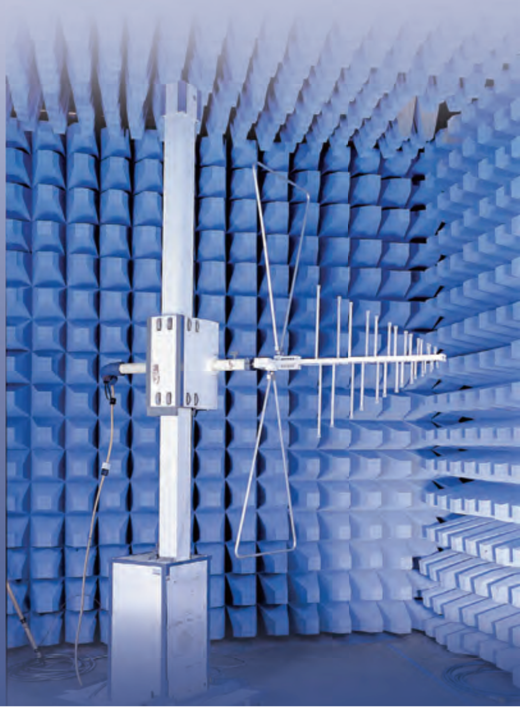
EMC ENCLOSURES



MASE 266

IP 55, NEMA 12, IK 10

H: 400-1000
W: 400-800
D: 210-300

MCSE 268

IP 54, NEMA 12, IK 10

H: 2000
W: 800
D: 600-800

Accessories

Side Panels	270
Doors	270
Separation plate	271
Gasket	271
Bottom and roof plates	272
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Cable entry	273
Fans	274

General Accessories 286

EMC Enclosures

- Based on the MultiFlex and MultiMount enclosures.
- Fully galvanized frame and body, only painted on the outside.
- Special conductive gasket on all panels and doors.
- No holes on the bottom plate for floor standing version and no gland plate for the wall mounting version ensures a good Faraday effect .
- Accessories that need a cut out to be mounted have a conductive surface to guarantee electrical continuity with the enclosure.
- Excellent attenuation levels.

Electromagnetic (EMI) shielding

MASE

Wall mounting enclosures, single door.

IP 55, NEMA 12 IK 10

Technical data

Material: Body: 1.2mm zinc plated steel /1.4mm MASE0606021R5 and above. Door: 1.2mm zinc plated steel / 1.4mm MASE0606021R5 and above/1.8mm MASE1006026R5 and above. Mounting plate: 2mm galvanized steel.
Body: Folded and seam welded. Four 8.5mm diameter holes for wall fixing, pressed out in 20.4mm diameter x 2mm depressions to allow air circulation around the rear part of the enclosure.
Door: Surface mounted with 130º opening. Concealed removable hinges with captive pin. Hinges can be mounted to allow left or right hand opening. From size MASE0505021R5 and above there are two removable mounting profiles on the door. Sealing is ensured by a conductive polyurethane EMC gasket.
Lock: Chrome plated double-bit lock with 3mm insert and 90º movement. 1000mm high enclosures and above have espagnolette three point locking system.
Mounting plate: The mounting plate is marked vertically at 10mm intervals for easy horizontal positioning of equipment. On the top and bottom are holes to facilitate cable fixing. Fixed onto M8 press welded studs to the rear of the enclosure. All sides from 800mm and above are strengthened by folded edges. By using the AMG accessory the mounting plate can be adjusted to any depth.
Gland Plate Opening: No gland plate opening for a maximum EMI protection.
Earthing: The door is earthed by means of a separate earthing stud M8.
Finish: RAL 7035 structure powder coating on the outside only.
Protection: Complies with IP 55, NEMA 12, IK 10.
Delivery: Zinc plated enclosure body and door, painted on the outside. Door equipped with EMI conductive gasket. Two door mounting profiles from size MASE0505021R5 and above. Earthing facilities.

MASE, IP 55, NEMA 12 IK 10

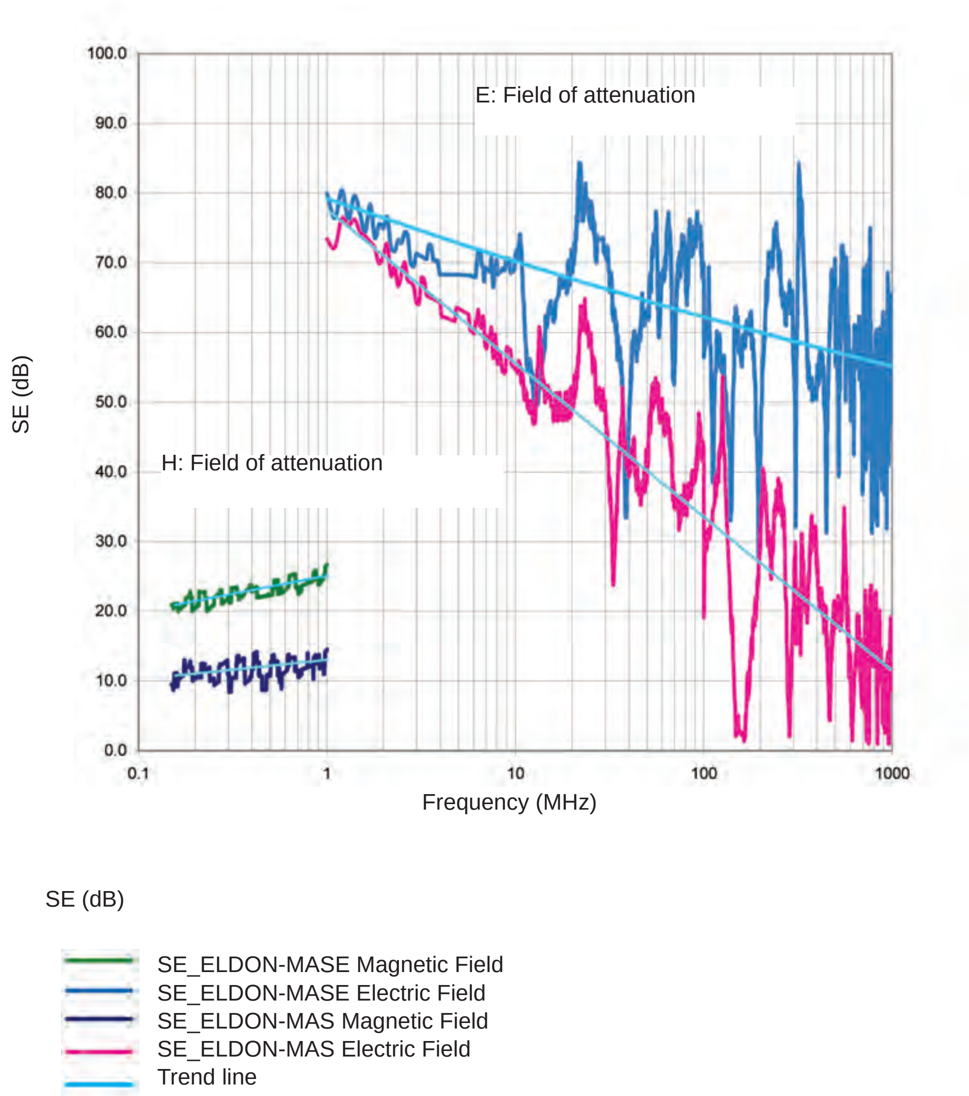
Enclosure dimension			Mounting plate dimension								
H	W	D	h	w	d	Size	Type	Openings	N° of locks	Weight	Part No.
400	400	210	370	350	192	310x96	2	1	1	8,6	MASE0404021R5
	600	210	370	550	192	510x96	4	1	1	12,2	MASE0406021R5
600	600	210	570	550	192	510x96	4	1	2	21	MASE0606021R5
1000	800	300	970	750	282	310x96	2	2	1*	47	MASE1008030R5

Product range MAS
All the MAS standard sizes are available in EMC version on request.

MASE: From 200/200/155mm to 1200/800/400mm.
e.g. MASE0606021R5, EMC single door enclosure 600x600x210mm
For more details please see MAS table.

Shielding Effectiveness

Shielding Effectiveness for Eldon wall mounting enclosures MAS, MASE.
EMC attenuation tested according to VG 95 373 part 15.



Electromagnetic (EMI) shielding

MCSE

Combinable version, single door.

IP 54, NEMA 12, IK 10

Technical data

Material: Frame: 1.5mm/1.75mm zinc plated steel. Door: 2mm zinc plated steel. Rear, roof and side panels: 1.35mm zinc plated steel. Mounting plate: 2.7mm galvanized steel. Bottom plates: 1mm galvanized steel.
Frame: Seam welded reversed open profiles with 25mm hole pattern according to DIN 43660. Including integrated external hole pattern.
Door: Surface mounted with hinges allowing left or right hand opening. Including door frame with 25mm hole pattern. Sealing is attained by a conductive polyurethane EMC gasket.
Rear panel: Fitted by M6 torx screws. Standard facilities for rear door mounting.
Side panels: Supplied as an accessory.
Roof panel: Removable.
Lock: Espagnolette 4-point locking system. Does not interfere with the enclosure inner space. Standard double-bit lock with 3mm pin. Can be exchanged for standard inserts or Euro-cylinder, T- or swing handle locking system.
Mounting plate: Double folded and slides into position. Adjustable in depth by steps of 25mm. In the enclosure delivery, mounting plate is attached on the outside of the package.
Bottom plates: Consists of three pieces. For 800mm deep 4 pieces.
Earthing: All panels are earthed through their fittings and are equipped with a separate earthing stud.
Finish: RAL 7035 structure powder coating on the outside only.
Protection: Complies with IP 54, NEMA 12. IK 10.
Delivery: Frame with fitted door, rear panel, roof panel, bottom plates, mounting plate and door frame. Delivery also includes earthing bolts and EMI conductive combination gasket. Delivered on a pallet with same width as the enclosure to allow suiting without removal. All packing material recyclable.
Note: In 400mm wide enclosures, the mounting plate, bottom plates and door frame are not included. * Also available in stainless steel (MCSSE).

Electromagnetic (EMI) shielding

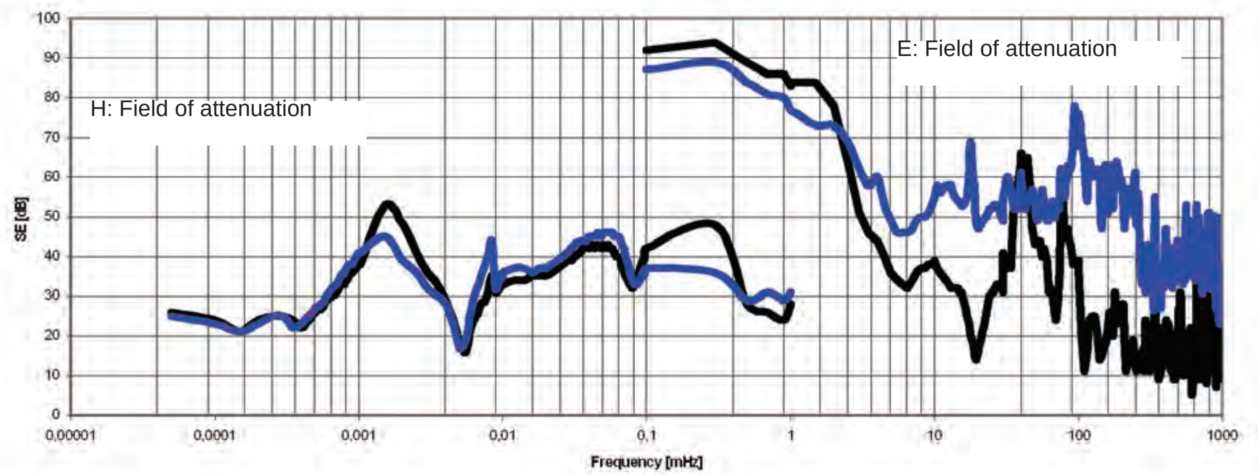
MCSE, IP 54, NEMA 12, IK 10

Enclosure dimension			Mounting plate dimension				
H	W	D	h	w	d	Weight	Part No.
2000	800	600	1894	694	559	132	MCSE20086R5
		800	1894	694	759	139	MCSE20088R5

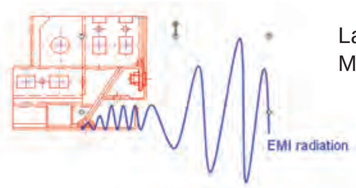
** All the MCS standard sizes are available in EMC version on request including other dimensions.*
For EMC sidepanels see SPME.

Shielding Effectiveness

Shielding effectiveness for Eldon floor standing enclosures MCS, MCSE.
EMC attenutation tested according to VG 95 373 part 15



Frequency (MHz)



Labyrinth protection of the MultiFlex enclosure line

Shielding Effectiveness

Standard Multi-Flex, Floor standing enclosures, MCS
EMI adapted Multi-Flex, Floor standing enclosures, MCSE

Electromagnetic (EMI) shielding

SPME, Side panels

Description: For covering the sides of the MCSE enclosures. Equipped with a conductive gasket providing both EMC/IP protection.
Material: 1.35mm zinc plated steel.
Finish: RAL 7035 structure powder coating on the outside only.
Protection: Compiles with IP 54, NEMA12.
Pack quantity: 2 panels with mounting accessories.

H	D	Part No.
2000	600	SPME2006R5
	800	SPME2008R5

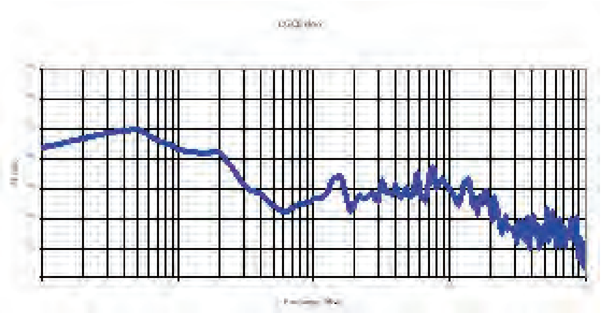
**Other sizes available on request*

DGCE, Glazed door (61%)

Description: Standard door fitted with clear safety glass to view the inside of the enclosure. Equipped with double-bit 3mm lock system and door frame. Allows all options of the locking program. Sealing is maintained by a conductive polyurethane EMC gasket. To ensure the EMI effectiveness a mesh wire is placed behind the glass window with a clearance percentage of 61%. Use hinge kit DMK if not for replacement of standard door.
Material: Frame: 2mm zinc plated steel. Viewing area: 3mm clear safety glass.
Finish: RAL 7035 structure powder coating on the outside only.
Protection: Complies with IP 54, NEMA12, IK 10.
Mounting requirement: If no door was fitted previously use hinge kit DMK01.
Pack quantity: 1 piece.

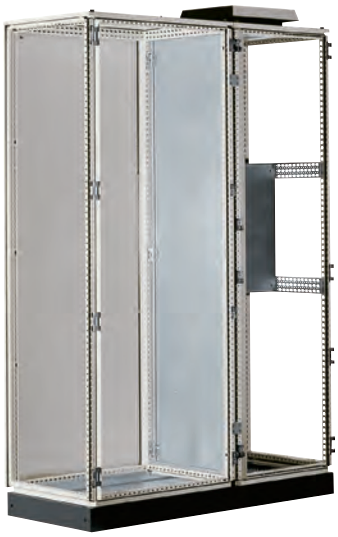
H	W	h	w	Part No.
2000	800	1776	615	DGCE2008R

Shielding Effectiveness
EMC attenuation tested according to VG 95 373 part 15



EMI adapted MultiFlex, Floor standing enclosures, MCSE

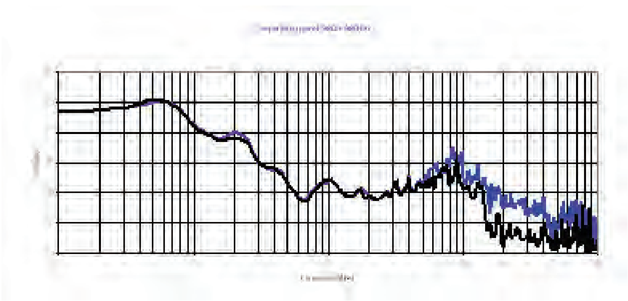
SPD EMC, Separation plates



Description: Separates two bayed enclosures. To be fixed with combining kit CCJ. To achieve IP 43, NEMA1 a neoprene gasket SPDG 01 can be fixed to the panel. For EMI separation the SPDEG gasket must be fitted.
Material: 1.5mm zinc plated steel.
Mounting requirement: Add CCJ brackets for mounting.
Pack quantity: 1 piece.

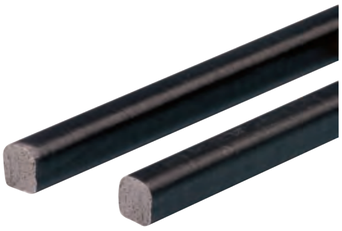
D	Part No.
600	SPD2006
800	SPD2008

Shielding Effectiveness
EMC attenuation tested according to VG 95 373 part 15



Shielding effectiveness for Eldon floor standing enclosure separation plate SPD

SPDEG, Gasket for EMC shielding



Description: To obtain an EMC shielded section in a suited panel in combination with the separation plate SPD.
Material: Polyurethane foam with conductive layer. (UL94HB)
Protection: Complies with IP 43, NEMA1.
Pack quantity: 6m.

Part No.
SPDEG01

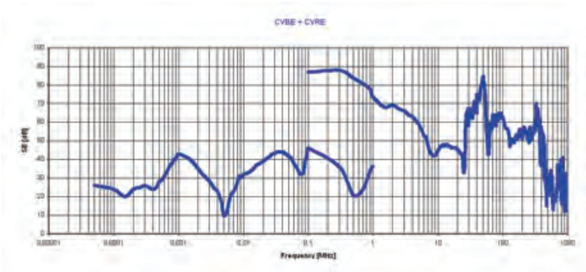
Electromagnetic (EMI) shielding

CVB EMC, Ventilated bottom plates

Description: Three piece bottom plates. Can be used in combination with a ventilated plinth PV. 33% ventilation.
Material: 1.5mm perforated zinc plated steel.
Pack quantity: 3 pieces with mounting material.
Mounting requirement: Use in combination with ventilated plinths PV.

For enclosure D	Part No.
600	CVB0806
800	CVB0808

Shielding Effectiveness
EMC attenuation tested according to VG 95 373 part 15.



Shielding effectiveness for top and bottom plates of the MultiFlex range

CVRE, EMI Ventilation roof

Description: Inner ventilation roof plate for a high EMI protection. Mounted directly into the frame of the enclosure. Can be used in combination with the CVR ventilation roof, CFR fan roof plate or the spacers to raise a standard roof CVK15. 33% ventilation.
Material: 1.5mm zinc plated steel.
Finish: Non painted zinc plated steel.
Pack quantity: 1 piece with mounting accessories.

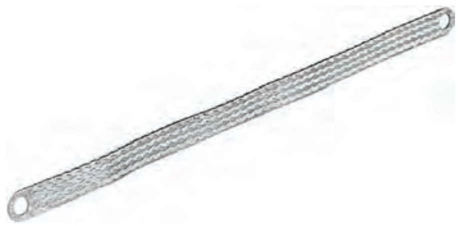
W	D	Part No.
800	600	CVRE0806
	800	CVRE0808

CCJ, Internal baying kit

Description: Mounted to the frame profile. Can be used both on the vertical and the horizontal frame profile.
Material: 3mm zinc plated steel.
Pack quantity: 12 brackets with mounting accessories.
Mounting requirement: IP 43, NEMA 1 sealing can be obtained by using SPDG gasket. For internal baying, use CCM brackets.

Part No.
CCJ12

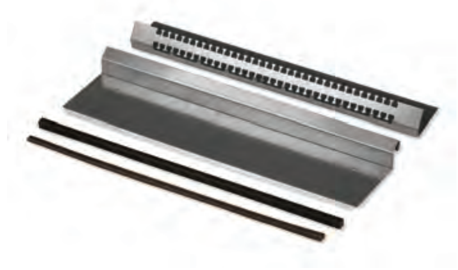
ECFE, Earthing strap



Description: For earthing and potential compensation between panels, parts and enclosure' s frame. Length: 300mm.
Material: Tinned electrolytic cooper 0.15mm wire.
Working temperature: Up to 105ºC.
Pack quantity: 10 pieces.
Mounting requirement: Add connection set ECF for fixing strap to painted frame.

Cross sectional area	Holes diam.	Current (A)	Part No.
16mm²	8.5	120A	ECFE1630
25mm²	10.5	150A	ECFE2530

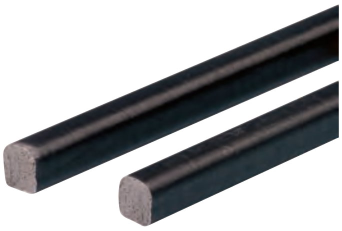
CBPE, EMC connection bottom plate



Description: Replaces two parts of the standard three or four piece bottom plates. Due to the hammer head cones, EMI cables can be directly earthed to the bottom plate keeping the "Faraday cage".
Material: 1.5mm zinc plated steel.
Pack quantity: 2 pieces with EMI gasket and mounting accessories.

For enclosure W	D	Part No.
600	600	CBPE0606
	800	CBPE0608
800	600	CBPE0806
	800	CBPE0808

BGE, EMC cable entry and bottom plate gasket



Description: The bottom of the enclosure is sealed by the use of an adhesive gasket applied to the frame around the bottom opening. The cables are sealed by the addition of adhesive foam placed between the bottom plates. The elasticity and the size of this foam ensures a tight seal around most cables. Added conductive material provides a good contact to shield the transfer of electro-magnetic radiation.
Pack quantity: 1.6m adhesive EMC gasket for cable entry and 6m adhesive bottom plate gasket. For 1600mm wide enclosures please order 2 sets.

Part No.
BGE01

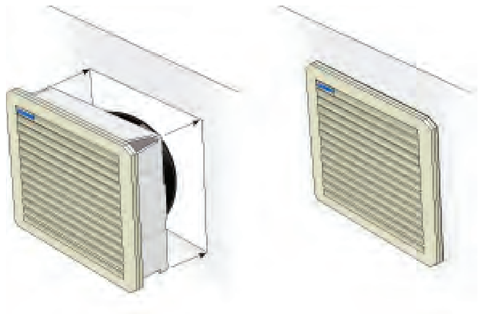
CABP, Cable fixing bar

Description: Suspended below the bottom plates, thereby maximizing the full usable space in the enclosure. Holds standard cable clamps CAC to secure incoming cables. Fully adjustable in depth. When EMC shielded earthing cables are connected to the support bar the Faraday effect will be kept intact for maximum EMI shielding.
Material: 2mm zinc plated steel.
Pack quantity: 2 bars with mounting accessories. For 1200mm wide, 4 bars with mounting accessories.
Mounting requirement: Add CAC clamps depending on diameter of cable.

W	Part No.
400	CABP400
500	CABP500
600	CABP600
800	CABP800
1000	CABP1000
1200	CABP1200

Electromagnetic (EMI) shielding

EMC, Shielded Filter Fans



EMC, Filter Fans and Exhaust Filters

When using fan and filter units in an enclosure, vent slots have to be made. This immediately results in a leakage in terms of the EMC-regulation. If EMC requirements are appropriate, special EMC-protected filter and fan units must be used. Eldon offers a "click-in" solution for which no screws are required! To prevent corrosion attacking the EMC-screen, the outer parts of the filter and fan units are mounted with a stainless steel frame in combination with Beryllium copper contact strips. Thus combining a high corrosion resistance with a high attenuation level.

Technical features:
- A wide air flow range from 61 m3/h to 845m3/h.
- No screws are required for fixing the units.
- Only square cut outs required.
- Units only protrude 6 mm from the enclosure surface.
- The filter mat can be quickly changed without dismounting the complete unit.
- Material conforms with the requirements of ISO 14000 (Environmental - Management System).
- Housing material is self extinguishing.

Screening effectiveness Thermal Management Filter and Fans EFE/EFAE:

EMC attenuation measured according to EN 50 147 - 1 (1996).

EMC Filter Fan	EFE200R5	EFE220R5	EFE250R5	EFE300R5	EFE500R5	EFE600R5	EFE700R5
Airflow Volume (free-flow) (m3/h)	61	110	156	256	480	640	845
Cooling Capacity (free-flow) (W/K)	20	37	52	85	160	213	282
Combination Airflow (Filterfan + Exhaust) (m3/h)	44	62	116	231	370	445	560
Combination Capacity (Filterfan + Exhaust) (W/K)	15	27	39	77	123	148	187
Filter Mat Type	IP 54-filter mat G3				IP 54-filter mat G4		
Max. Static Pressure (Pa)	60	66	52	116	76	134	192
IP	IP 54, IP55 on request*						
Rated Voltages AC	230V,115V*	230V,115V*	230V,115V*	230V,115V*,400V 2-*	230V,115V*	230V,115V*,3x400V*	230V,115V*,3x400V*
Available Voltages DC*	12 V, 24 V, 48 V	12 V, 24 V, 48 V	12 V, 24 V, 48 V	12 V, 24 V, 48 V			
H x W (mm)	145 x 145	202 x 202	252 x 252	252 x 252	320 x 320	320 x 320	320 x 320
Cutout Dimensions (mm)	126,5 x 126,5	178 x 178	224 x 224	224 x 224	292 x 292	292 x 292	292 x 292
Operating Temperature (°C)	From -15 °C to +55°C						
Material	Thermoplastic, self-extinguishing, UL 94 VO						
EMC Shielding	Stainless Steel						
Approvals	UL approval						

Available IP55 Filterfan on request, reference EFEPxxxR5*
* On request

EMC Exhaust Filter	EFAE200R5	EFAE220R5	EFAE250-300R5	EFAE500-700R5
H x W x D (mm)	145 x 145 x 26	202 x 202 x 34	252 x 252 x 38	320 x 320 x 39
Cutout Dimensions (mm)	126,5 x 126,5	178 x 178	224 x 224	292 x 292
IP	IP 54, IP55 on request*			
Material	Thermoplastic, self-extinguishing, UL 94 VO			
EMC Shielding	Stainless Steel			

Available IP55 Exhaust filter on request, reference EFAEPxxxR5*

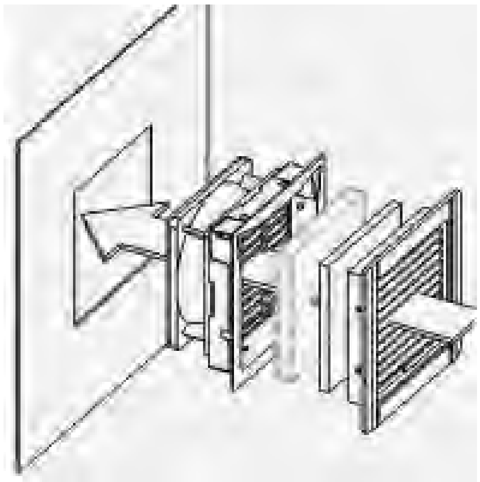
Shielded Filter Fans
IP 54 Thermal Management

Our EMC-shielded filter fans affect the EMC shielding of your enclosure as follows:

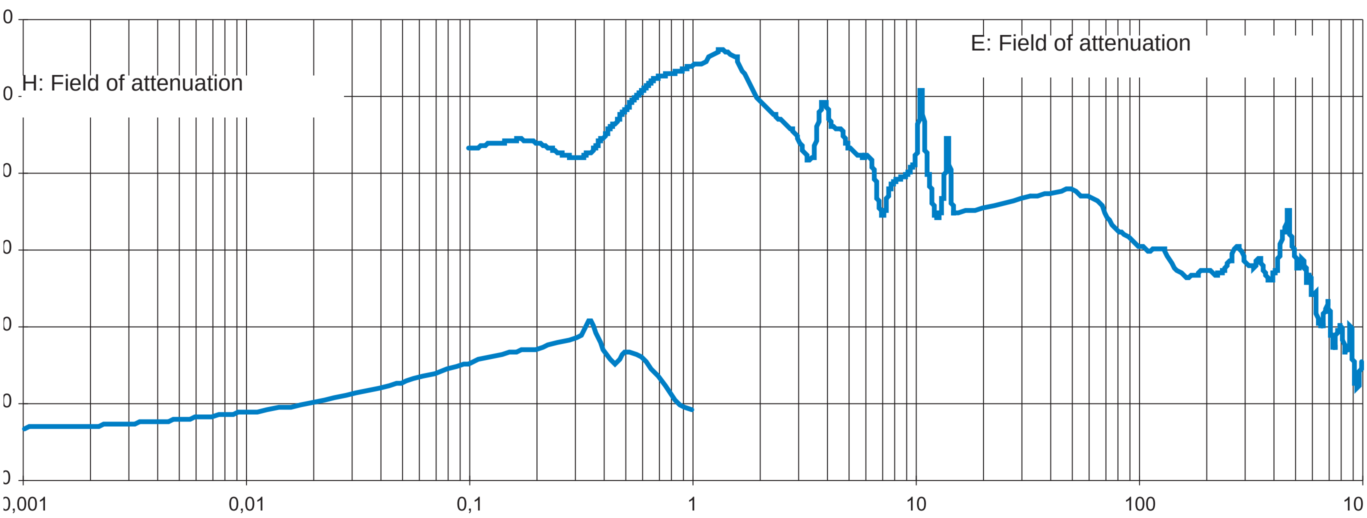
Damping at 30 MHz approx. 71 dB
Damping at 400 MHz approx. 57 dB
Measured according to EN 50 147 - 1 (1996)

No extensive extra work on the installation cut out
- no copper band or similar auxiliary materials to glue in place
- no need to scratch away layers of material to ensure surface-to-surface contact

1. Surface-to-surface contact made via edge of the cut out for the filter fan or exhaust filter
2. Innovative surface-to-surface contact along the edge of the cut out makes mounting a simple task
3. Reliable surface-to-surface contact by means of specially shaped contact springs on screen grid
4. Low environmental impact due to use of separate screen grids made of stainless steel (1.4301)
5. Low environmental impact because grid plates and contact surfaces are in one piece; beryllium copper band is not necessary to provide contact, and materials can be separated for easy recycling.



Shielding effectiveness Thermal Management Filter and Fans EFE/EFAE:
EMC attenuation tested according to EN 50 147- (1996)



Electromagnetic (EMI) shielding

1.The mechanism of Electromagnetic Interference (EMI)

The definition of EMC

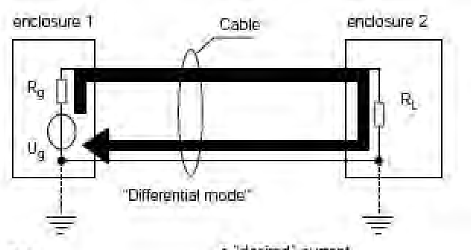
The council of the European Union defines EMC in Article 4 of their "council directive on the approximation of the lawsof the Member States relating to Electromagnetic Compatibility (89/ 336/EEC)" as property of an "apparatus":- The apparatus shall be so constructed that: the electro-magnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment andother apparatus to operate as intended" (emission requirement)- The apparatus has an adequate level of intrinsic immunityof electromagnetic disturbance to enable it to operate as intended" immunity requirement. This is a very broad definition. The customary route to compliance is the application of standards. There are product standards, applicable to a specific product type(e.g. lighting) and, when not available, there are "generic standards" that can be used. When your product passes all required tests this provides the "presumption of compliance".

What can you do?

The problem is that there is no direct relation between the tests to establish the fact of "EMC" and the measures you can take to behave satisfactory in that respect. What you need is some basic knowledge on the mechanisms of electromagnetic interference.

Differential and common-mode currents

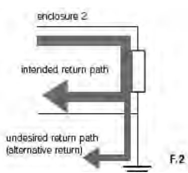
All electric currents run in loops. When you measure current in a wire there must be a return current some whereto the original source. The currents that determine the functional behaviour of a design are called "differential-mode"currents (dm-currents for short). There is another type, however: 98% of all interference problems are caused by common-mode currents (cm-currents). It depicts an intended o rdesired current loop formed by a cable: a signal and a return line transferring some current from a source Ug to a load RLand back. This is a differential-mode current, which means that, if we would use a current probe around the cable to measure the net current passing through the probe,we would find a zero value: all currents going from the source to the load return via the intended return conductor.Consider the circuit in figure 1



F.1

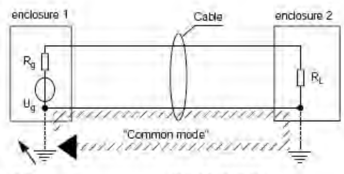
It depicts an intended ordesired current loop formed by a cable: a signal and areturn line transferring some current from a source Ug to aload RL and back. this is a differential-mode current, whichmeans that, if we would use a current probe around thecable to measure the net current passing through the probe,we would find a zero value: all currents going from thesource to the load return via the intended return conductor.

Complications arise, when there are alternative return pathsavailable e.g. via connections for safety grounding.In that case there is a choice for the return current: Figure 2.



F.2

When a portion of the return current takes the alternative path, we will be able to measure a net amount of current with a current probe around the cable. Figure 3.



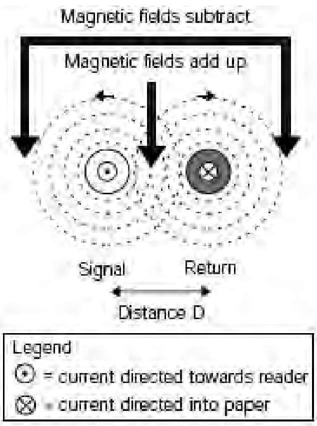
F.3

These undesired currents are not intended by the designer of the equipment and, worse, usually not included into hisan alyses. It is these "forgotten" currents that create most of the sometimes damaging interference in electronic systems.

Cables convert from dm to cm and back

Cables or, more generally, interconnections have the property to convert differential mode currents into common-mode currents and vice-versa. This property iscalled "transfer-impedance". This is the basic phenomenon which is responsible for electromagnetic interference.

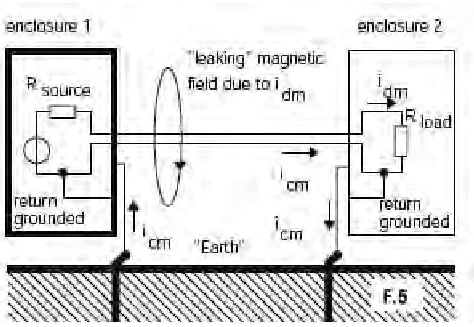
The rest is "related topics". For instance: all currents are accompanied by a magnetic field. The picture in figure 4 shows a two wire cable. Each wire carries the same current but their directions are opposite.



F.4

The magnetic field lines belonging to each of them "add up " between the two wires and "subtract" outside that area. Assuming ideal conditions, the combined magnetic field magnitudes could be reduced to zero if it were possible to position the two wires "on top of" each other, exactly centred. The then equal but opposite fields at any position would exactly cancel ("coax" situation)!

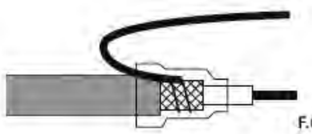
In any practical situation there will, however, be some dis-tance between the two wires. This means that some amount of field will be measurable outside the cable. This field inturn induces currents in any conducting loop in the neigh-bourhood. This includes the loop formed by the cable itself and any alternative return conductor (a "common-mode" or ground-loop)! Figure 5.



F.5

This alternative conductor could be the machine' s structure,safety grounding provisions, the enclosure wall or othercables. This (induced) current in the usually larger loop is a common-mode (cm) current. Transfer impedance is aproperty of a complete interconnection: cable plus connectors, patch panels etc. from source to load!

The properties of a very good cable can be ruined by a lousy finishing e.g. the infamous "pig-tail" construction on shielded cables. Figure 6.


F.6

2. Interference sources and susceptibility threats

Thus, interconnections are our sole concern for all EMC related issues. From printed circuit board traces to systemcabling! We can divide the threats to our systems into "man-made" and "natural". Actual interference is always a susceptibility problem: the disturbed system is unable to cope with the fields or currents that threaten it. Whether the system should be able to cope with them is determined by the prescribed levels in the EMC standards! If the system is too susceptible (civil standards call it "insufficient immunity") you will have to improve it by working on the various interconnections by improving their transfer-impedance. If the system is ok., the interference source has to be located and a similar process must be carried out to reduce its "emissions"

Man-made threats

Interference with a continuous character

Most interference emerges from equipment either your own system or the neighbour' s. Well known sources of high-frequency fields are transmitters from public services to GSM telephones. Notably the portable telephones are a threat since they are mobile and can get very close to the susceptible equipment. Fields related to transmitters and other high frequency equipment are in the range from 1 to 100 Volts per meter (Electric field value). Typically 10 V/m or an industrial environment (but: no guarantee)! As a rule of thumb each lt-per-meter of field gives rise toa common-mode current of 10 mA in an unprotected able.100 mA of cm-current is considered a critical value inprocess control installations. Apart from intentional transmitters there are the unintentional transmitters formed by interconnections hich generate common-mode currents and corresponding fields. A high-frequency current in a cable with inadequate transfer-impedance is the common cause.

This common-mode current can either flow directly on a sensitive cable (e.g. from analogue sensors) or create a high frequency electromagnetic field which induces common-mode currents in sensitive cables. Interference with an intermittent character A special type of interference are "impulsive disturbances" caused e.g. by switching inductive loads. Examples are relays, frequency converter/motor combinations and switched mode power supplies. When inadequately "snubbered", high peak values in voltage and current are reached when the load is switched. These currents travel through the interconnecting cables and are converted into common-mode currents. The interference mechanism is, of course, identical to the continuous case but due to the intermittent character, it can be more difficult to locate the source of the problem. Common-mode currents from these sources can be considerate: several hundreds of millions amperes especially when relay contacts degrade over time.

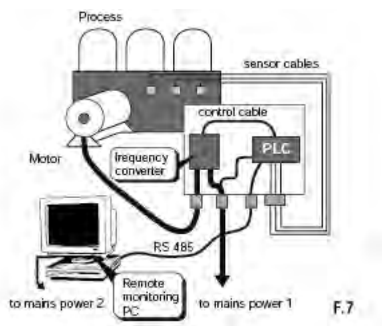
Natural sources of interference

Natural sources are lightning and electrostatic discharge (ESD). The phenomena are related. In either case a (static) electric discharge occurs. In the lightning case a large circuit is involved with dimensions reaching many kilometres. In the ESD case, there is usually a person carrying the charge and discharging into a piece of equipment by touching it.
The lightning stroke is a high-energy phenomenon with a relatively low frequency character. Consequently most interference is transferred by conduction. ESD is a high frequency phenomenon with a lower energy content. High frequencies, however, can travel "through air" (capacitive effect) and the corresponding damaging current in the equipment cannot easily be diverted. If there is a susceptible component in its path: too bad for the component. Common-mode currents as a result from these natural sources can reach very high values.
Amperes are not uncommon. (A direct lightning stroke typically has 50 kA -i.e. 50000 A-, ESD from 5 -40 A)

3. Measures to improve compatibility

Packaging of equipment can have a major effect on the behaviour in electromagnetically "hostile" environments. In the following sections several approaches are shown. Most of them are very cheap when considered at the design stage. Later in the lifecycle protective measures becomescarce and more expensive.

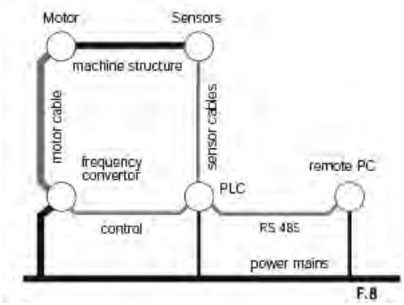
Recognize common-mode or ground loops
Split up cables into categories
All EMC problems (well, 98%) are common-mode problems. Try to develop an instinct for common-mode or ground-loops. Once found, they can be treated followingthe systematic approach given below. A first example was given in figure 5, a slightly more complex example is shown in figure 7.



F.7

Electromagnetic (EMI) shielding

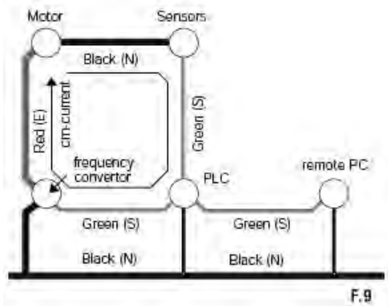
Several cable types can be observed in this diagram. It is usually helpful to draw a simplified diagram showing equipment as circles with interconnecting conductors.
Do not forget to include power, "ground" and machine structure as conductors! In the diagram of figure 8, several cable types can be recognized:



- Cables with large and/or high frequency currents. Indicate this type using a red colour or the letter "E" for Emission: due to transfer-impedance it will generate possibly large common-mode currents.
Example: the cable between frequency converter and motor
- Cables that neither generate nor are susceptible to common-mode currents. Indicate them using a blackcolour or the letter "N" for Neutral.
Example: power cables, machine or building structure,metal piping etc.
- Cables that carry small analog signals or are otherwise sensitive to interference by common-mode currents across them. Indicate this type using a green colour or the letter "S" for Susceptible.
Example: sensor cabling, RS-485 line, PLC/frequency converter control cable. Figure 9.
Of course, more detailed distinctions can be made. Books on EMC generally use five to seven cable categories.
The RS-485 cable in our example can be susceptible to cm-currents from the motor cable but could be an interference source to sensitive analog signals! The three categories used here are only used to demonstrate the principle: our effort should be focused on keeping the emission sources separated from the sensitive cables!

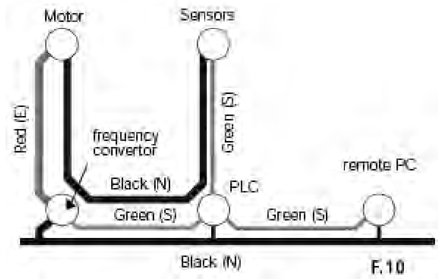
Reduce your sensitivity to cm-currents

Keep interconnections short
The first thing we can do is keep cable lengths short. All interference is ultimately coupled through transfer-impedance, the cable property that converts common-modecurrents to differential and vice versa. This effect increases with cable length! The shorter the cable, the smaller the effect. For that reason interference risks in our examplein figure 8 and figure 9 would go down dramatically if we could manage to build the frequency converter right down on the motor! No cable length to speak of, no generation of common-mode currents. Of course, external fields remain as threats to our sensitive cables.



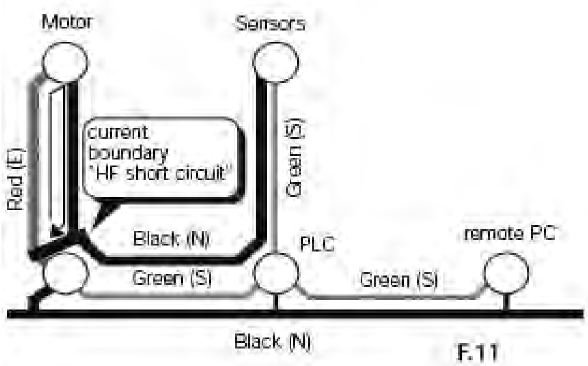
Shield cables
The conversion of differential-mode to common-mode currents and vice-versa can be reduced considerably by shielding the cables. In other words, this reduces their transfer impedance. It is important to connect the shielding on both ends to the equipment the cable connects. The best way to do this is using an EMC gland (discussed later) or metal connector shell i.e. by providing a contact over 360° between the braid and the enclosure wall itenters. The measures described below are, nevertheless, appropriate when considerable distances have to be covered.

Reduce common-mode loop areas
As a next step it is useful to reduce the areas of (all) common-mode loops detected. This does not readilyremove the common-mode currents in our loops but at leastthe field outside the loop will be reduced by this action.Further, it makes the loop less sensitive to external fields.The reduction can be achieved by routing the categorymarked "black" or "N" alongside the green and red ones.Figure 10.



In our specific situation the black conductor between motor and sensors is the machine structure! It is cumbersome to bend it alongside the cables so a solution where the cables are routed along the structure is more appropriate here! But, as long as the enclosure containing the PLC and frequency converter cannot be built on the machine structure itself, this will remain difficult. So we will have to look for other alternatives.

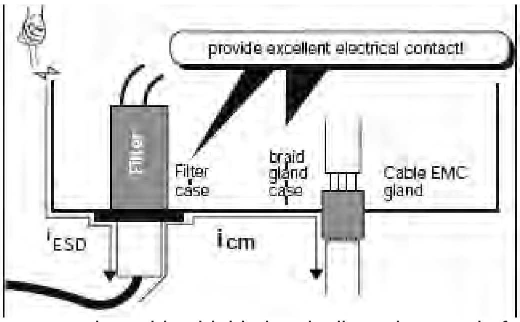
EMC grounding: current boundaries
For that we will take our next step first: try to divert the threatening common-mode currents away from the sensitive cables i.e. provide an alternative path for them.This alternative is called a "current boundary" or referenceconductor.
Figure 11.



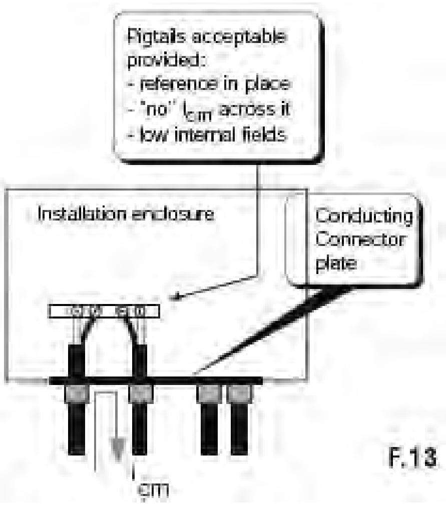
In the situation of figure 10, this would call for a (high frequency) connection between the bottom end of the red cable and the black conductor next to it. Of course, the closer the current boundary is to the end of the cable, the larger the effect will be.

The construction of current boundaries

The current boundary is defined as a path for at least the high frequency part of the common-mode currents. In case the red cable is a shielded type cable (highly recommended, see below), the cable shield could be connected to the black conductor. If this is the machine structure, a bracket could be used to electrically connect the braid to the structure. If it is another cable with shielding, the twoshields could be bracketed together. In any case: keep this connecting device as small as possible.
Whatever the construction, the obvious spot to locate it is at the interface with our equipment (the circles in figure 11). It is practical to always use "natural boundaries" for thispurpose. A natural boundary that is obvious in figure 7 isthe enclosure containing PLC and frequency converter. Assuming it is a metal case, the interconnections between the various cables could be made at their entry point. Special EMC glands are commercially available for this purpose. Figure 12.



They connect the cable shield electrically to the metal of the enclosure. For cables without shields, filters are theavailable option. Filters are insulators for mains frequencies(50 - 400 Hz) while forming a short circuit to the enclosurefrom, say, 100 kHz upward. Actually, what happens at thecurrent boundary (= enclosure wall) is that an originallylarge common-mode loop is cut into a very small enclosure-internal one and a large outside version. Figure 13.

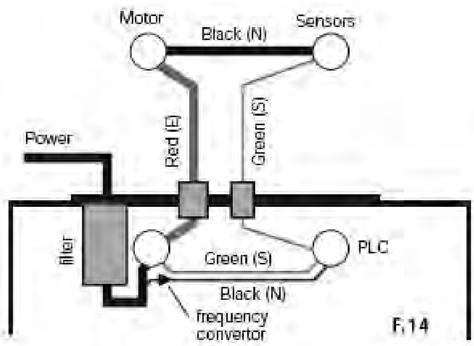


F.13

The small portion of the red cable remaining inside will cause only a small common-mode current. In many cases, small pigtails (figure 6) may even be acceptable inside the enclosure! To enable an excellent electrical contact between EMC glands, filters and other current boundary techniques, the enclosure entrance plate for cabling is often given a lasting conductive finish. If not, the locations for your EMCglands should be thoroughly ground or polished bare before mounting them. Afterwards a protective layer of paint can be applied.

Use metal cable guides

Let us assume these provisions have been made on our enclosure of figure 7. Our diagram would look like the one below. Figure 14.

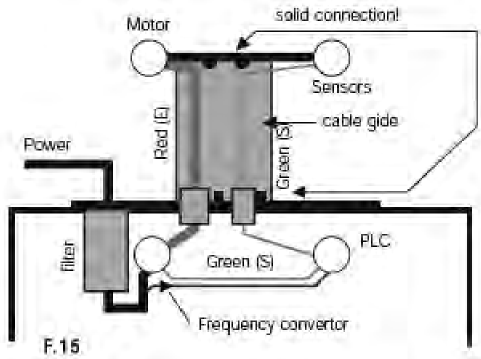


F.14

Objections may be brought in to the mounting of the filter in the enclosure wall. From an EMC point of view this is, however the best option. If mounted inside, place it as close as possible to the entry point of the power cable (no EMC gland here) and keep the wire between the entry point and the filter very close to the enclosure wall. Make sure the filter has very good electrical contact to the enclosure. It is advisable to check all current boundaries using a milli-ohm meter. Measure between the metal case and each cablebraid or to the filter.

It is advisable to check all current boundaries using a mili-ohm meter. Measure between the metal case and each cable braid or to the filter.

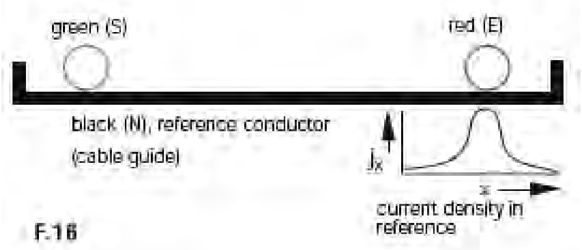
Having done all this, we are faced with a new problem:running between instrumentation enclosure and machine are two cables: the motor cable (red) and the sensor cable (taken together, green). No black conductor to protect them! The solution is: the cable guide. To be effective, it should be made out of metal (conducting). This cable guide is connected (directly or with very short litz wire straps) to the instrumentation enclosure and to the m\achine structure. The red and green cabling is then placed against the metal of the cable guide with some distance between red and green. Figure 15.



F.15

Electromagnetic (EMI) shielding

The cable guide provides the alternative path for the common-mode current. It separates the two cables by virtue of the proximity effect: a current will always take thenearest possible conductor as return conductor (provided it is connected electrically!). For high frequencies, the returncurrent (our common-mode current) will concentrate underthe conductor that generates the current. Figure 16.



F.16

The distance between the red and green cable (-sets) should be between 5 and 10 times the diameter of the larger cable. Note: Cabling should always be routed along wide metalsurfaces. A separate construction is not always needed though. Any wide metal can be used! The machine structure already mentioned is fine but the metal enclosure wall is excellent for this purpose too!

4. The final option: shielding equipment against electromagnetic fields

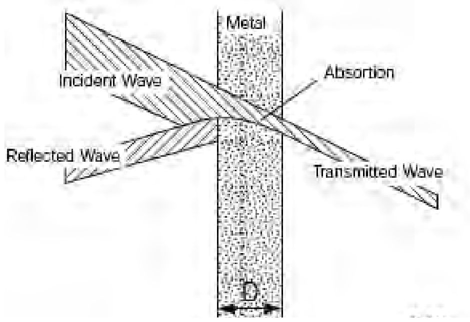
The effects of shielding

Shielding is a means to keep electromagnetic fields out of an enclosure.

For that purpose the enclosure should, theoretically, be completely made out of metal and be "gas-tight". The enclosure wall can then, more or less, be considered to extend infinitely. A model often encountered for an infinite shielding wall is the transmission line model given in figure 17. When an electromagnetic wave encounters a metal wall, some of the energy is reflected and some passed into the metal. At the other side of the wall, a similar process again reflects part of the transmitted wave and passes the rest. This final wave which emerges from the inside of the wall in relation to the original incident wave on the outside is called the shielding effectiveness (SE).

SE = 20 log incident wave transmitted wave (db)

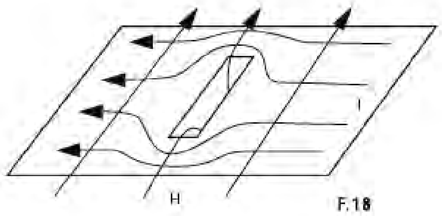
It is generally expressed in dB' s. The absorption which reduces the intensity of the wave on its path through the wall is a phenomenon called the skin effect. Important parameters in this mechanism are wall thickness and material properties like the conductivity of the metal and its magnetic permeability property.



Treatment of apertures in shielding

The effect of a hole in a shielded enclosure

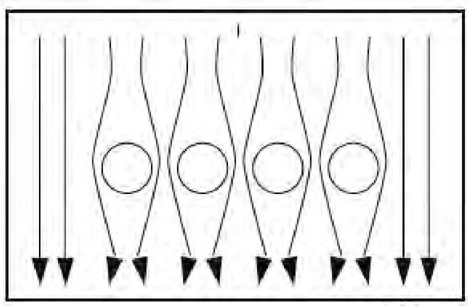
Practical enclosures, however, are never "gas-tight"! They have apertures, slits and seams which "leak" electromagnetic energy. These apertures determine the entire shielding behaviour of the enclosure. The effect can be imagined with the help of figure 18.



F.18

The effect of the field is a current in the shielding. This current generates a field which opposes the incident field. That way even non-magnetic materials can be used as shielding. When an aperture is encountered, the current has to flow around it. This deflects the external field into the aperture!

One way to reduce this effect is to replace one large aperture by a number of small apertures. This technique can be applied for apertures to allow light and air into an enclosure. Figure 19.

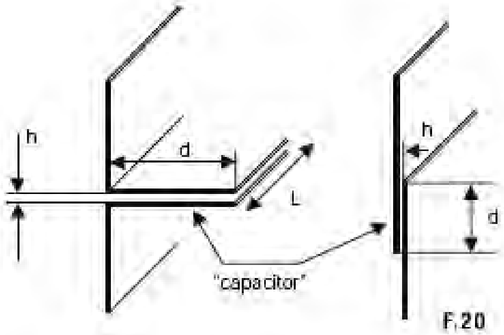

F.19

The effect of slits and seams

EMC enclosures built out of sheet metal are usually spot-welded. In that way small slits are formed which potentially leak electromagnetic energy. This leak is small when the slits are much smaller than one half wave length of the highest frequency to be shielded.

For GSM telephone fields (900 MHz), the slits would have to be considerably smaller than 16 cm (approximate half wavelength). Enclosures not originally intended for EMC can be improved by connecting the various metal panels using litz wire straps (short)! The number of straps can be determined using the same rule given for seamwidths (between straps) above.

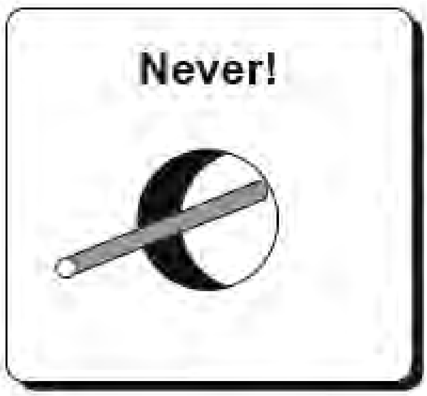
Overlap in seams can help to reduce higher frequencies too (e.g. with wavelengths shorter than the seam width). This measure works due to the effect of the so created capacitor. Figure 20.



F.20

Cabling of shielded enclosures

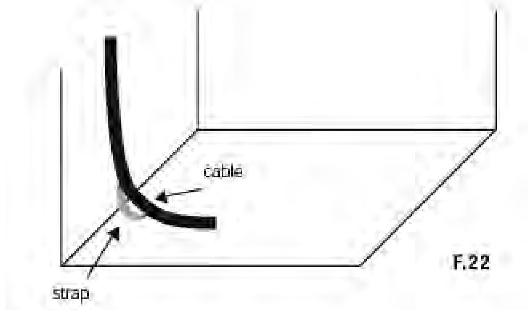
Never should a conductor be allowed to enter an enclosure unhindered: no cables or other conductors like shafts of controls or metal tubing. Figure 21.



F.21

There should be a direct electrical connection to the enclosure wall. If it is a cable, an EMC gland should be used (see figure 12). If you would allow the cable to pass the hole insulated while connecting the cable braid via a (long) cable, the loop formed by it would pick up electromagnetic energy (a common-mode current) and it would be conducted over the braid to the inside of the enclosure.

There it would reradiate, forming a leak! An unshielded cable passing an enclosure wall intended for shielding, should be filtered, if possible, directly on the wall. Figure 22.



F.22

Almost as bad as an unfiltered cable through an EMC shield is a cable crossing a slit in the enclosure wall.
When this is necessary, it is good practice to connect both sides of the slit electrically using a short strap of litz wire.

When is an EMC enclosure needed?

Most installations can be made to comply to the EMC directive using the measures described in section 3.

As long as the distances between cabling and protecting machine-structures or cable guides is much smaller than a half wavelength of the highest frequencies, few problems will be encountered. Field levels in an industrial environment are in the order of 10 Volts per meter (E-field) while the domestic value hardly exceeds 3 Volts per meter. Be aware though that the external threats like GSM telephones are everywhere and their frequency will go up to 1800 MHz (half wavelength 8 cm)!

The most sensible approach is to shield at the smallest possible scale: at the printed circuit board (PCB) level or at the PCB-rack level. The larger the enclosure (with respect to the wave length of the field) the more difficult shielding will be.