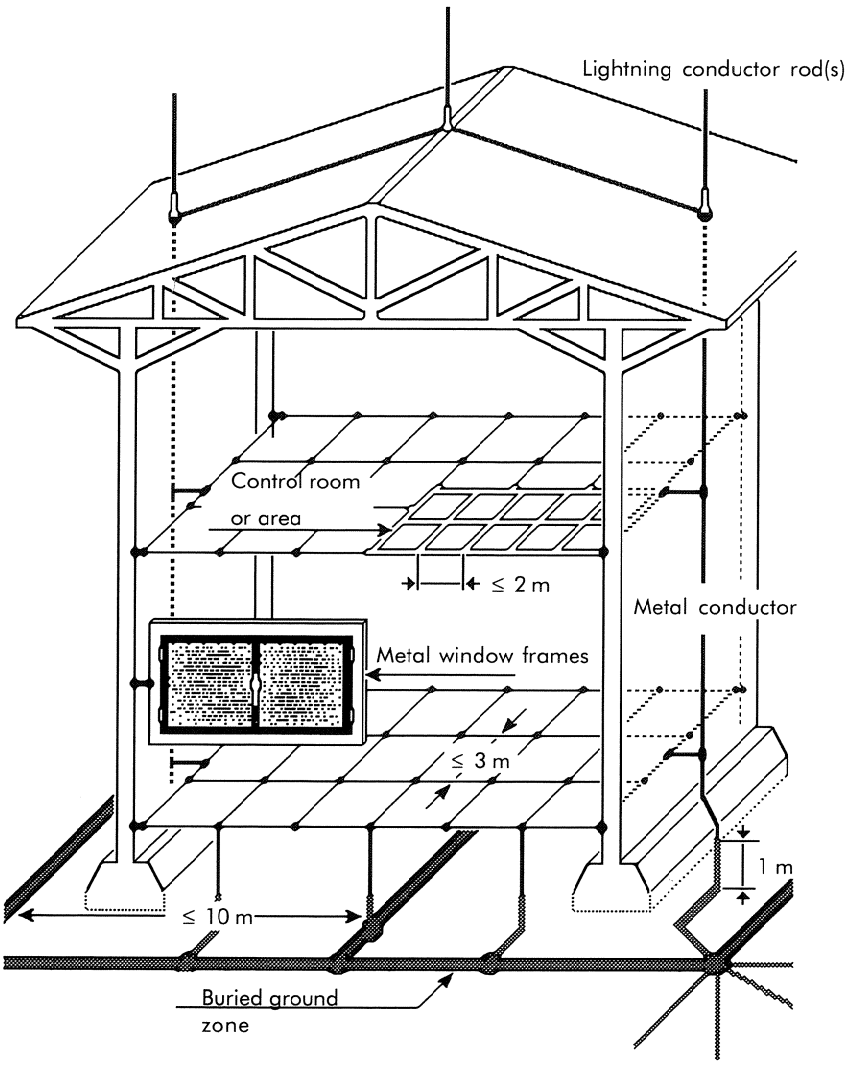
For satisfactory operation of electronic equipment it is essential that the grounds of each piece of equipment are at equipotential.

Pieces of equipment which are interconnected must have the ground connections joined.

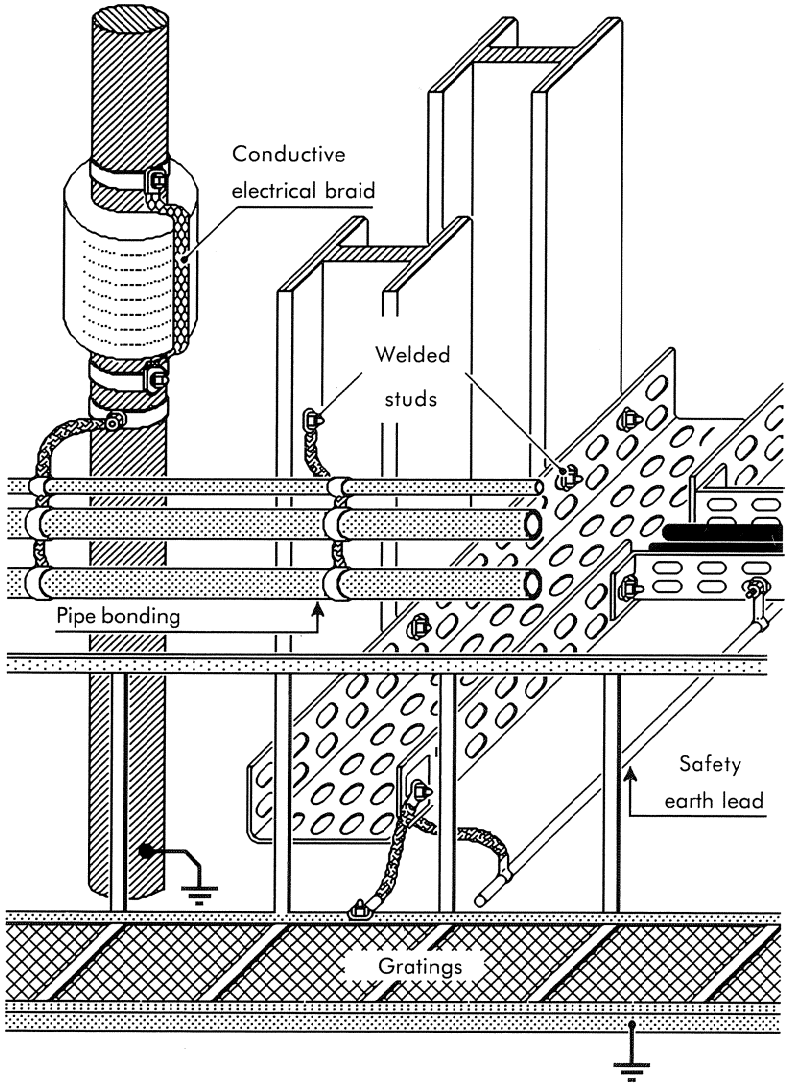
In practice it is difficult to achieve equipotential grounds since the wiring offers a high impedance at high frequency. The only practical solution is to minimise the potential differences on the site by forming a ground mesh between the central ground reference point and the associated equipment. Ideally any rectangle within the mesh should be 3m x 3m maximum.

Creating an effective mesh on a large site is both costly and difficult to do. To make it easier to install this mesh we can use the idea of 'islands'. An 'island' is a concentration of electronic equipment in one or more zones on the site. It is essential to have a ground mesh in these zones because there is a high concentration of equipment in these zones.

The rest of the site may have a larger mesh. For this local mesh to be effective all the 'islands' must be connected to minimise EMC problems.



In practice this mesh is achieved by interconnecting all of the metal parts of the installation.



III - Cable wiring

A number of precautions must be taken when routing cables. In practice, in the majority of cases, the root cause of electromagnetic disturbance is associated with the wiring.

III - 1 Wiring types

Cabling can be grouped into four categories :

- Category 1 : Analogue wiring
  All analogue connections including analogue input circuits
  These circuits are very susceptible

- Category 2 : Digital wiring
  Digital circuits and communication networks
  These circuits are also susceptible but in addition generate noise which can affect wiring circuits in category 1.

- Category 3 : Relay circuits
  Circuits containing arcing relay contacts which may affect other circuit operation
  These circuits generate noise which can affect categories 1 and 2.

- Category 4 : Mains wiring
  Mains wiring and power connections in general
  These circuits generate noise which can affect categories 1 and 2.

III - 2 Wiring rules

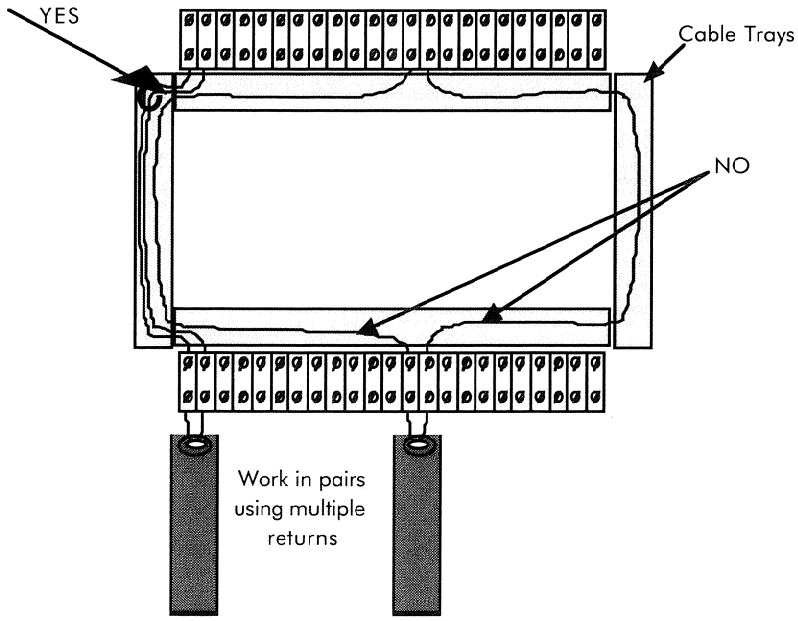
10 wiring rules must be observed

- Rule 1 :

  The outbound and returning cable must be routed side by side.

  For digital and analogue circuits the cables must always be routed in pairs.

  Pay careful attention when wiring cabinets which use separate cables. The wires must be grouped by signal type and in pairs.



- Rule 2 :

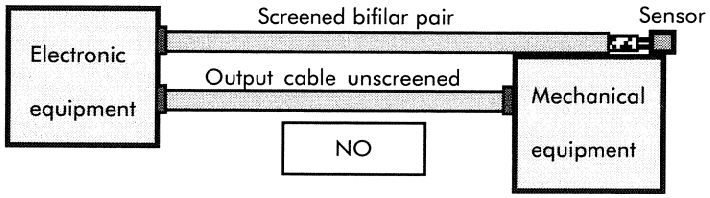
  All cables should be fitted closely against the metalwork in order to reduce high-frequency effects.

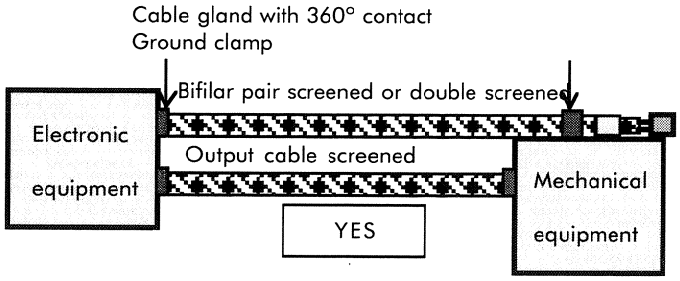
  The ideal solution is to use screened cables or double screened cables, containing individually screened pairs with an outer screen. This is a satisfactory practice in most cases.

  However, the careful routing of cables gives a satisfactory level of protection in most cases. As a minimum one would want the cables to be routed with a ground wire.

- Rule 3 :

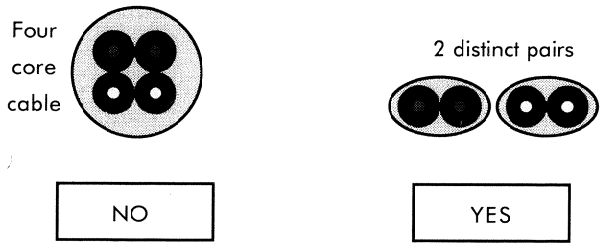
  It is desirable to double screen sensitive cables and noisy cables. This double screen would normally be grounded at both ends.

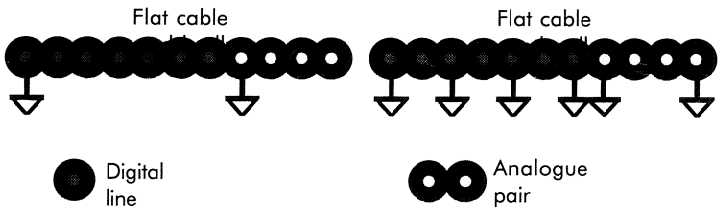




- Rule 4 :

  Only pairs of the same category should be put side by side in the same cable tray or in the same multiway cable with unscreened pairs.



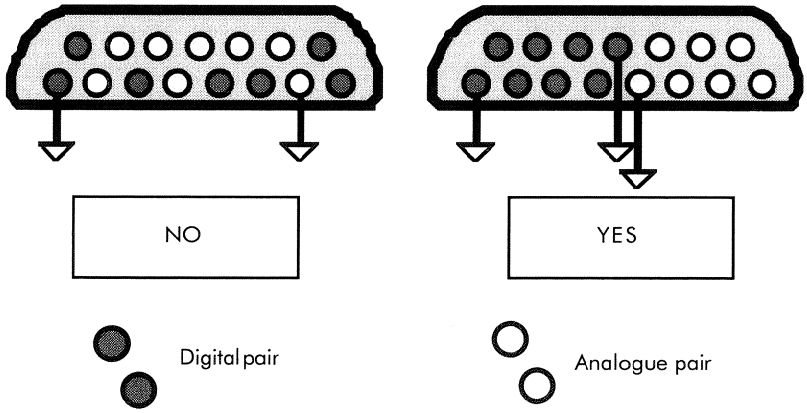


If possible, with flat ribbon cables a ground lead should be alternated with a signal lead in order to limit crosstalk.

- Rule 5 :

  It is not recommended to use the same connector for connecting different categories of cables. (Except categories 3 + 4 if this is the only way possible)

  If the same connector is used for categories 1 and 2, the end connections must be separated by pins connected to 0V.



- Rule 6 :

  All spare conductors in a multi-core cable of categories 2 (digital), 3 (relay), and 4 (power) must be grounded at both ends.

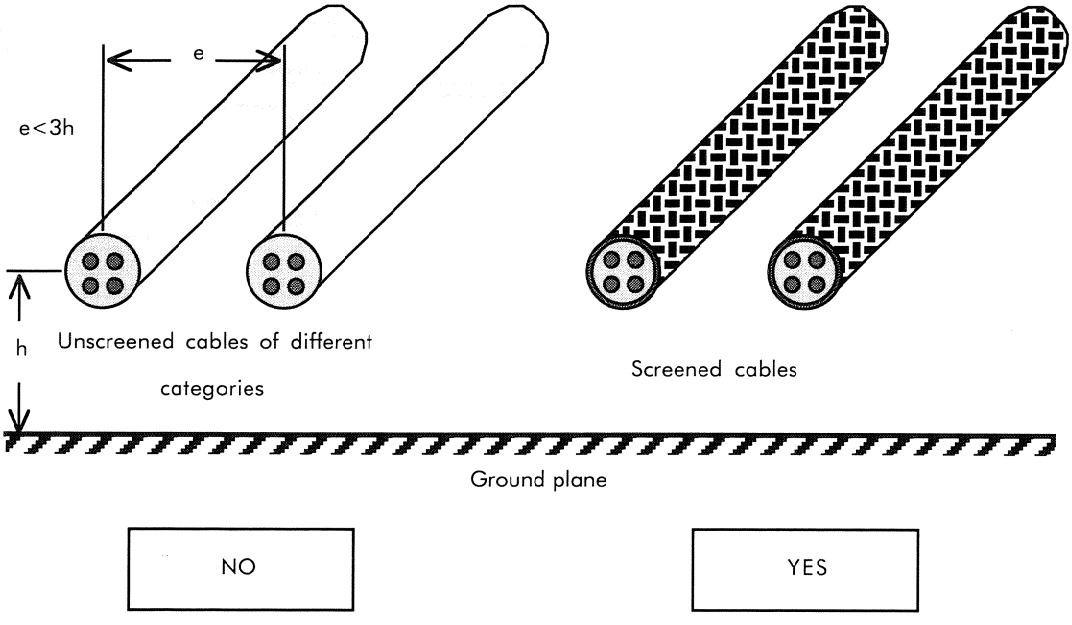
  This also reduces high frequency effects (see III-3).

- Rule 7 :

  Screened cables have reduced sensitivity to crosstalk.

  Screened cables can be used in close proximity. This is only true provided the screening is connected correctly.

  When the cables are not screened one should maintain a distance between the cables of at least 3 times the distance between the cables and the ground plane.



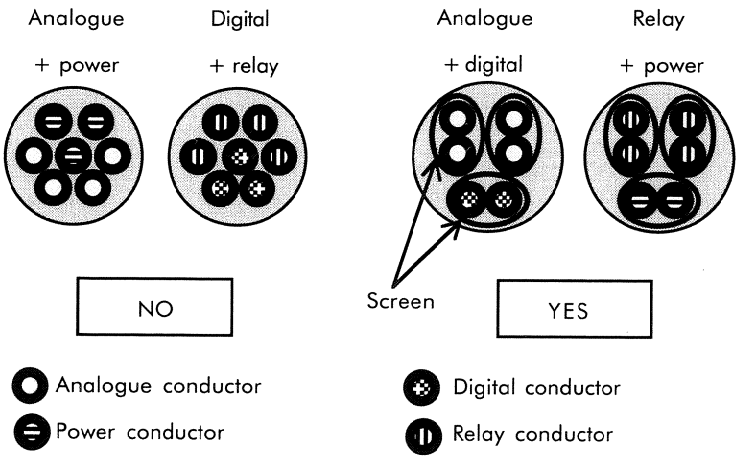
- Rule 8 :

  Keep interference generating cables (categories 3 and 4) away from susceptible cables (categories 1 and 2)

  Ideally a distance of 1 metre should be maintained but 30cms is usually sufficient if advantage is taken of the reduction obtained by mounting cables against metalwork (rule 2).

- Rule 9 :

  In a multi-core cable never put sensitive signal carrying cables (categories 1 and 2) with interfering cables (categories 3 and 4).



- Rule 10 :

  Cables in category 4 (power) don't need to be screened if they are fitted with filters.

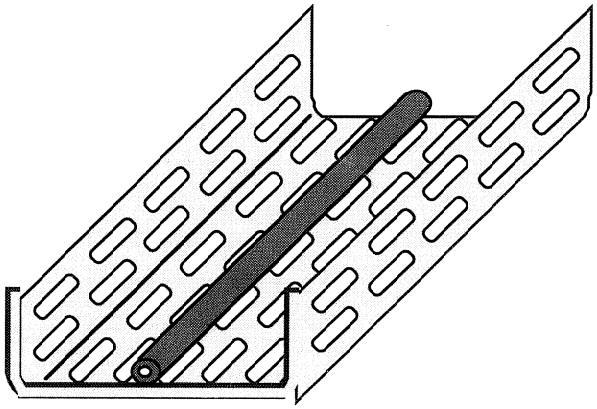
III - 3 Noise reduction

The method of approaching this is to use a wiring system which reduces coupling between cables. It is qualified by the ratio between the disturbance seen on protected cables and the disturbance seen on unprotected cables.

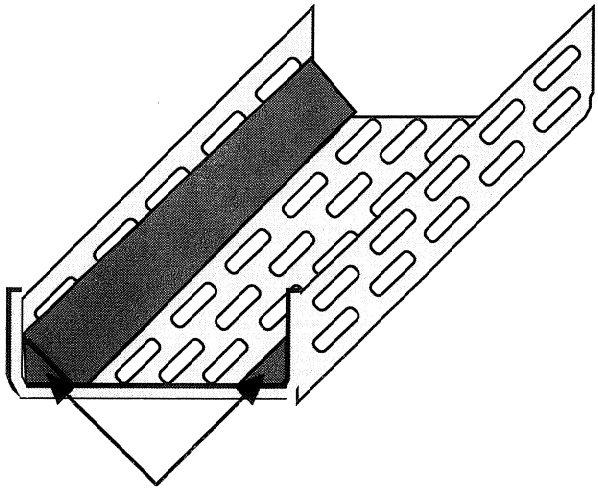
Every ground structure can bring about an improvement.

III - 3 - 1 Cable routing

Cable routing in a galvanised steel cable tray gives a 50 times improvement between 1 and 100 MHz



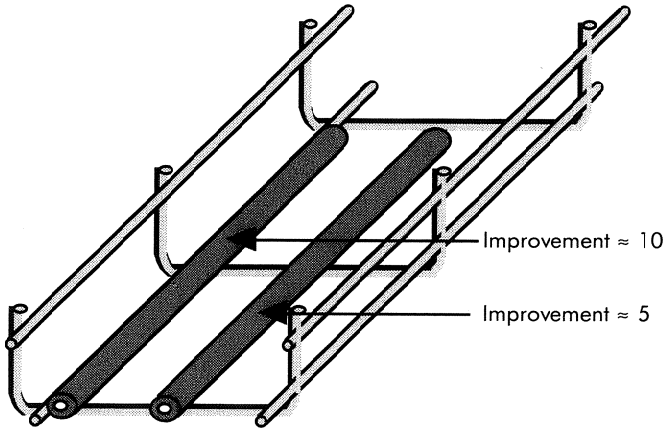
On the other hand, at the edge of a cable tray there is a 'shadow' zone.
When a susceptible cable is placed in this zone, it is protected from interference. By the principal of reciprocity an interfering cable placed in this zone will create less interference.

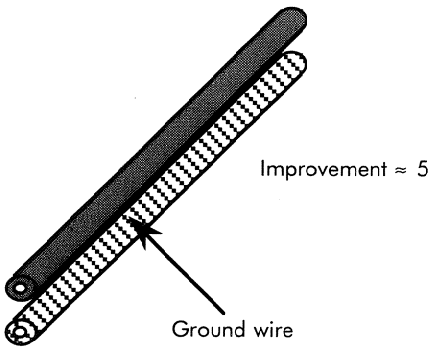


Protected area : • sensitive cables protected
• effect of interference limited

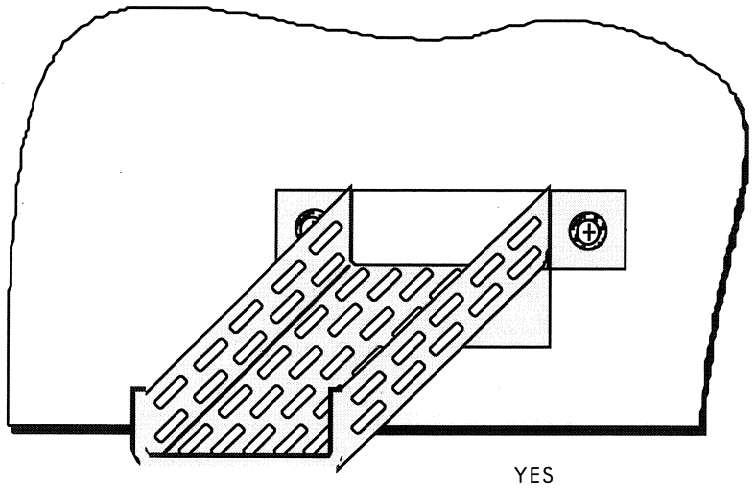
III - 3 - 2

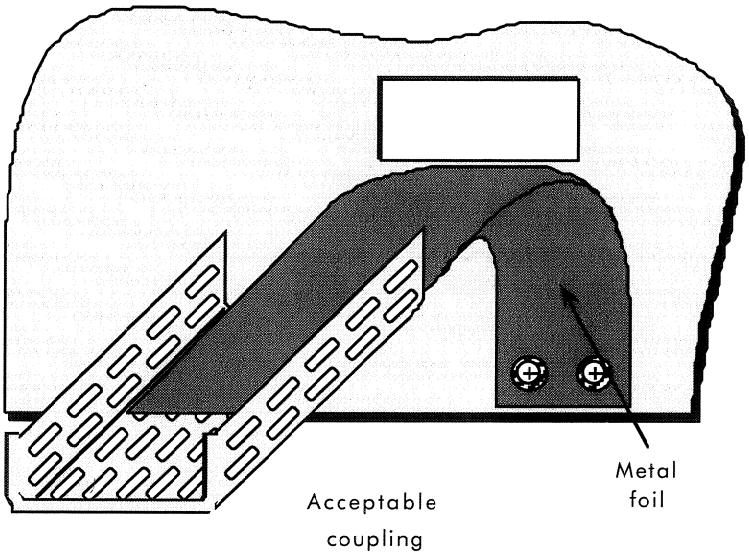
Alternative methods :

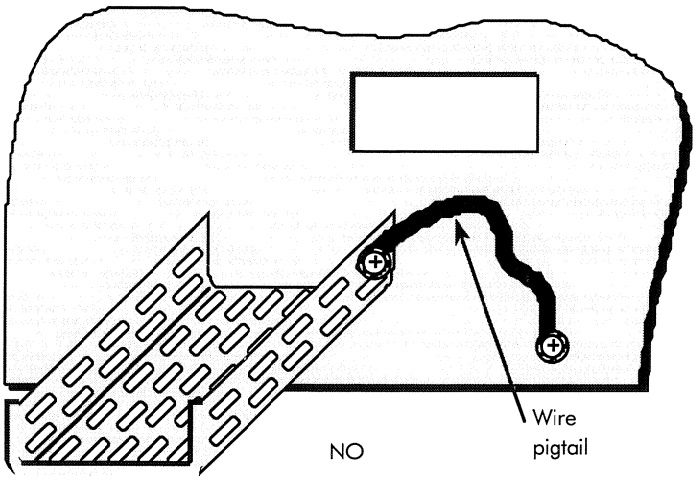




These improvements are only possible if both end points of the cable trays are connected to ground. To obtain the required results, the cable tray must have electrical continuity from end to end and be directly connected to the ground of the cabinet. One should make this coupling using a metal strap or foil since a thin ground wire 10cm long reduces the effectiveness by at the very least a factor of 5.


YES


Metal
foil
Acceptable
coupling


Wire
pigtail
NO

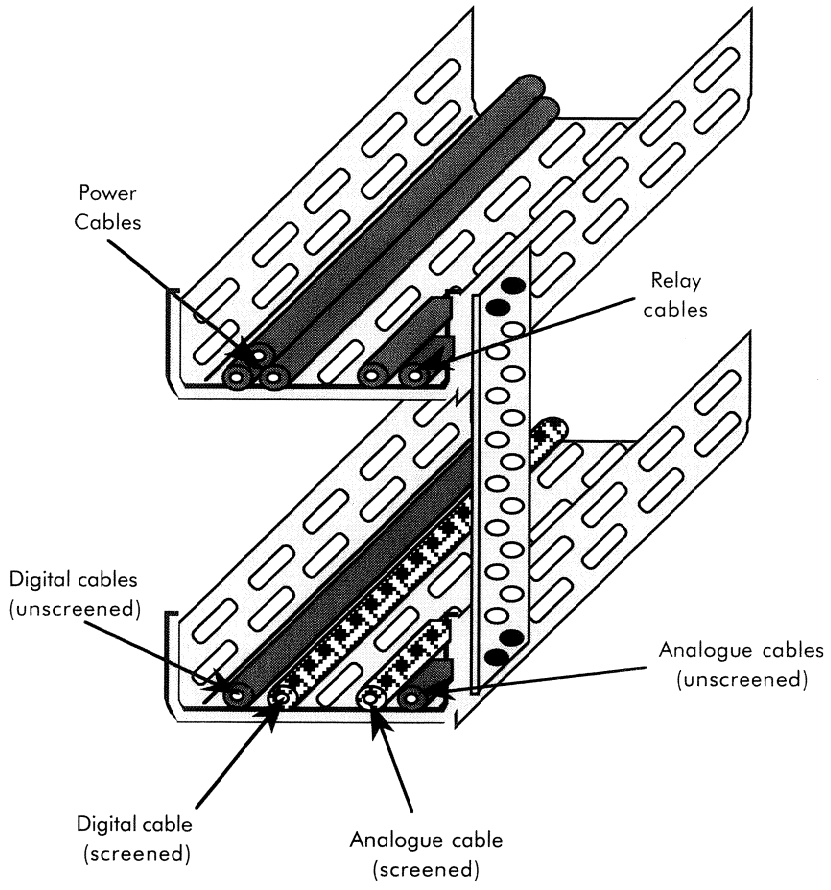
III - 4 Routing of the cables between cabinets

All cables should be routed in accordance with rule 2 sections III-2.

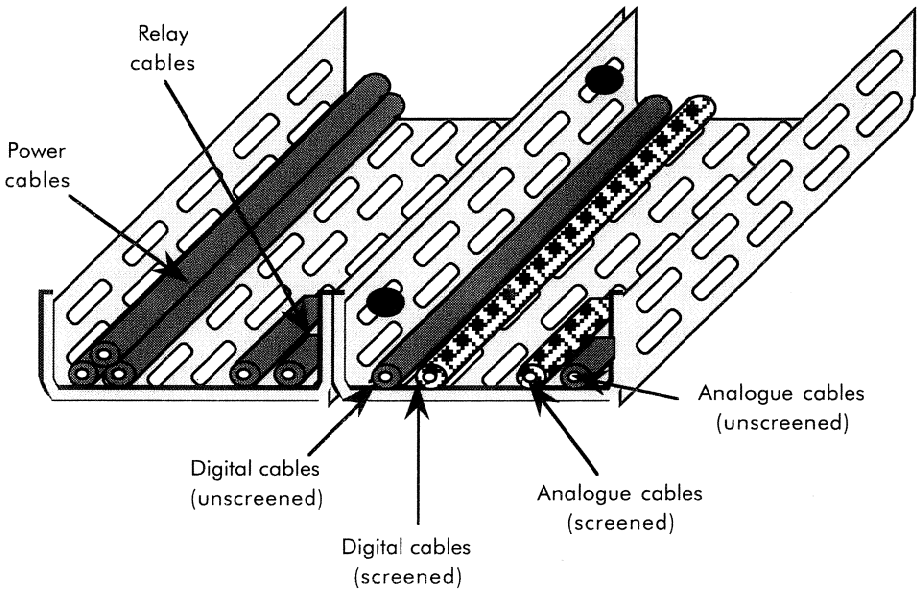
Cables should be routed between cabinets on metal cable trays where possible. In practice we recommended you use two cable trays, mounted one above the other, one for power and relay cables and the other one for analogue and digital signal cables.

If plastic cable trays have to be used then ground connecting cables must be included in each tray to link the cables together.

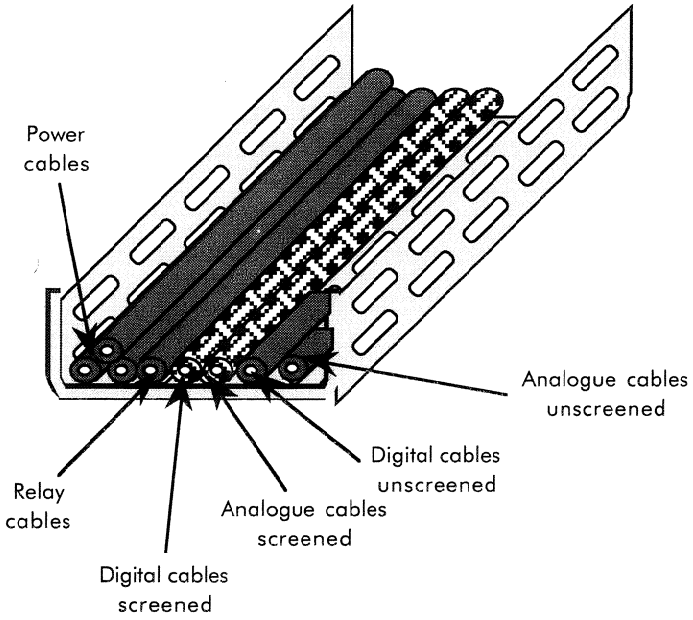
Do not overfill cable trays.



Another possible configuration :



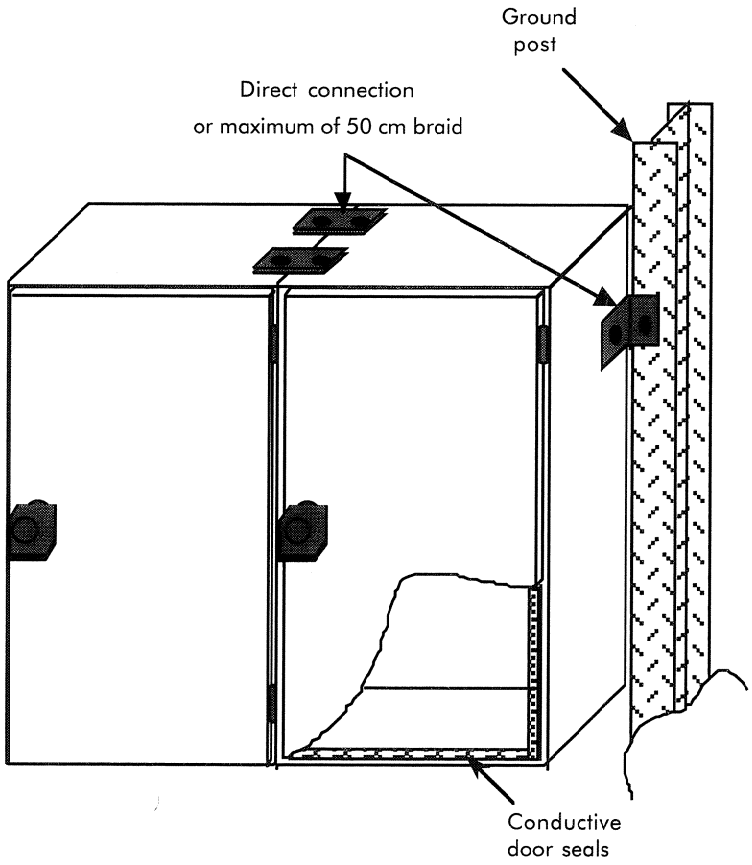
In the case when a single cable tray is used, the unscreened cables must be put in the 'shadow' area and screened cables in the centre of the tray.



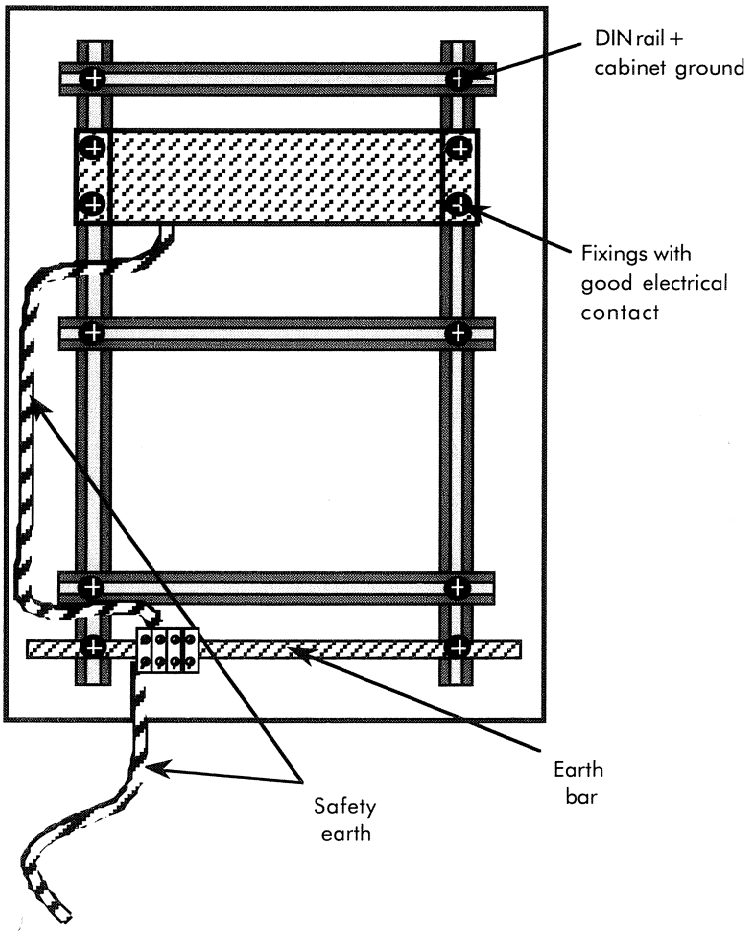
IV - Cabinet wiring

IV - 1 Grounding the cabinets

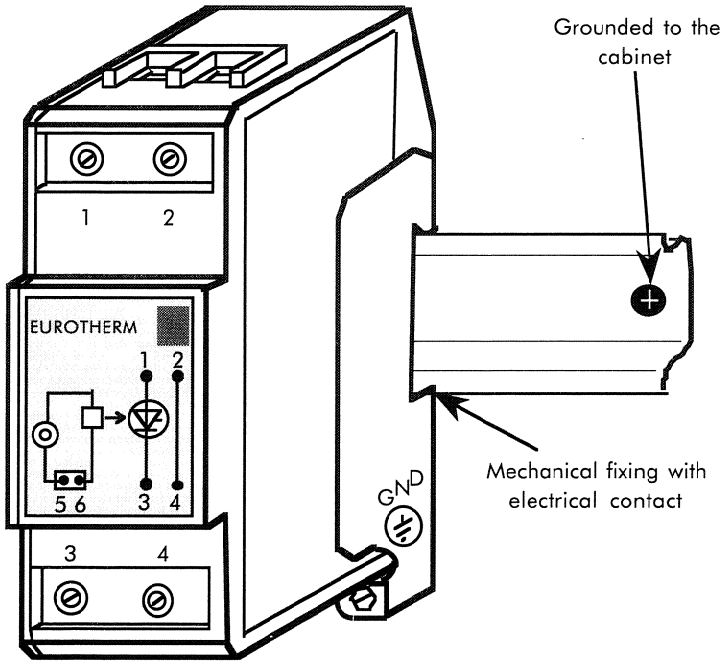
The problem is to maintain all cabinets at the same ground potential. To achieve this they must be connected to the same ground network.



Within the interior of the cabinet, creation of a ground mesh is achieved by interconnecting all metal parts.
The equipment must be connected to ground by the shortest possible wire (yellow/green) and directly to DIN rail or other cabinet metalwork.



Equipment mounted on a DIN rail will often be linked directly through the mechanical mounting. This should be checked.



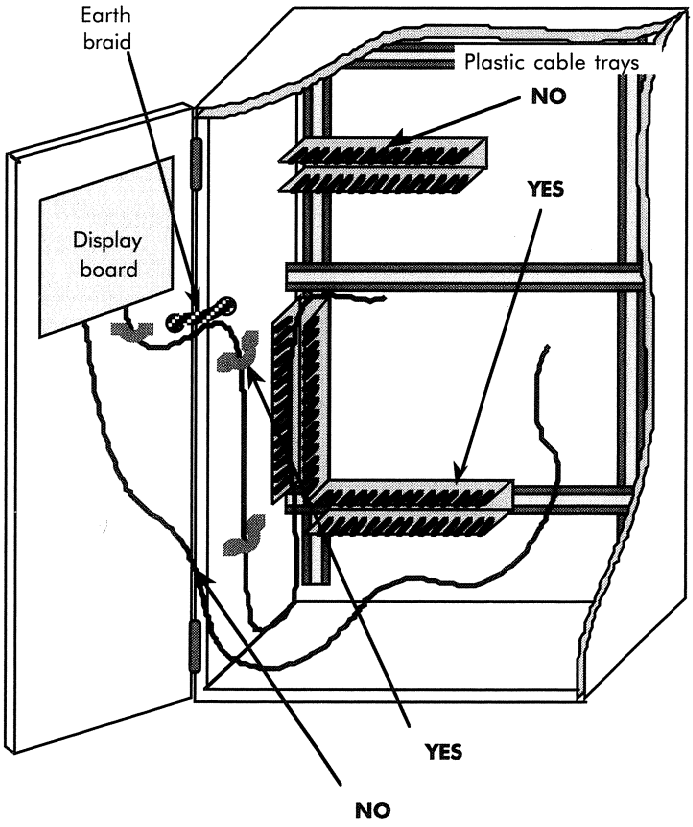
IV - 2 Internal cabinet wiring

The first choice would be systematically to place outbound and return wires next to each other. The simplest solution is to use a twisted pair. For large cables the position of the outbound and return conductors must be managed in such a way that they are routed closely together.

Use all the metalwork of the cabinet to best effect

For example:

- place plastic wiring trays close to the cabinet with or along DIN rails rather than in free space. The metalwork will then act as a ground shield.
- run power cables securely in the angles of the cabinet, reserving cable trays for signal cables.
- if a cable has to cover a joint, a door for example, then route it so that it lies close to the hinge, the bolts or any ground link which has been added for safety reasons.

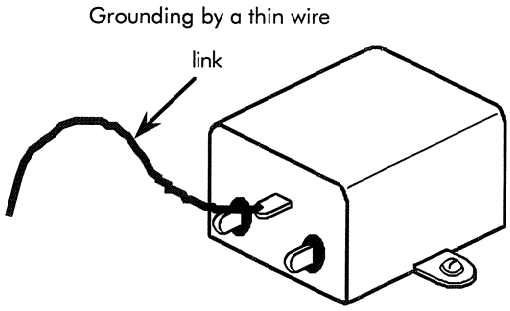


IV - 3 Filtering

IV - 3 - 1 (Electrical) Filter units

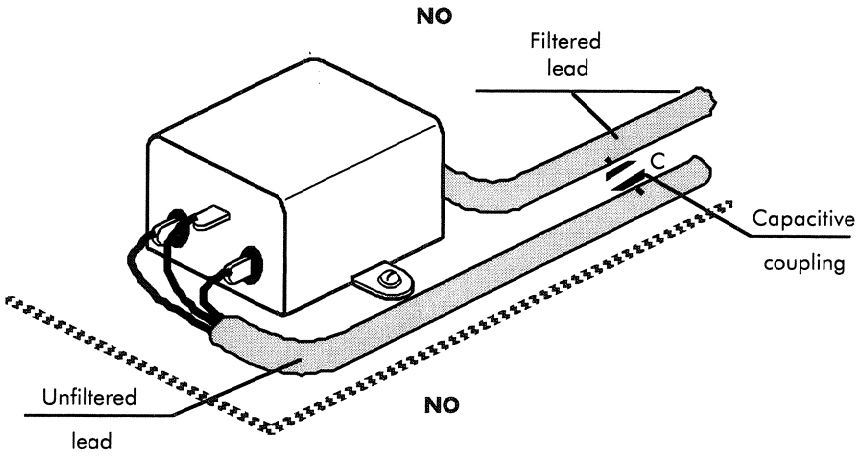
The efficiency of the filter at high frequencies is significantly affected by the way it is wired. Three things must be avoided when mounting and wiring a filter unit.

- Thin wire.

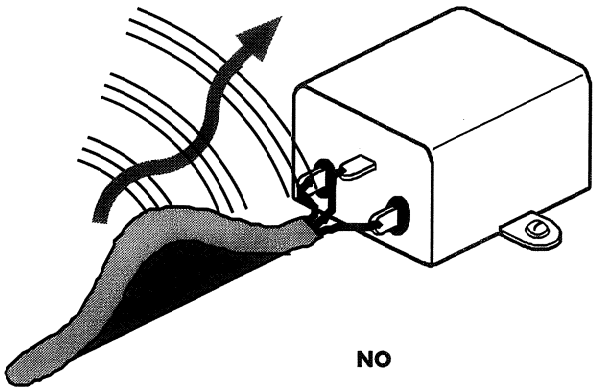


NO

- Crosstalk between the input and output cables - do not run the input and output cables in close proximity

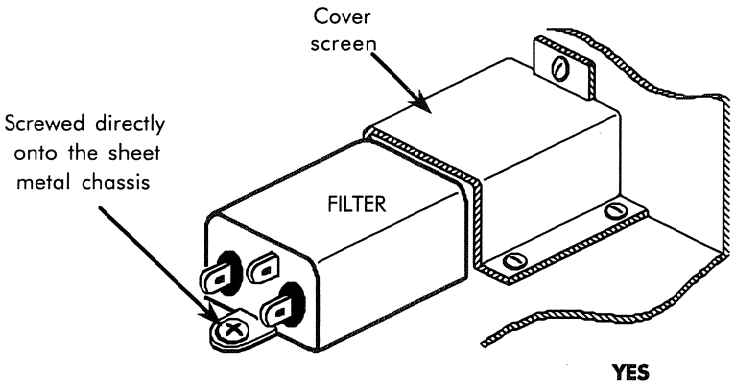


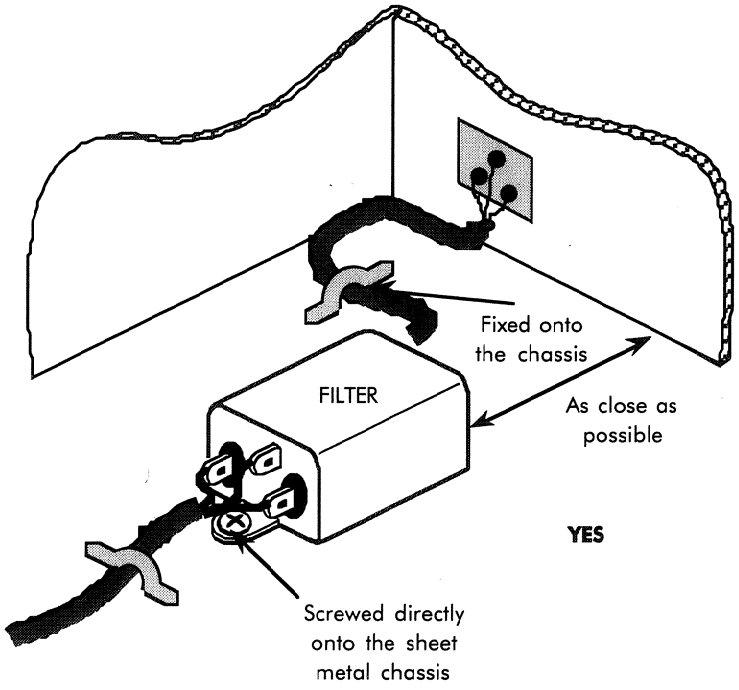
- Loose wiring- keep input and output cables close against the metal chassis in order to prevent them picking up airborne interference



NO

Different ways of mounting the filter units :



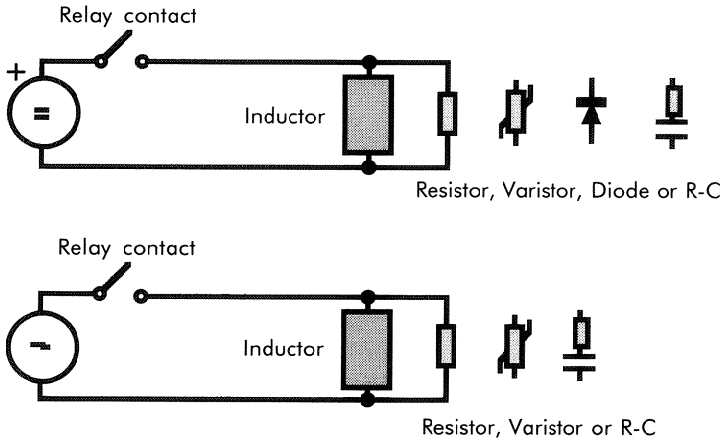


IV - 3 - 2 Relay output

All the circuits associated with relay contacts are a source of noise. When the contact opens fast transients (5ns) appear at the contact points. The noise is carried on both cables associated with the contact and can generate interference by causing crosstalk with neighbouring cables. One should therefore not route these cables with measurement or signal cables.

These conductors should be placed with the power cables.

To limit the risk of interference from these contacts a snubber network should be fitted across the coil of the contactor.



V - Screened cables

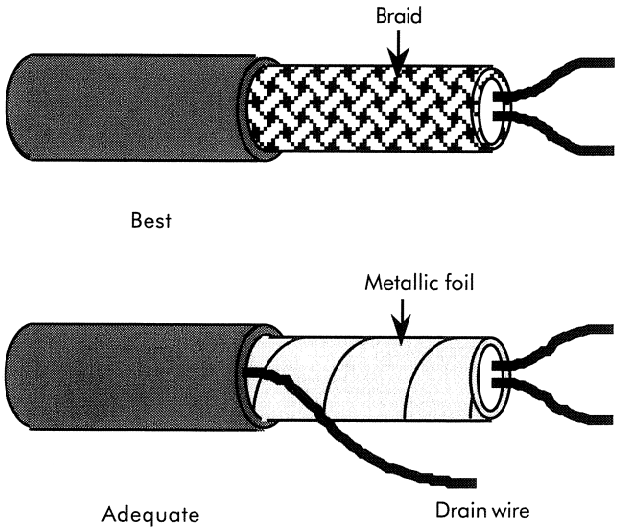
Three questions must be asked when using screened cables :

- What type of cable ?
- How should it be connected ?
- Which end of the screen should be connected ?

VI - 1 Choice of cables

The problem with copper foil screened cables is fragility. Its screening performance is also degraded by mechanical distortion such as tension, and bending.

Cable which has a braided screen is no doubt the best solution for industrial application. The effectiveness of the screen goes up to several hundred MHz. The effectiveness of the screen from a few MHz can reach several hundred MHz if the screen is well terminated. This flexible and robust screen is simple to use and is compatible with 'D' and DIN connectors.



V - 2 How to wire it up ?

The connection to the cable screen is particularly important to ensure effective HF performance.

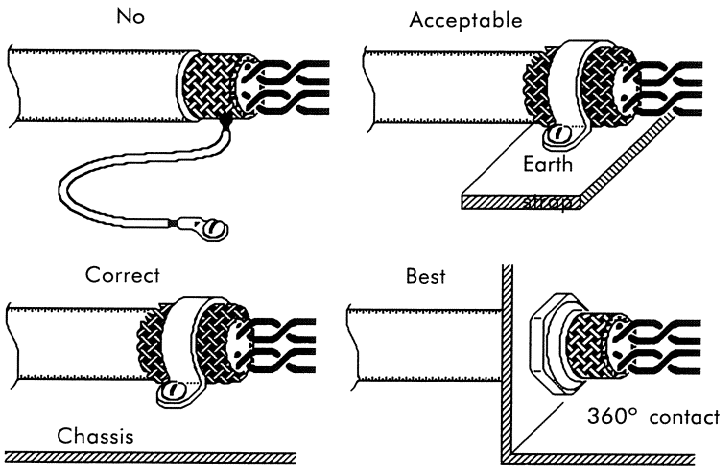
The screen must be wired directly to the input ground of the equipment.

The ground contact should always be effective over a full circumference of the cable around the termination.

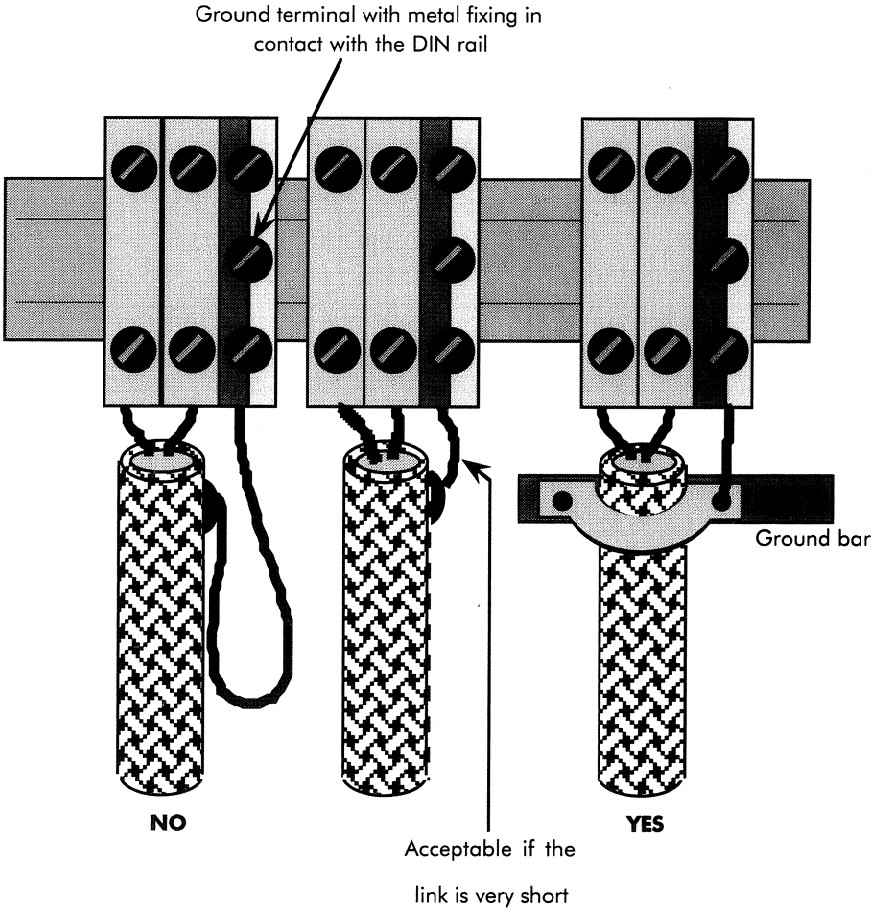
If this connection is made by using a pigtail, that is to say a wire, its high frequency effectiveness is dramatically reduced. The fixed connection should be made by a coupling gland.

In a certain number of cases one could tolerate a clamp which generates a contact in an area of at least 180°.

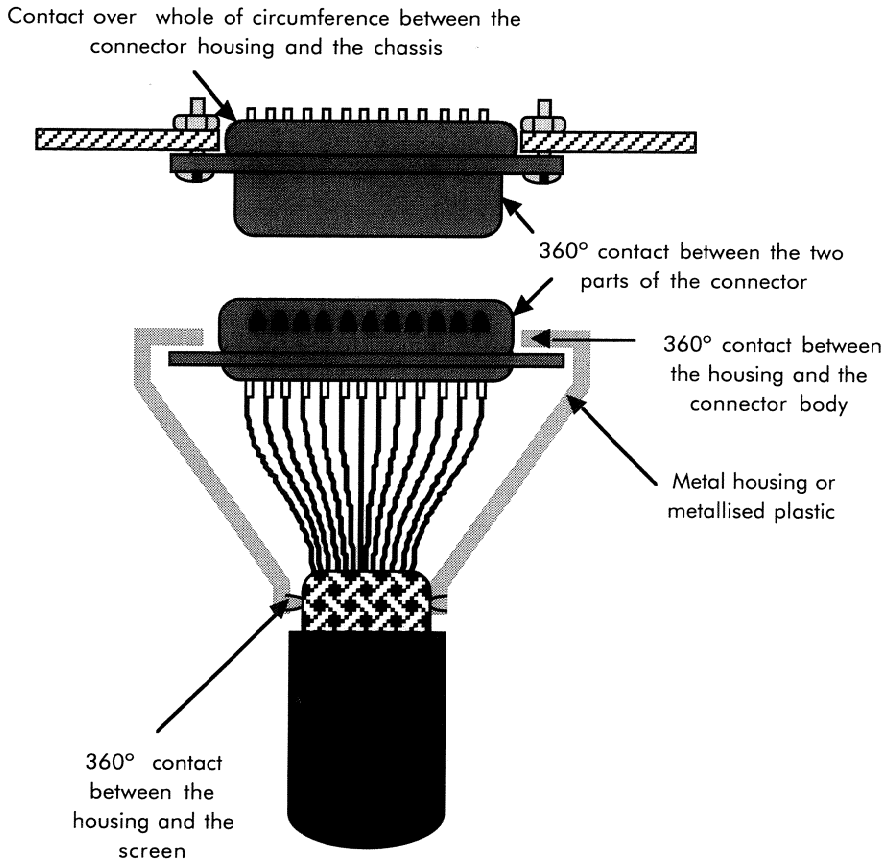
The use of a pigtail is to be avoided.



When connection is made by a screw connector block, the length of the pigtail must be minimised. This type of connection is preferably to be avoided.



In the case of wiring using a connector, the mechanical coupling of the connection must achieve continuity throughout its circumference between the screen of the cable and the case of the equipment.



V - 3 Which end to terminate the screen

- Terminating at one end

  Terminating the screen at one end stops low frequency currents circulating in the braid. The screen shields the low frequency electric field. Differential signals are therefore protected at low frequency. At high frequency this type of connection is less satisfactory as the effectiveness of the screening is reduced for frequencies above the resonant frequency of the cable.

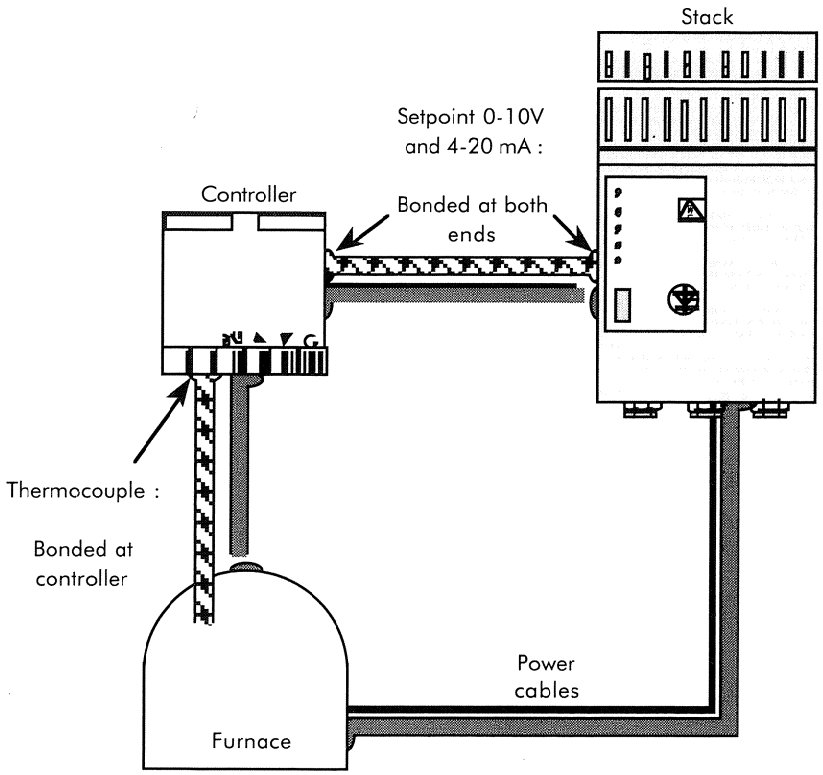
- Terminating at both ends

  Terminating at both ends of the screen gives protection against the most severe common mode interference. Even at the resonant frequency the improvement remains excellent. The problem is that at low frequencies a current can be generated in the screen as a result of magnetic fields within the area of the cable. These currents can crosstalk to the interior pair leading to interfering signals being superimposed onto the desired signal.

- The wiring of screened cables on Eurotherm Controls equipment should be done in the following way

  Power cables

  In the majority of cases power cables are not screened. They must be routed in protected areas to minimise EMC problems. A filter should be fitted on the power input and any auxiliary supplies.



Control signals and low level analogue signals

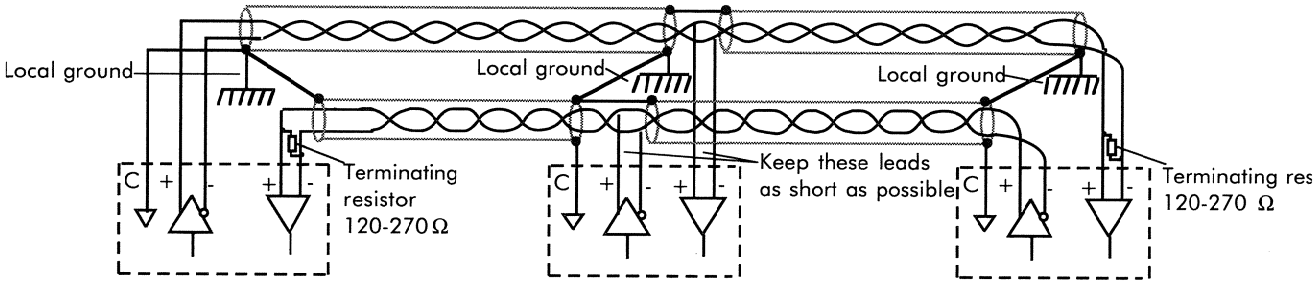
If control signals between controllers and thyristor stacks are analogue signals 0-10V or 4-20mA (category 1). The cables must be screened and the screening must be connected to the ground of the stack and the controller.

The thermocouple connections between furnaces and controllers are very susceptible (category 1). They must therefore be screened and routed with great care. The screening must not be wired to the ground of the controller.

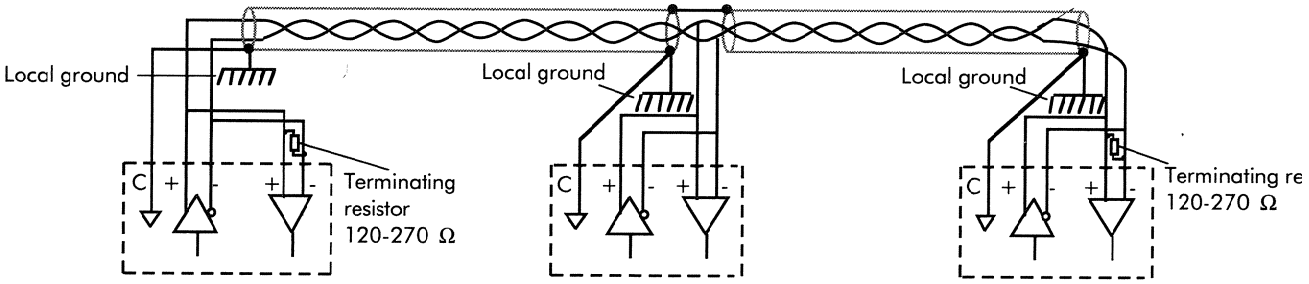
- Digital wiring.

  Certain equipment uses RS422 or RS485 communications. The wiring is screened and the screening should be connected to ground at both ends.

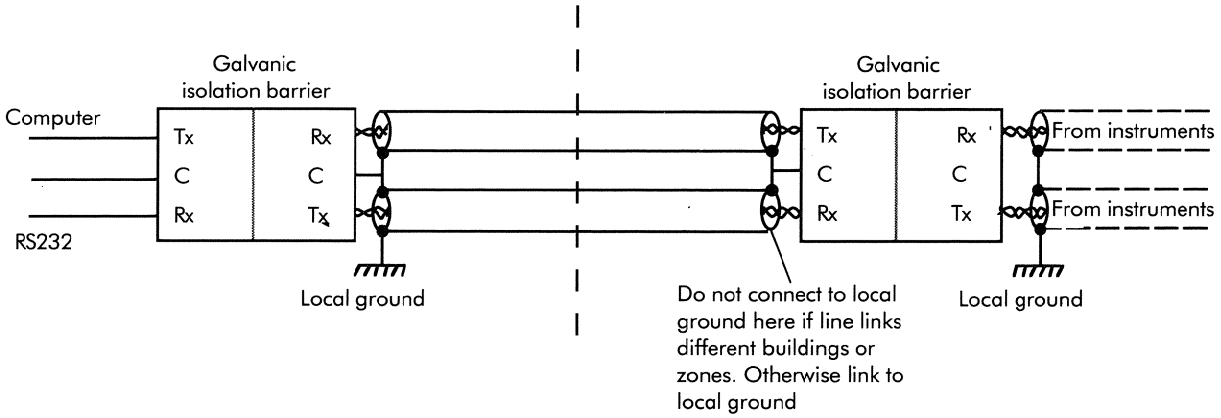
422



485



Long lines and computer 232-422 links



Use of isolating line drivers for long distance digital transmission has safety implications. If ends are located in this case break the ground connections at the isolators in the building or zone remote from the computer.

VI - Existing installations

The resolution of site problems can pose a number of difficulties. In practice it is very often difficult to reproduce the same effect.

VI - 1 IEC 1000-4-4/IEC 801-4/EN 61000-4-4 Testing

In case of persistent problems, one must carry out a technical analysis of the problem. In order to verify the correct functioning of equipment and the alteration achieved by the modifications made.

We recommend you use a site test following the method described in paragraph 7.3 of IEC1000-4-4. This test provides a quick way to see the majority of HF problems encountered on site, is quick and shows a true position. Equipment that does not comply with level 1 would suffer from problems on site. Level 3 must be achieved for satisfactory operation in the case of interference.

It allows one to reproduce the observed problems, also to quickly evaluate solutions that are being tried.

For more details about the way to conduct this test refer to the documents given in the heading.

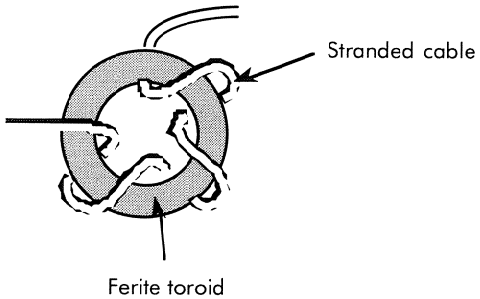
VI - 2 Use of ferrites

Once a cable has been identified as being susceptible then this is a simple way to add a filter at the installation, provided the current in the cable is small enough to avoid saturation of the ferrite ring.

Ferrite cores allow filtering of HF interference in the cables. These cores work in common mode on the cables, that is to say all the wires contained in the cable pass in the same sense through the core. This type of protection gives a reasonable improvement.

The effectiveness of this as a solution depends on the impedance which it offers to common-mode currents in the cables passing through it. This impedance is proportional to the square of the number of times the wire passes through the core. Two turns will increase the impedance 4 times, three turns 9 times etc.

On site it is easy to add this type of filter using split ferrite cores which allow installation without breaking into the lead. This is particularly advantageous if the equipment is in constant use, or cannot easily be rewired.

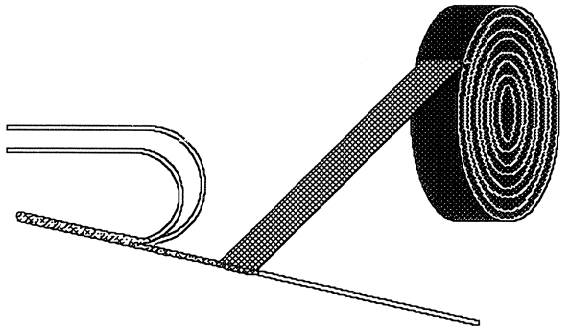


VI - 3 Other solutions

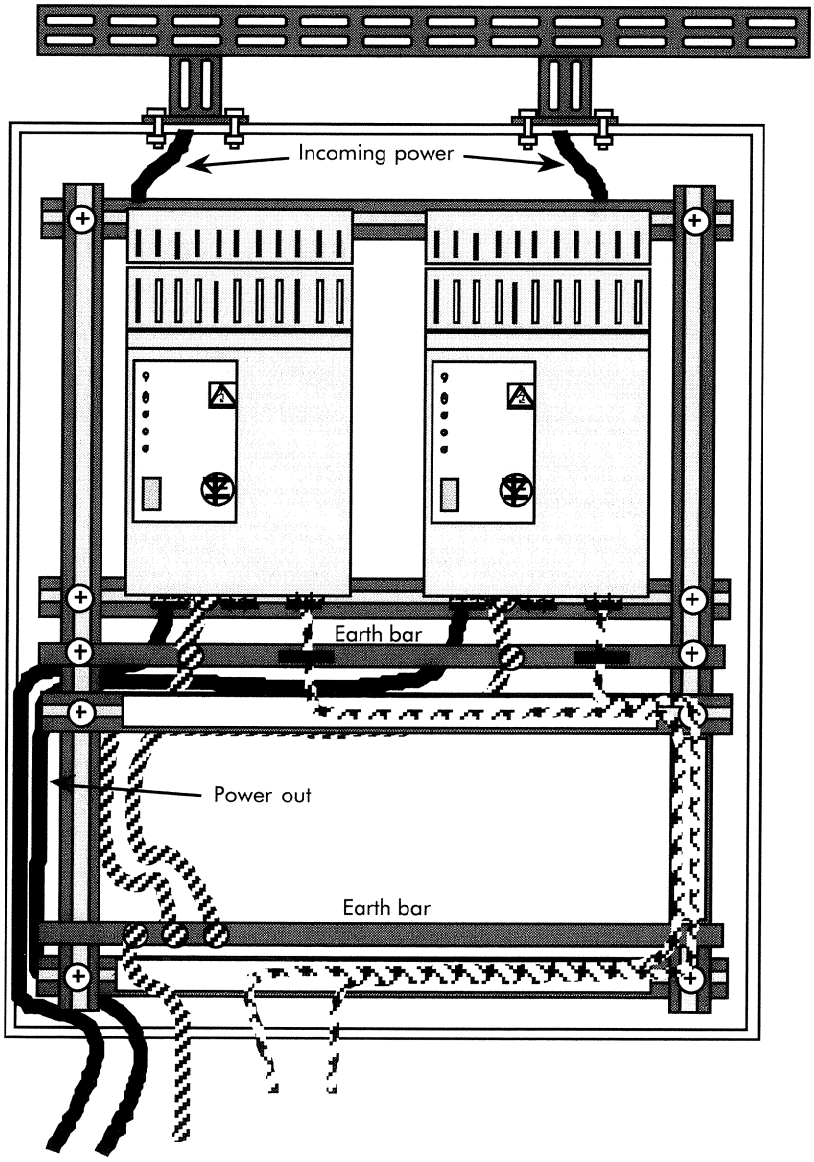
First, it is desirable to correct the largest errors. Experience shows that using screened cables where appropriate and routing cables correctly can achieve spectacular improvements.

When a susceptible cable is discovered modifications can be performed in the following way :

- First, when the cable is placed in a metal cable tray one should wire this tray to the ground using the shortest possible route.
- If no EMC precautions have been taken it is possible to install a ground wire in close proximity to the sensitive wire (see III-3) the improvement is about five times but this is sufficient in the majority of cases.
- One could also screen the cables on site by wrapping a knitted mesh around the cable. This solution gives satisfactory results but its application is awkward.
- In extreme cases the simplest solution is to disconnect the existing cable and replace it with a new screened cable, taking care that you have wired the screen to the grounds.



VII - General plan



VIII - Appendix - Definitions

VIII - 1 Coupling

EMC interference couples in six different ways into electronic circuits.

- Coupling by common impedance. The impedance of conductors is never zero, the current circulating in the cable sets up a potential difference between the two ends of the conductors.

- Coupling from PCB to chassis. An electronic PCB can never be isolated from its environment, it is at least coupled by its self capacity. As soon as a board is powered a potential exists in relation to its environment originating from currents which are found on the board itself.

- Crosstalk.

  Crosstalk has two origins:-

  a) The circulation of a current in a cable generates around the cable a magnetic field which induces a parasitic voltage onto the neighbouring conductors(inductive crosstalk)

  b) The potential difference between a conductor and the environment generates an electric field which injects parasitic current into neighbouring conductors (capacative crosstalk)

  In both cases, differential mode crosstalk (interference as directly super imposed on the signal) is negligible. In contrast common mode crosstalk is the most severe.

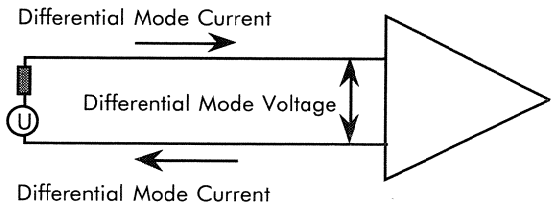
- Coupling from an electric field. A straight conductor in a changing electric field has a current induced into it. Cables in the installation can therefore act as aerials and pick up parasitic currents.

- Coupling by inductive loop. A varying magnetic field in the vicinity of a cable induces a difference in potential. This phenomenon is critical for loops between signal wires and the ground wires.

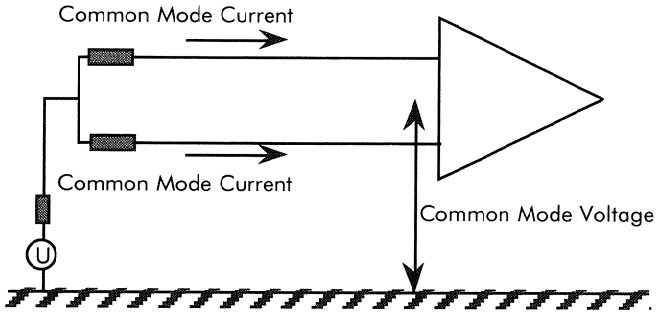
VIII - 2 Differential mode - Common mode

Differential mode is the required mode for transmitting information. Signals propagated on one conductor come back on the other conductor.

When this mode of interference is experienced the interfering voltage can be measured between the two conductors.



Common-mode is a parasitic mode. The interfering signals are propagated in the same sense onto all the conductors and appears with reference to ground. High frequency interference is thus coupled onto the cables.



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