EMC OF INSTALLATIONS AND RECOMMENDED CABLE SEPARATIONS

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INTRODUCTION

The EMC Directive has now been effective since 1st January 1996, enforced in the UK by statutory instrument SI2372 (1992). However, even before this date, which took into account a 4 year transition period to allow manufacturers time to comply with the requirements of the directive, the installer seemed to have little choice but to install compliant products in a compliant manner.

The requirement that contractors met the essential requirements of the directive, i.e. when equipment is installed it will:-

a. not interfere with other equipment in the vicinity (i.e. it must limit its emissions); and
b. be able to withstand likely interference levels present in the vicinity, (i.e. it must have sufficient immunity).

Prompted the Association to enter into a research project.

The purpose of this research was to ascertain what the minimum separation would be to protect against power frequency, high frequency and transient interference for a variety of power and signal cable combinations. On completion of the first two phases of this work, an advisory leaflet, including a table of minimum cable separation distances, was issued to members.

Since this early research further work has been undertaken to establish, among other things, best practice for cable routing, separation, screening, bonding and termination. The following guidance and tables of separation are a result of this further research.

WHAT THE CONTRACTOR CAN DO

To comply with the requirements of the directive the contractor should ensure that only equipment manufactured to comply with the relevant standards for interference and, where available, immunity is used, e.g.

BS EN 55011 for industrial, Scientific and Medical Equipment.
BS 905 (EN 55013 and EN 55020) for Broadcast Receivers and Associate Equipment.
BS EN 55014 and BS 5406 (EN 60555) for Household Electrical Appliances, Portable Tools and Similar Electrical Apparatus.
BS EN 55015 for Electrical Lighting and similar.
BS EN 55022 for Information Technology Equipment.
BS EN 50065 for Mains Signalling Equipment.
BS 6667 (HD481) and BS EN 60801 for Industrial Process Measurement and Control Equipment.

Where equipment does not have a specific standard or where a specific standard covers only emissions and not immunity, equipment should conform to the appropriate generic standard:

For Domestic, Commercial and Light Industrial Equipment:
BS EN 50081-1 for emissions; and
BS EN 50082-1 for immunity.

For Heavy Industrial Equipment
BS EN 50081-2 for emissions; and
BS EN 50082-2 for immunity.

CABLING AND INSTALLATION PRACTICE

However, the contractor can still not guarantee that, in using equipment manufactured to these standards, his completed installation will meet the requirements of the Directive. This is because an incorrectly installed cable connecting equipment to the supply could cause disturbances resulting in, for example, corruption to data on a Local Area Network.

The avoidance of any such problems should be given due regard at the design stage. Proper segregation, along with due regard to terminating, environmental conditions and earthing and bonding, are ways of overcoming the problems of EMI. Installing in a new build situation should be a comparatively straightforward task as attention can be given to these issues at the design stage. This, along with proper liaison with those responsible for other services e.g. telecommunications and security, will ensure cables are properly installed. In an existing installation, however, mitigating the effects of EMI is not so straightforward. In particular, achieving proper segregation can be more difficult, and careful consideration of how to meet the requirements of EMC must be given. The challenge is to find practical solutions that are cost-effective. Guidelines for installation practice can be found in the following documents:

BS EN 50173 for Information Technology - Generic Cabling Systems.
prEN 50174 for Information Technology

IEC 61000-5-1 Electromagnetic Compatibility (EMC)
Part 5: installation and mitigation guidelines Section 1: General considerations-basic EMC Publication.

IEC 61000-5-2 Electromagnetic compatibility (EMC)
Part 5: installation and mitigation Guidelines Section 2: Earthing and cabling.

IEC 61000-5-6 Electromagnetic compatibility (EMC)
Part 5: Installation and mitigation Guidelines Section 6: mitigation of external influences.

All standards shown above as prEN (proposed European standard) will become BSEN with the same numbers in due course.

CABLING AND INSTALLATION PRACTICE

Remember, an installation does not need to meet the requirements for CE marking, i.e. a declaration of conformity does not have to be issued neither does a Technical Construction File have to be kept. It should also be realised that the segregation details given in this leaflet apply only to cases where adjacent runs of both power and signal cables are envisaged.

No two installations are the same but if the following recommendations are applied then the risk on non-compliance will be reduced, thus avoiding the possible serious cost implications of having to implement mitigation methods after the installation has been completed.

General Considerations

As a first step towards good EMC engineering practice, the following guidelines should be observed.

1. Mains cables, including power feeds and lighting circuits, carrying up to 230V should not be grouped with sensitive cables (i.e. data cables).
2. All data, telecommunications or sensitive cabling should not be placed near 3 phase cables as these are normally used for heavy electrical inductive loads e.g. air conditioning, welding equipment and motors.
3. All cabling should avoid any proximity to radio or television transmitters, beacons and overhead transmission lines.
4. High level impulse cables, due to their fast rise times, produce a large frequency distribution of disturbances. Special precautions need to be taken with these types of cabling; efficient screening, good earths at both ends and consideration of an increase in the separation with adjacent cables would need to implemented.
5. All cables should be terminated whenever possible in accordance with their intended terminating impedance, and as per the manufacturers instructed.
6. Cable trays of metallic construction should be considered. Where used these should have an adequate mesh for the frequencies in use and be properly earthed. The tray will effectively become screen or enclosure for the cables if it has a lid fitted. If not it will only act as a parallel earthing conductor (PEC).
7. Cable trunking of metallic construction or incorporating a metallic element, if correctly designed and installed, can effectively become a screen or enclosure for the cables.

Installation Check List

The following checklist summarises the specific points that should be addressed when considering the installation of cabling within new or refurbished building.

Environmental Considerations

1. Does the environment intend to house telecommunications equipment?
2. It is intended to use Information Technology equipment?
3. Has the building been designed or constructed with a single or multi-role usage in mind?
4. Are the medium/high voltage switching or disconnect devices contained within this environment?
5. Are there high power machine/motors contained within the installation?
6. Is medical equipment used within the building?
7. Is the building installation contained near to, or within a railway environment?
8. Are there commercial businesses in the form of shops or restaurants within the environment in which cables are being installed?

Earthing and Bonding

1. Is the earthing system multiple bonded to earth?
2. Are cable trays and trunking of metallic construction or incorporation a metallic element, utilised within the installation for routing power and signal cables?
3. Have the cable trays and trunking of metallic construction or incorporating a metallic element, been bonded using a short braid or direct surface to surface connection?
4. Have the contact surfaces for all electrical connection been made free from grease corrosion, paint and insulating materials?
5. Are the two metals at the point of connection galvanically compatible?
6. Is the earthing system electrically safe?

Types of Cables

1. Have all cables of similar sensitivity been bundled with other cables of a similar sensitivity?
2. Have particularly noisy cables been adequately screened?
3. Have all cables been terminated into the recommended terminating impedance?
4. Has an adequate type of cable been chosen for the severity of the environment in which it is being used?

Terminations

1. Have all power cable screens or armour been bonded to ground at both ends using 360º peripheral glands?
2. Is the cable screen for sensitive cabling attached to terminating equipment that is grounded at the same end?
3. Is the cable screen grounded at both ends of the terminating equipment which is grounded at both ends?
4. Has the cable screen been terminated according to the manufacturers recommendations?
5. Has the cable screen been terminated in the best way achievable considering the circumstances?

Cable Separations

1. Is it possible to achieve all the relevant separation distances stated in this Guide?
2. If the minimum separation distances are not achievable, have the maximum allowable length of parallel runs been exceeded?
3. If the minimum separation distances and maximum parallel runs have been exceeded, then has additional screening (i.e. suitably designed conduit or trunking of metallic construction or incorporating a metallic element) been implemented?
4. Have all cables been classified in terms of their noisiness or sensitivity?
5. Have the minimum clearances between overhead telecommunications and power lines been achieved?
6. Do cable runs which crossover, do so at right angles?

Cables and Cable Separation

It is important to consider routing at the design stage. Normally the shortest distance allowed within an installation would be chosen. However, for EMC requirements the shortest distance properly protected must be chosen.

IEC 61000-5-2 recommends the routing of cables along with a parallel earthing conductor)PEC). The purpose of the PEC is to provide a continuous, well-conducting metallic structure that will divert disturbances from the adjacent cables. The PEC should be connected at both ends to the earth of the apparatus. The effectiveness of the PEC is related to its shape (Fig 1) When a PEC is made of a number of shorter elements care should be taken to ensure the continuity of the structure by correct bonding between the parts.

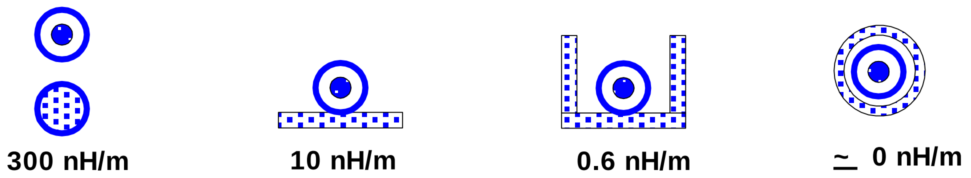


Figure 1: Shapes of parallel earthing conductors and their effect on transfer impedance.

Separation Distances for Cables

General Considerations

The use of screened or twisted pair cables allows the separation distances between signal and power cables to be reduced. From previous research it was thought that incorrectly installed conduit and trunking would have little effect on the attenuation of fast transient disturbances, although it was clear that trunking and conduit made from ferrous metals could reduce the strength of 50Hz magnetic fields. However, more recent research is showing that properly designed trunking and conduit systems are effective in the reduction of fast transient disturbances.

From the recent work a table of minimum separation distances between power and signal cables was devised.

Table 1: Separation distances between power and signal cables.

Signal Cable	Power Cable		
	Twin & Earth	**Steel Wire Armoured**	**MICC**
Plain	150mm	125mm	Touching
UTP	75mm below 100 MHz 125mm above 100 MHz	50mm	Touching
Screened	Touching	Touching	Touching

SEPARATION DISTANCES FOR IT INSTALLATIONS

There are many factors to consider when designing and installing IT systems such as:

Voltage

Power

Disturbing source frequency

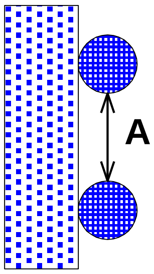
Parallel length of run

The draft standard prEN 50174-2 has tabulated separation distances for IT cables from power cables against typical installation scenarios; it must be noted that the separation distances given are worst case. It must also be remembered that experience gained first hand in the installation of IT systems will very much influence the separation distances that are decided upon for a given installation scenario.

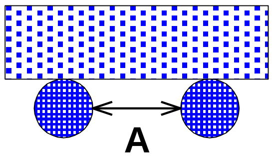
Table 2: Example of information technology cable separation from power cabling
(Taken from prEN 50174-2: June 1998)

Type of installation	Without divider	With metallic divider (2)
Unscreened power lines and unscreened information technology lines	300mm	150mm
Unscreened power lines and screened information technology lines (1)	70mm	30mm
Screened power lines and unscreened information technology lines (1)	30mm	2mm
Screened power lines and screened information technology lines (1)	15mm	1mm
(1) The values of the distance (A) depend upon the way the screen and metallic divider is bonded and earthed. Here bonded and earthed screens and metallic dividers have been chosen.		

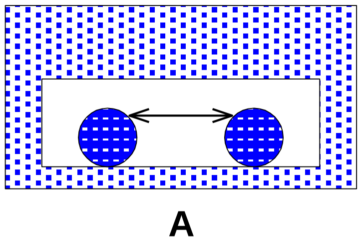
C11 - Wall Installation



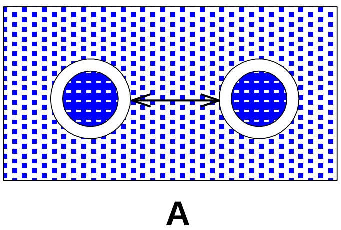
C12 - Floor or ceiling installation



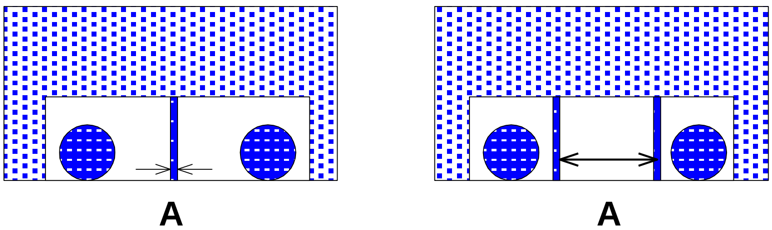
C21 - Underfloor system without divider.



C21 - Underfloor system with separate conduits



C22 - Underfloor system with divider(s)



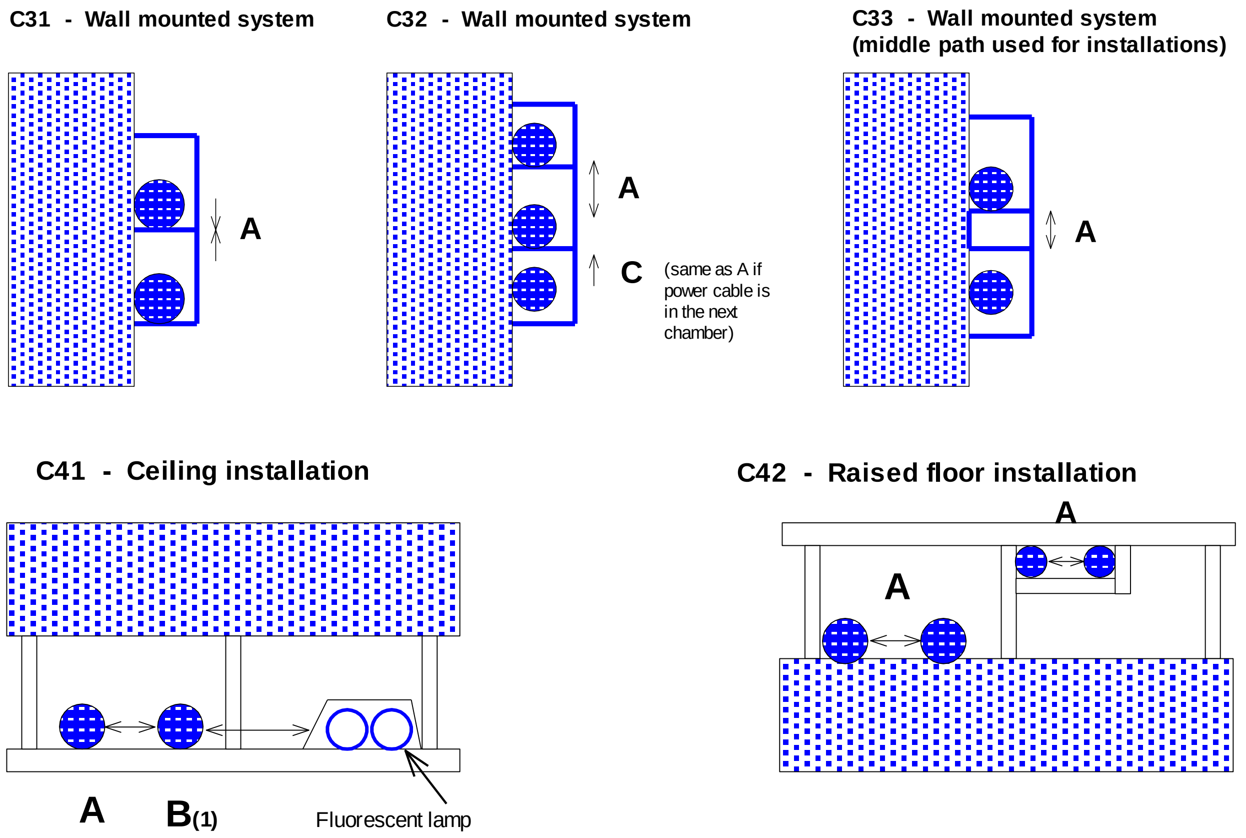


Figure 2: The distance between the cable and the fluorescent, neon or high-density discharge fixtures shall be at least 130mm.

Cables in Parallel

A flat cable is often used for parallel data transmission between digital equipment. Each data line and return line should be at alternate positions. The flat cable can be shielded.

Some rules for parallel runs of cables should be observed in order to minimise any EMC problem:

1. Cables can run in parallel for 100 meters if both the IT cable and power cable are installed in a completely enclosed, well-grounded aluminium or steel channel. These channels shall be separated from each other by a common metal divider that is continuously bonded to the main channel.
2. Coincident runs of no more than 5 metres are permissible if dividers or suitable retention hardware maintains a 25mm separation distance. If the separation is less than 25mm for distance of up to 150mm, it is necessary that no contact occurs between the IT and power cables.
3. Coincident runs of no more than 9 metres are permissible if dividers or suitable retention hardware maintains a 50mm separation distance. If the separation is less than 50mm for a distance of upto 300mm, it is important that no contact occurs between the IT and power cables.
4. In case of multiple cables and limited separation, cables should be arranged in such a way that the same IT cable is not always nearest the power cable at every outlet or junction.
5. Electrical wiring closets and data wiring closets should ideally be in separate cabinets. In any event, data wiring racks and electrical equipment, where possible, should be separated by at least 1 metre.
6. For parallel runs of under-carpet cables and power cables, maintain at least 130mm of separation for the first 15 metres of the run. Any cable in excess of this should be separated by at least 460mm for the remainder of the run.

Installation Scenarios and Applicable Separation Tables

Six different installation types have been selected to represent the most common types of installation that members would normally encounter. These are:

- Single Occupancy IT building
- Multi-occupancy office building
- Heavy industrial environment
- Hospital environment
- Railway station (under and over-ground)
- Shopping Mall

The following guide (Table 3) provides a cross-reference to tables of cable separation for these types of installation. The guide also provides a cross-reference to separation tables for generic installation types and for common services.

Table 3: Guide for separation tables against type of scenario

Type of Installation	Coupled Cables Involved		See table (s) No.		
	Source	**Victim**			
Single occupancy IT building	Power	Data	Table 1	3.1.1	3.1.2
Multi-occupancy IT building	Power Power 3-phase	Data Control Control	Table 1 3.1.2 3.1.2	3.1.1	3.1.2
Heavy Industrial movement	Power Power 3-phase	Data Control Control Control	Table 3 3.1.2 3.1.2 3.1.2	3.1.1	3.1.2
Hospital Environment	Power Power 3-phase	Data Control Control	Table 1 3.1.2 3.1.2	3.1.1	3.1.2
Railways over or underground	Switched power line Switched power line	Data Control	3.1.2 3.1.2		
Shopping Mall	Power 3-phase Switched power line	Data Data Data	Table 1 3.1.2 3.1.2	3.1.1	3.1.2
Common Services		Control Data	3.1.2 3.1.2		
Any type of installation	Parallel runs of cable		3.1.3		

Table 3.1.1: Minimum separation (mm) between power and signal cable according to the way they are mounted.

	Metal Separation	Non-Metallic Separation
Unscreened power lines, or electrical equipment and unscreened IT lines	150	300
Unscreened power lines, or electrical equipment and screened IT lines*	30	70
Screened power lines*, or electrical equipment and unscreened IT lines	2	30
Screened power lines*, or electrical equipment and screened IT lines	1	15

*screened = screened and earthed at both ends.

Table 3.1.2: Minimum separation (mm) between source and victim cables when unshielded.

Victim	Source			
	Indifferent	Noisy	Very Noisy	Fluorescent Lamp
Very Sensitive	300	450	600	
Sensitive	150	300	450	130

Table 3.1.2: Minimum separation (mm) between source and victim cables when unshielded.

		Separation (mm)	Max parallel run (m)
Types	Any, screened or very well armoured and separated by a metallic divider	close	100
of cables	IT/Power	25 50	5 9
	IT/Power	130 460	15 >15

CABLES SCREENING & TERMINATION

Of the mitigation techniques available the selection of the most appropriate cable screen and its correct termination, will help to prevent radiated emission from one cable type being received by another. Table 4 shows the effectiveness of various cable screens at 50Hz and RF.

Table 3.1.2: Minimum separation (mm) between source and victim cables when unshielded.

	Noise Reduction	
Cable Type	**50 Hz magnetic**	**RF**
Plain (no screen, no twist)	None	None
Twisted pair	Good	None
MICC	None	Good
Twisted pair MICC	Good	Good
Plain in steel trunking or conduit	Good	Good
Plain with braid or metal tape screen	None	Good
Twisted pair with braid or metal tape screen	Good	Good
Steel wired armoured	Good	Good
Plain in correctly designed and installed aluminium trunking or conduit.	None	Good
Twisted pair in correctly designed and installed aluminium trunking or conduit.	Good	Good

Remember that the best screen without good bonding is ineffective in most situations.

As stated previously the effectiveness of the cable screen will be significantly reduce if it not terminated correctly. The following diagram (figure 3) gives a best to worst case of termination methods.

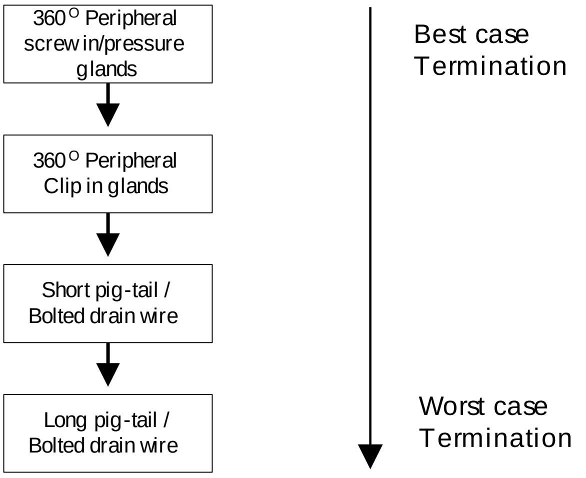


Figure 3: Best to worse case cable screen termination

EARTHING AND BONDING

Without adequate earthing and bonding the effectiveness of other mitigation methods will be impaired.

The terms earthing and bonding are often confused. Earthing is defined in BS 7671 as: 'The act of connecting exposed-conductive-parts of an installation to the main earthing terminal of an installation'. Equipotential bonding is defined as 'Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential.' (N.B. referred to as bonding throughout this document).

It is important to note at this point that the primary function of an earthing network is for safety. Safety must take precedence over any mitigation methods that are implemented to reduce the EMI in the environment.

When making bonding connections between earthed metal conductors it is important to take account of a number of environmental factors to ensure a successful long-term connection:

Temperature
Humidity
Vibration
Mechanical Damage

It is also essential that when making the connection the contact surfaces should be clean, i.e. free from grease, paint, corrosion, insulation materials and any other effect that may cause a high contact resistance. This is a practical point to note when bonding to cabinets, cable trays, trunking etc. that have protective painted coatings applied during manufacture.

When bonding connections are made it is important that compatible metals are used, to minimise the effects of corrosion that would inevitably lead to a deterioration of the initial low contact impedance.

Two ways of achieving good bonding connections are:

i. ensure that earthing contact areas are of the same or similar contact potentials; and

ii. using a grounding strap of fastening of intermediate contact potential to separate the two. (This, for direct contact would take the form of plating one of the metallic contacts or for the indirect contact a bonding strip with an intermediate contact potential).

For low-impedance bonding, the length of the strap between the apparatus and the earthing network should be a minimum. In practice, this implies that apparatus should always be connected to the nearest earthing network conductor.

For bonding straps, suitable conductors include metal strips, metal mesh straps or round cables. Yet, round cables are not effective above 10 MHz, because they have higher impedance than flat conductors with the same material cross-section:

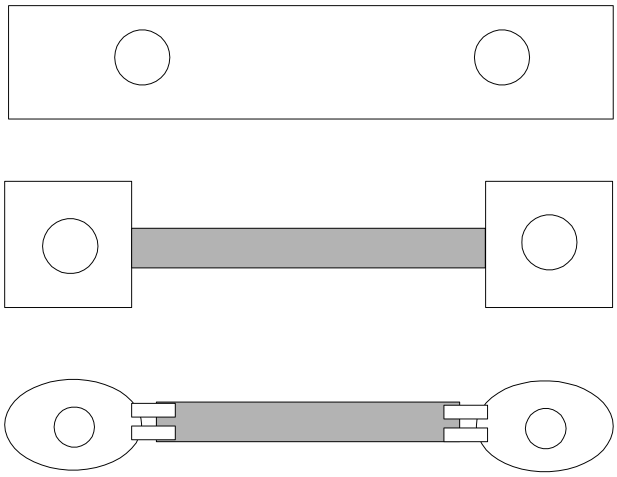


Figure 4: Examples of Bonding straps

(The length to width ration for these straps should be five or less)

For cable terminations the most effective bonding is to have a 360^{o} peripheral connection around the shield. The best to worst methods are shown at figure 3.