EMERSON Industrial Automation

CONTROL TECHNIQUES

UNIDRIVE SPM drive modules (90 to 710 kW)
ELECTROMAGNETIC COMPATIBILITY DATA

PRODUCT SPMD1401 – 1404, 1601 – 1604, SPMC/SPMU1401 – 1402, 2402, 1601
(Please refer to Unidrive SP drive, size 6 data sheet, for SPMA modules)

General note on EMC data

The information given in this data sheet is derived from tests and calculations on sample products. It is provided to assist in the correct application of the product, and is believed to correctly reflect the behaviour of the product when operated in accordance with the instructions. The provision of this data does not form part of any contract or undertaking. Where a statement of conformity is made with a specific standard, the company takes all reasonable measures to ensure that its products are in conformance. Where specific values are given these are subject to normal engineering variations between samples of the same product. They may also be affected by the operating environment and details of the installation arrangement

Modules

The modular range comprises rectifier and inverter modules, which can be used in various combinations, either individually or in parallel for higher output currents. The EMC data applies to all permitted combinations, provided that the interconnection instructions in the user guide are adhered to.

Issue 3 An error regarding the standard for radiated emission on page 14 has been corrected.

IMMUNITY

The modules comply with the following international and European harmonised standards for immunity:

Standard	Type of immunity	Test specification	Application	Level
EN 61000-4-2 IEC 61000-4-2	Electrostatic discharge	6kV contact discharge 8kV air discharge	Module enclosure	Level 3 (industrial)
EN 61000-4-3 IEC 61000-4-3	Radio frequency radiated field	80% AM (1kHz) modulation Levels prior to modulation: 10V/m 80 - 1000MHz 3V/m 1.4 – 2.0GHz 1V/m 2.0 – 2.7GHz	Module enclosure	Level 3 (industrial)
EN 61000-4-4 IEC 61000-4-4	Fast transient burst	5/50ns 2kV transient at 5kHz repetition frequency via coupling clamp	Control lines	Level 4 (industrial harsh)
		5/50ns 2kV transient at 5kHz repetition frequency by direct injection	Power lines	Level 3 (industrial)
EN 61000-4-5 IEC 61000-4-5	Surges	Common mode 4kV 1.2/50µs waveshape	AC supply lines: line to earth	Level 4
		Differential mode 2kV	AC supply lines: line to line	Level 3
		Common mode 1kV	Control lines[1]	
EN 61000-4-6 IEC 61000-4-6	Conducted radio frequency	10V prior to modulation 0.15 - 80MHz 80% AM (1kHz) modulation	Control and power lines	Level 3 (industrial)
EN 61000-4-11 IEC 61000-4-11	Voltage dips, short interruptions & variations	All durations	AC supply lines	
EN 61000-6-1 IEC 61000-6-1[2]	Generic immunity standard for the residential, commercial and light - industrial environment			Complies
EN 61000-6-2[3] IEC 61000-6-2	Generic immunity standard for the industrial environment			Complies
EN 61800-3 IEC 61800-3	Product standard for adjustable speed power drive systems (immunity requirements)		Meets immunity requirements for first and second environments	

[1] Applies to ports where connections may exceed 30m length. Special provisions may be required in some cases – see additional information below.
[2] Supersedes EN 50082-1
[3] Supersedes EN 50082-2

Unless stated otherwise, immunity is achieved without any additional measures such as filters or suppressors. To ensure correct operation the wiring guidelines specified in the User Guide must be carefully adhered to. All inductive components such as relays, contactors, electromagnetic brakes etc. associated with the drive must be fitted with appropriate suppression; otherwise the immunity capability of the drive may be exceeded.

Surge immunity of control circuits – long cables and connections outside a building
The input/output ports for the control circuits are designed for general use within machines and small systems without any special precautions.
These circuits meet the requirements of EN 61000-6-2 (1kV surge) provided the 0V connection is not earthed, i.e. in the common mode. Generally they cannot withstand the surge directly between the control lines and the 0V connection, i.e. in the series mode.

The surge test simulates the effect of lightning or severe electrical faults in a physically extended electrical system, where high differential transient voltages may appear between different points in the grounding system. This is a particular risk where the circuits extend outside the protection of a building, or if the grounding system in a large building is not well bonded.

In applications where control circuits may be exposed to high-energy voltage surges, some special measures may be required to prevent malfunction or damage. As a general rule, if the circuits are to pass outside the building where the drive is located, or if wiring runs within a building exceed 30m, some additional precautions are advisable. One of the following techniques should be used:

1. Galvanic isolation, i.e. do not connect the control 0V terminal to ground. Avoid loops in the control wiring, i.e. ensure every control wire is accompanied by its associated return (0V) wire.

2. Screened cable with additional power ground bonding. If isolation at one end is not acceptable, the cable screen may be connected to ground at both ends, but in addition the ground conductors at both ends of the cable must be bonded together by a power ground cable (equipotential bonding cable) with cross-sectional area of at least $10mm^2$, or 10 times the area of the signal cable screen, or to suit the electrical safety requirements of the plant. This ensures that fault or surge current passes mainly through the ground cable and not in the signal cable screen. If the building or plant has a well-designed common bonded network this precaution is not necessary.

3. Additional over-voltage suppression – for the analogue and digital inputs and outputs, a Zener diode network or a commercially available surge suppressor may be connected in parallel with the input circuit as shown in Figures 1 and 2.

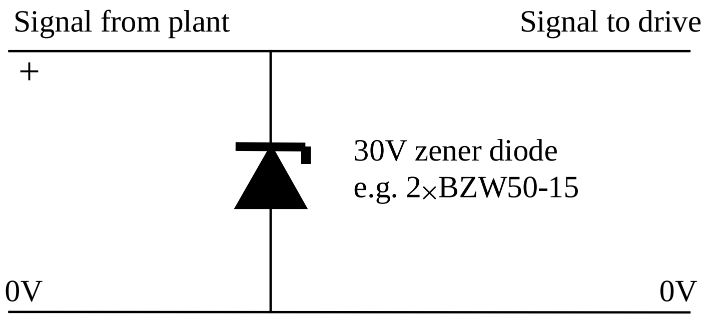

Figure 1: surge suppression for digital and unipolar analogue inputs and outputs

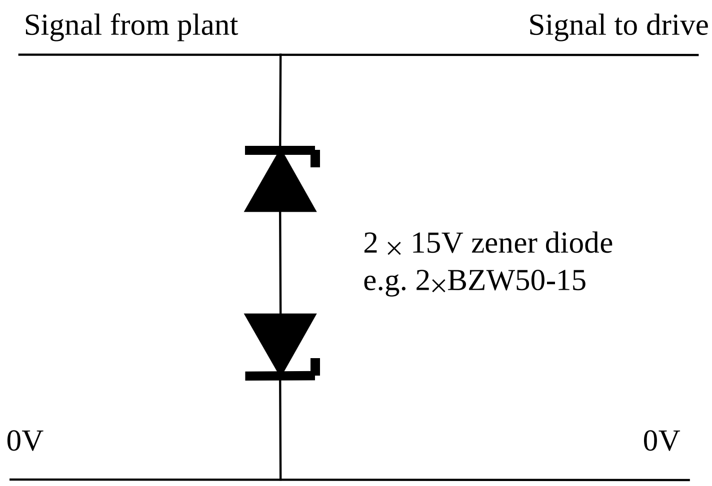

Figure 2: surge suppression for bipolar analogue inputs and outputs

Surge suppression devices are available as rail-mounting modules, e.g. from Phoenix Contact GmbH:

Unipolar	TT-UKK5-D/24 DC
Bipolar	TT-UKK5-D/24 AC

These devices are not suitable for encoder signals or fast digital data networks because the capacitance of the diodes adversely affects the signal. Most encoders have galvanic isolation of the signal circuit from the motor frame, in which case no precautions are required. For data networks, follow the specific recommendations for the particular network.

EMISSION

Emission occurs over a wide range of frequencies. The effects are divided into three main categories:

– Low frequency effects, such as supply harmonics and notching.
– High frequency emission below 30MHz where emission is predominantly by conduction.
– High frequency emission above 30MHz where emission is predominantly by radiation.

SUPPLY VOLTAGE NOTCHING

Because of the use of uncontrolled input rectifiers the drives cause no significant notching of the supply voltage.

SUPPLY HARMONICS

The input current contains harmonics of the supply frequency. The harmonic current levels are affected to some extent by the supply impedance (fault current level). The tables show the levels calculated for a single module on the assumption that there is a supply transformer with a realistic rating, between 4 and 10 times that of the drive. The ratio X/R is taken as 1. This would be typical of an industrial installation with the supply arrangements chosen to prevent excessive voltage distortion arising from the operation of a single drive. For installations where the fault level is lower, so that the harmonic current is more critical, the harmonic current will also be lower than that shown.
Note that the r.m.s. current in these tables may differ from the maximum specified in the user guide, since the latter is a worst-case value provided for safety reasons which takes account of permitted supply voltage imbalance. The motor efficiency also affects the current, a standard Eff2 4-pole motor has been assumed.
For multiple parallel modules, all of the relative data (e.g. harmonics as %) remain the same.
For balanced sinusoidal supplies, all even and triplen harmonics are absent.

The supply voltages for the calculations were 400V and 690V 50Hz. The harmonic percentages do not change substantially for other voltages and frequencies within the drive specification, and in particular they are very similar at 480V 60Hz since the per-unit inductive reactances are unchanged.

The data is given for full and half load power. Note that it is power and not torque or motor current which governs input current. For other loads in the range 50% to 100% of rating, linear interpolation of the harmonics as % of input current gives an adequate estimate for most purposes.

The results are classified according to the inverter model and rating (heavy or normal duty). It is assumed that the appropriate rectifier is in use according to the instructions in the user guide. There is no difference in harmonic behaviour between the SPMC and SPMU rectifiers, nor between SPMC1402 and SPMC2402. The harmonic current is determined by the following parameters:

- Electrical power input to motor
- Input choke inductance value
- Inverter module model (small effect only)

400V drives – single rectifier/inverter pairs classified by SPMD model number

Model and duty (H/N)	1401 HD	1401 HD	1401 ND	1401 ND	1402 HD	1402 HD	1402 ND	1402 ND	1403 HD	1403 HD	1403 ND	1403 ND	1404 ND	1404 ND
											1404 HD	1404 HD		
Load power	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half
I RMS (A)	175.5	93.0	206.4	111.2	202.6	110.6	236.9	130.3	245.7	133.2	289.7	158.6	353.7	194.3
I_1 (A)	143.3	70.6	174.3	86.1	174.0	86.3	208.6	103.6	208.6	103.2	253.0	125.4	317.0	157.3
THD (%)	70.8	85.7	63.4	81.6	59.6	80.2	53.8	76.2	62.2	81.6	55.7	77.4	49.5	72.4
Power Factor	0.8021	0.7509	0.8302	0.7653	0.8441	0.7689	0.8651	0.7825	0.8348	0.7647	0.8589	0.7792	0.8807	0.7960
cosϕ	0.9826	0.9891	0.9830	0.9877	0.9826	0.9857	0.9825	0.9839	0.9831	0.9869	0.9833	0.9852	0.9825	0.9829
Distortion Factor	0.8162	0.7591	0.8446	0.7748	0.8590	0.7801	0.8805	0.7953	0.8492	0.7749	0.8735	0.7909	0.8964	0.8099
Input power (kW)	97.5	48.4	118.7	58.9	118.5	58.9	142.0	70.6	142.1	70.6	172.4	85.6	215.8	107.1
Harmonic order:	% of fundamental (I_1)													
5	60.99	70.01	55.70	67.69	52.77	66.81	48.52	64.41	54.73	67.63	50.00	65.15	45.30	62.04
7	34.68	47.32	29.02	43.88	26.18	42.63	21.69	39.24	28.13	43.81	23.10	40.26	18.12	36.01
11	5.18	10.64	5.47	8.20	6.22	7.92	6.36	6.58	5.92	8.43	6.14	6.70	6.24	5.73
13	6.39	5.99	5.22	6.16	4.90	6.70	3.92	6.87	5.27	6.48	4.16	6.70	3.18	6.74
17	2.40	5.57	2.51	4.57	2.85	4.39	2.93	3.45	2.71	4.69	2.83	3.68	2.85	2.74
19	2.54	3.18	2.07	2.54	1.94	2.64	1.61	2.60	2.08	2.68	1.66	2.51	1.43	2.65
23	1.44	2.87	1.49	2.67	1.69	2.64	1.70	2.19	1.61	2.74	1.66	2.29	1.61	1.69
25	1.33	2.38	1.04	1.83	1.02	1.75	0.95	1.43	1.08	1.89	0.93	1.46	0.96	1.37
29	0.97	1.41	1.03	1.49	1.14	1.58	1.13	1.43	1.09	1.55	1.11	1.48	1.00	1.15
31	0.82	1.52	0.66	1.34	0.67	1.31	0.67	1.02	0.68	1.39	0.64	1.08	0.72	0.87
35	0.69	0.90	0.70	0.90	0.79	0.97	0.75	0.99	0.77	0.94	0.75	0.98	0.64	0.82
37	0.55	0.95	0.46	0.98	0.50	0.98	0.56	0.77	0.48	1.00	0.52	0.84	0.56	0.60
41	0.53	0.77	0.57	0.56	0.61	0.61	0.53	0.67	0.59	0.60	0.55	0.64	0.42	0.63
43	0.40	0.57	0.32	0.62	0.38	0.69	0.43	0.65	0.36	0.65	0.41	0.66	0.44	0.48
47	0.40	0.66	0.42	0.52	0.45	0.49	0.39	0.46	0.45	0.54	0.41	0.44	0.29	0.46
49	0.31	0.54	0.30	0.44	0.33	0.47	0.36	0.47	0.31	0.46	0.35	0.49	0.33	0.38

600V drives – single rectifier/inverter pairs classified by SPMD model number

Model and duty (H/N)	1601 HD	1601 HD	1601 ND	1601 ND	1602 ND	1602 ND	1603 HD	1603 HD	1603 ND	1603 ND	1604 ND	1604 ND
			1602 HD	1602 HD					1604 HD	1604 HD		
Load power	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half
I RMS (A)	99.5	53.7	117.0	64.1	136.7	75.4	139.5	76.6	165.0	91.2	188.0	103.9
I_1 (A)	82.7	40.9	100.6	49.9	120.6	60.0	120.5	59.8	146.1	72.7	169.2	84.2
THD (%)	66.7	84.8	59.3	80.4	53.5	76.4	58.4	80.1	52.4	75.7	48.5	72.3
Power Factor	0.8164	0.7523	0.8452	0.7674	0.8663	0.7812	0.8485	0.7684	0.8706	0.7833	0.8841	0.7952
cosϕ	0.9815	0.9866	0.9824	0.9849	0.9824	0.9830	0.9827	0.9846	0.9828	0.9827	0.9824	0.9811
Distortion Factor	0.8318	0.7625	0.8603	0.7792	0.8818	0.7947	0.8634	0.7804	0.8858	0.7972	0.8999	0.8105
Input power (kW)	96.8	48.3	117.8	58.8	141.1	70.5	141.0	70.4	171.0	85.5	197.7	98.9
Harmonic order:	% of fundamental (I_1)											
5	57.86	69.42	52.41	66.91	48.14	64.47	51.77	66.71	47.27	64.04	44.30	61.80
7	31.68	46.47	26.00	42.80	21.52	39.34	25.39	42.51	20.70	38.76	17.63	35.85
11	6.31	10.45	6.52	8.24	6.62	6.89	6.66	8.19	6.75	6.87	6.74	6.40
13	6.27	6.72	5.00	6.93	4.03	7.09	4.94	7.04	3.93	7.19	3.35	7.15
17	2.84	5.63	2.99	4.54	3.04	3.61	3.05	4.52	3.10	3.53	3.07	2.97
19	2.53	3.29	1.99	2.76	1.66	2.70	1.98	2.80	1.66	2.76	1.56	2.86
23	1.68	3.01	1.77	2.72	1.78	2.25	1.80	2.71	1.79	2.19	1.71	1.79
25	1.30	2.37	1.06	1.83	0.99	1.50	1.07	1.81	1.01	1.51	1.06	1.51
29	1.14	1.58	1.19	1.62	1.15	1.49	1.21	1.64	1.16	1.47	1.07	1.21
31	0.82	1.62	0.70	1.36	0.72	1.06	0.71	1.36	0.74	1.04	0.77	0.94
35	0.80	0.96	0.83	1.00	0.78	1.01	0.84	1.01	0.77	1.01	0.67	0.86
37	0.55	1.02	0.52	1.01	0.57	0.82	0.54	1.01	0.59	0.80	0.62	0.65
41	0.64	0.78	0.63	0.63	0.55	0.69	0.63	0.65	0.54	0.70	0.43	0.64
43	0.39	0.65	0.41	0.71	0.46	0.65	0.42	0.72	0.47	0.64	0.47	0.50
47	0.47	0.68	0.47	0.51	0.39	0.48	0.47	0.50	0.39	0.50	0.32	0.48
49	0.33	0.52	0.35	0.48	0.37	0.51	0.36	0.49	0.38	0.50	0.34	0.40

Input line reactors (line chokes) and d.c. chokes

Where necessary, a reduction in harmonic current levels can be obtained either by fitting increased values of reactor (chokes) in the input supply lines to the drive or by including d.c. chokes between the rectifier module(s) and the inverter module(s).

A.c. chokes have the benefit of giving increased immunity from supply disturbances such as voltage surges caused by the switching of high-current loads or power-factor correction capacitors on the same supply circuit. Their main disadvantage is that they cause some voltage drop as the load power increases. This means that there is a limit to how much harmonic reduction can be achieved before the loss of torque at full speed becomes unacceptable.

D.c. chokes have the advantage that they cause negligible d.c. voltage drop. However they show rapidly diminishing benefits as their value increases, since the harmonics can only approach the "textbook" limits of 20% 5^{th}, 14% 7^{th}, 9.1% 11^{th} etc. as the value approaches infinity.

The following table shows the corresponding harmonics where increased reactors are fitted in the supply lines, chosen to enable the following limits to be met at full load:

IEC 61000-3-4	Table 3	$R_{SCE} \geq 350$
IEC 61000-3-12	Table 4	$R_{SCE} \geq 120$

(The scope of IEC 61000-3-12 is limited to equipment rated at ≤75A)

The key limits in these standards are 5^{th} harmonic of 40% and THD of 48%.

The reactors cause a reduction of up to 3.4% in the d.c. link voltage, which will normally still permit the full rated torque to be developed in a standard motor. Higher values should only be used if some reduction of available torque at maximum speed is acceptable. The inductance value (L) is the required external inductance which should be used in place of the standard choke (INL401 – INL602). A tolerance of –10% and +20% is permitted. The current rating should at least be equal to the r.m.s. current shown in the table, and the peak current rating at least equal to twice that value.

Input line reactors (line chokes) and d.c. chokes

Where necessary, a reduction in harmonic current levels can be obtained either by fitting increased values of reactor (chokes) in the input supply lines to the drive or by including d.c. chokes between the rectifier module(s) and the inverter module(s).

A.c. chokes have the benefit of giving increased immunity from supply disturbances such as voltage surges caused by the switching of high-current loads or power-factor correction capacitors on the same supply circuit. Their main disadvantage is that they cause some voltage drop as the load power increases. This means that there is a limit to how much harmonic reduction can be achieved before the loss of torque at full speed becomes unacceptable.

D.c. chokes have the advantage that they cause negligible d.c. voltage drop. However they show rapidly diminishing benefits as their value increases, since the harmonics can only approach the “textbook” limits of 20% 5^{th}, 14% 7^{th}, 9.1% 11^{th} etc. as the value approaches infinity.

The following table shows the corresponding harmonics where increased reactors are fitted in the supply lines, chosen to enable the following limits to be met at full load:

IEC 61000-3-4	Table 3	$R_{SCE} \geq 350$
IEC 61000-3-12	Table 4	$R_{SCE} \geq 120$

(The scope of IEC 61000-3-12 is limited to equipment rated at ≤75A)

The key limits in these standards are 5^{th} harmonic of 40% and THD of 48%.

The reactors cause a reduction of up to 3.4% in the d.c. link voltage, which will normally still permit the full rated torque to be developed in a standard motor. Higher values should only be used if some reduction of available torque at maximum speed is acceptable. The inductance value (L) is the required external inductance which should be used in place of the standard choke (INL401 – INL602). A tolerance of –10% and +20% is permitted. The current rating should at least be equal to the r.m.s. current shown in the table, and the peak current rating at least equal to twice that value.

400V drives with increased a.c. chokes – single rectifier/inverter pairs classified by SPMD model number

Model and duty (H/N)	1401 HD	1401 HD	1401 ND	1401 ND	1402 HD	1402 HD	1402 ND	1402 ND	1403 HD	1403 HD	1403 ND	1403 ND	1404 ND	1404 ND
											1404 HD	1404 HD		
Load power	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half
I RMS (A)	154.9	82.9	188.8	100.8	187.9	100.0	225.0	119.1	224.4	118.5	273.3	144.9	342.3	180.9
I_1 (A)	143.2	71.2	174.6	86.6	174.5	86.5	209.4	103.7	209.2	103.6	253.8	125.6	318.1	157.0
THD (%)	41.2	59.8	41.1	59.6	40.0	57.8	39.4	56.5	38.8	55.6	39.9	57.5	39.7	57.2
Power Factor	0.9052	0.8421	0.9051	0.8432	0.9086	0.8498	0.9102	0.8547	0.9123	0.8583	0.9092	0.8512	0.9094	0.8529
$\cos\phi$	0.9790	0.9813	0.9787	0.9815	0.9788	0.9816	0.9782	0.9819	0.9784	0.9819	0.9789	0.9821	0.9786	0.9824
Distortion Factor	0.9246	0.8581	0.9248	0.8590	0.9283	0.8657	0.9305	0.8705	0.9324	0.8741	0.9288	0.8667	0.9293	0.8682
Input power (kW)	97.2	48.4	118.4	58.9	118.3	58.9	141.9	70.5	141.8	70.5	172.1	85.5	215.7	106.9
Harmonic order:	% of fundamental (I_1)													
5	38.31	52.55	38.36	52.47	37.35	51.04	36.86	50.16	36.27	49.35	37.34	50.95	37.32	50.78
7	12.50	26.65	12.30	26.41	11.71	25.15	11.11	24.12	10.83	23.45	11.41	24.85	11.10	24.46
11	6.84	7.23	6.67	7.01	6.78	7.31	6.61	7.16	6.69	7.36	6.61	7.08	6.40	6.80
13	2.94	5.43	2.86	5.27	2.93	5.13	2.87	4.84	2.94	4.78	2.84	4.97	2.74	4.77
17	2.96	3.30	2.86	3.20	2.89	3.34	2.77	3.28	2.78	3.37	2.79	3.24	2.68	3.12
19	1.73	2.19	1.70	2.13	1.77	2.08	1.76	1.96	1.80	1.97	1.73	2.02	1.68	1.91
23	1.48	1.95	1.43	1.89	1.41	1.97	1.33	1.93	1.33	1.98	1.36	1.90	1.28	1.84
25	1.22	1.17	1.18	1.13	1.21	1.14	1.18	1.10	1.19	1.11	1.18	1.10	1.14	1.06
29	0.81	1.31	0.77	1.28	0.75	1.32	0.70	1.28	0.70	1.31	0.71	1.28	0.67	1.22
31	0.82	0.77	0.79	0.74	0.80	0.77	0.76	0.75	0.76	0.77	0.77	0.74	0.73	0.71
35	0.50	0.92	0.47	0.88	0.48	0.91	0.46	0.89	0.46	0.90	0.46	0.88	0.45	0.85
37	0.53	0.57	0.51	0.56	0.50	0.59	0.46	0.58	0.46	0.61	0.47	0.58	0.43	0.55
41	0.36	0.70	0.36	0.68	0.37	0.68	0.38	0.65	0.38	0.66	0.37	0.66	0.37	0.63
43	0.37	0.44	0.34	0.42	0.34	0.46	0.31	0.47	0.31	0.48	0.32	0.44	0.30	0.44
47	0.30	0.52	0.30	0.50	0.31	0.51	0.31	0.48	0.32	0.48	0.31	0.49	0.30	0.47
49	0.25	0.38	0.24	0.38	0.25	0.40	0.25	0.39	0.25	0.41	0.24	0.39	0.25	0.37
L (μH)	180		150				130				100		80	

600V drives with increased a.c. chokes – single rectifier/inverter pairs classified by SPMD model number

Model and duty (H/N)	1601 HD	1601 HD	1601 ND	1601 ND	1602 ND	1602 ND	1603 HD	1603 HD	1603 ND	1603 ND	1604 ND	1604 ND
			1602 HD	1602 HD					1604 HD	1604 HD		
Load power	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half	Full	Half
I RMS (A)	89.1	47.4	108.6	57.8	130.1	68.9	129.6	68.4	157.4	82.9	182.3	95.6
I1 (A)	82.8	41.1	100.9	50.1	121.2	60.0	121.1	60.0	147.2	72.8	170.6	84.3
THD (%)	39.8	57.4	39.8	57.5	39.1	56.1	38.2	54.6	38.0	54.4	37.7	53.7
Power Factor	0.9098	0.8511	0.9096	0.8510	0.9113	0.8561	0.9142	0.8617	0.9145	0.8627	0.9154	0.8654
cosϕ	0.9791	0.9814	0.9790	0.9815	0.9784	0.9818	0.9786	0.9819	0.9785	0.9821	0.9781	0.9822
Distortion Factor	0.9292	0.8672	0.9291	0.8670	0.9314	0.8719	0.9342	0.8776	0.9346	0.8785	0.9358	0.8811
Input power (kW)	96.7	48.3	117.7	58.8	141.0	70.4	140.9	70.4	170.9	85.3	197.7	98.7
Harmonic order:	% of fundamental (I1)											
5	36.96	50.60	37.08	50.71	36.55	49.79	35.68	48.53	35.63	48.42	35.36	47.97
7	11.77	24.98	11.66	24.96	11.07	23.90	10.64	22.85	10.43	22.58	10.08	22.00
11	6.99	7.64	6.88	7.48	6.71	7.35	6.80	7.60	6.66	7.44	6.53	7.32
13	3.05	5.25	2.99	5.17	2.93	4.87	3.02	4.76	2.96	4.63	2.92	4.46
17	2.99	3.50	2.93	3.42	2.82	3.37	2.81	3.48	2.75	3.41	2.66	3.36
19	1.83	2.14	1.80	2.11	1.78	1.99	1.85	1.99	1.81	1.94	1.80	1.87
23	1.47	2.06	1.44	2.02	1.34	1.98	1.34	2.03	1.28	1.99	1.22	1.96
25	1.26	1.19	1.23	1.16	1.21	1.12	1.22	1.14	1.20	1.12	1.17	1.10
29	0.78	1.37	0.76	1.34	0.70	1.31	0.70	1.35	0.67	1.32	0.64	1.29
31	0.83	0.80	0.81	0.79	0.77	0.77	0.76	0.80	0.74	0.78	0.71	0.78
35	0.50	0.96	0.48	0.93	0.48	0.91	0.47	0.91	0.48	0.88	0.47	0.87
37	0.52	0.61	0.51	0.60	0.46	0.60	0.46	0.65	0.43	0.64	0.41	0.63
41	0.38	0.71	0.38	0.70	0.39	0.66	0.39	0.67	0.40	0.65	0.40	0.62
43	0.35	0.49	0.34	0.48	0.32	0.48	0.31	0.50	0.30	0.49	0.29	0.49
47	0.32	0.53	0.32	0.52	0.31	0.49	0.33	0.48	0.31	0.47	0.30	0.45
49	0.25	0.41	0.25	0.41	0.26	0.41	0.26	0.43	0.27	0.42	0.27	0.41
L (μH)	540		440		380				310		270	

D.C. chokes

D.c. chokes need to be selected with some care since unfortunate choices of inductance value can result in undesirable resonant frequencies with the d.c. link capacitors, resulting in undue sensitivity to unbalance between supply phases. It is recommended that reactance values of approximately 2.5% or 7% should be used, based on the rating of the motor. The following data for the SPMD1404 illustrate typical results. At 2.5% the effect is similar to that of added a.c. reactance, except that the 5th harmonic is slightly lower, higher-order harmonics are higher, and the d.c. link voltage drop is negligible. At 7% the main harmonics are reduced further and the d.c. link voltage drop is still negligible. It is not recommended that higher values be used because of the increased risk of resonance with the d.c. capacitance and the diminishing returns in terms of harmonic reduction.

	63	63	180	180
Model and duty (H/N)	1404 ND	1404 ND	1404 ND	1404 ND
	Full	Half	Full	Half
L (µH)	63		180	
I RMS (A)	335.8	176.5	327.6	165.9
I_1 (A)	314.8	156.1	313.5	154.9
THD (%)	37.1	52.8	30.3	38.3
Power Factor	0.9238	0.8723	0.9458	0.9252
cosϕ	0.9853	0.9863	0.9882	0.9908
Distortion Factor	0.9375	0.8844	0.9571	0.9338
Input power (kW)	214.9	106.6	214.7	106.4
Harmonic order:	% of fundamental (I_1)			
5	34.62	47.00	27.45	34.61
7	10.05	21.89	8.39	12.48
11	6.88	7.11	7.14	7.82
13	3.14	4.23	4.14	3.85
17	3.17	3.48	3.31	4.06
19	2.01	1.87	2.42	2.46
23	1.65	2.14	1.61	2.49
25	1.34	1.19	1.41	1.76
29	0.90	1.45	0.83	1.62
31	0.86	0.89	0.75	1.29
35	0.53	1.02	0.53	1.07
37	0.53	0.72	0.43	0.95
41	0.37	0.76	0.43	0.71
43	0.34	0.58	0.36	0.67
47	0.33	0.55	0.37	0.47
49	0.25	0.49	0.33	0.48

Further measures for reducing harmonics

With drives of high power rating, harmonics may pose a problem if a substantial part (e.g. over 50%) of the supply system capacity is accounted for by drives or other power electronic loads. Further guidance on harmonic reduction techniques is available from Control Techniques. Please contact your drive supplier for further information.

Note that the input current of the drive, including the harmonic content, is determined by the output power, i.e. the product of torque and speed. For a system of drives it is often the case that there is diversity of loading, i.e. the drives never deliver full rated power simultaneously. This should be allowed for in estimating the total harmonic current.

If the harmonic current is excessive, possible remedial measures are:

- 12-pulse rectifier (or higher pulse number if needed)
- Quasi-12-pulse operation (some drives on a separate supply with 30° phase shift)

- Series input filter (dedicated to one or more drives)
- Active input stage (regenerative Unidrive)
- Parallel harmonic filter (for the complete installation, not for individual loads)

12-pulse operation

For 12-pulse operation the preferred solution is to use the SPMC2402 (or SPMU2402) rectifier which has a dual 3-phase input. The simplest arrangement is to provide a dedicated fully-wound transformer to supply the rectifier. Then, provided the transformer is designed to have "loose coupling" between the phase-shifted secondary groups, no additional chokes are required, the transformer can feed the rectifier directly. The requirement is for a transformer reactance of at least 4% both from primary to secondaries and between secondaries.

The cost of the transformer can be reduced by using an autotransformer or polygonal autotransformer. In this case however some additional chokes are required to bring up the reactance of the source to at least 4%. The effect of insufficient reactance is to cause high input current in the two input rectifier groups, which includes high levels of 5th and 7th harmonic current circulating between the groups. This causes unnecessary additional losses and may result in overloading of the transformer, and of the rectifier especially in the case of the SPMD1404.

Further guidance is available from the drive supplier regarding the design of systems using Unidrive SP modules in high pulse numbers.

The table shows typical calculated harmonic levels for 12-pulse systems using a dedicated transformer with a reactance of 5% and loosely coupled secondary windings.

Load power	Full	Half
THD (%)	5.82	8.11
Power Factor	0.9353	0.9121
cosϕ	0.9369	0.9151
Distortion Factor	0.9983	0.9967
Harmonic order:	% of I_1	
5	0.02	0.01
7	0.02	0.01
11	4.54	6.35
13	3.13	4.60
17	0.02	0.01
19	0.02	0.01
23	1.27	1.55
25	0.94	1.03
29	0.02	0.01
31	0.02	0.01
35	0.60	0.58
37	0.47	0.54
41	0.02	0.01
43	0.02	0.01
47	0.29	0.33
49	0.28	0.31

The theoretical worst-case values of the 11th and 13th harmonics are 9.1% and 7.7% respectively. These are reduced in practice because of the transformer leakage inductance. If the transformer is not fully loaded by the drive then its reactance will be proportionately less effective and these harmonics will increase but they will not exceed the values shown for 6-pulse operation.
With such low levels of inherent harmonics, the effects of imperfections can be significant. It is recommended that allowance be made for the possible existence of 5th and 7th harmonics at about 5%, caused by imperfect balance between the 6-pulse groups, and of 3rd harmonic at about 5% caused by unbalance between supply phases.

Approved input filters
Some special series-connected passive harmonic filters are offered for use specifically with variable speed a.c. drives. Although these can be effective, some designs can seriously disturb the operation of the drive inrush current control system. Some designs can cause substantial reductions in d.c. bus voltage. Please consult the drive supplier before considering the use of such a filter.

Regenerative Unidrive
Regenerative operation is also referred to as "Active Front End". The diode rectifier at the input is replaced by an active converter which generates a sinusoidal back-e.m.f. which does not generate harmonics, although it may absorb harmonic current from a distorted supply. Please refer to the separately available user guide and EMC data sheet for regenerative operation of Unidrive SP.

Parallel passive filters
These filters are applied to complete installations, or complete LV power systems. Although they can be effective, they present difficulties with a.c. voltage-source drives because filters have a leading power factor whilst the drives have virtually unity displacement factor, so the system has a surplus of VAr. Also, parallel filters must be rated to manage the harmonics which they absorb from an existing distorted supply. An experienced supplier must be consulted before specifying such a filter.

CONDUCTED RADIO FREQUENCY EMISSION
Radio frequency emission in the range from 150kHz to 30MHz is generated by the switching action of the main power devices (IGBTs) and is mainly conducted out of the equipment through electrical power wiring. It is essential for compliance with the emission standards that the recommended filter and a shielded (screened) motor cable should be used. Most types of cable can be used provided it has an overall screen, which is continuous for its entire length. For example the screen formed by the armouring of steel wire armoured cable is acceptable. The capacitance of the cable forms a load on the drive and filter, and should be kept to a minimum. Compliance tests were done with cable having a capacitance between the three power cores and the screen of 412pF per metre (measured at 1kHz), which is typical of steel wire armoured cable. In addition to motor cable length, conducted emission will also vary with drive switching frequency: selecting the lowest switching frequency will produce the lowest level of emission. In order to meet the stated standards the drive, filter and motor cable must be installed correctly. Wiring guidelines are given later.

The drive contains a cost-effective internal input filter which gives a reduction of about 30dB in the level of emission at the supply terminals. Unlike a conventional filter, the internal filter continues to provide this attenuation with a long motor cable. For practical purposes, this filter in conjunction with a screened motor cable is sufficient to prevent the drive from causing interference to most good-quality industrial equipment. It is recommended that the filter be used in any situation unless the earth leakage current , which is up to 56mA, is unacceptable. The User Guide gives instructions on how to remove and replace it.

For applications where there are stricter requirements for radio frequency emission, e.g. to the generic standards EN 61000-6-4 etc. or unrestricted distribution in EN 61800-3, the optional external filter must be used.

The tables summarise the performance of all filters when used with single pairs of SPMD drives and SPMC or SPMU rectifiers, assembled in the standard recommended configuration.

SPMD1401 - 1404 (400V supply):

Motor cable length (m)	Switching frequency (kHz)		
	3	**4**	**6**
Using internal filter:			
100	**E2U**	**E2U**	**E2U**
Using external filter:			
0 – 25	**I**	**I**	**I**
25 – 50	**I**	**I**	**-**
50 – 100	**I**	**-**	**-**

SPMD 1601 - 1604 (690V supply):

Motor cable length (m)	Switching frequency (kHz)		
	3	**4**	**6**
Using internal filter:			
100	**E2U**	**E2U**	**E2U**
Using external filter:			
0 – 25	**I**	**I**	**I**
25 – 100	**I**	**I**	**-**

Key to table

The requirements are listed in descending order of severity, so that if a particular requirement is met then all requirements listed after it are also met.

Code	**Standard**	**Description**	**Frequency range**	**Limits**	**Application**
I	EN 61000-6-4 IEC 61000-6-4 EN 50081-2	Industrial: Generic emission standard for the industrial environment	0.15 – 0.5MHz	79dBμV quasi peak 66dBμV average	AC supply lines
			0.5 –30MHz	73dBμV quasi peak 60dBμV average	
	EN 61800-3 IEC 61800-3	Product standard for adjustable speed power drive systems	- Requirements for the first environment[1]: restricted distribution[2]		
E2U	EN 61800-3 IEC 61800-3	Product standard for adjustable speed power drive systems	- Requirements for the second environment: unrestricted distribution		
E2R	EN 61800-3 IEC 61800-3	Product standard for adjustable speed power drive systems	- Requirements for the second environment: restricted distribution		
1	The first environment is one where the low voltage supply network also supplies domestic premises				
2	When distribution is restricted, drives are available only to installers with EMC competence				

- Caution -

This caution applies where the drive is used in the first environment with restricted distribution according to EN 61800-3.

This is a product of the restricted distribution class according to IEC 61800-3. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Notes
1. **Where the drive is incorporated into a system with rated input current exceeding 100A, the higher emission limits of EN 61800-3 for the second environment are applicable, and no filter is then required.** 2. **Operation without a filter is a practical cost-effective possibility in an industrial installation where existing levels of electrical noise are likely to be high, and any electronic equipment in operation has been designed for such an environment. This is in accordance with EN 61800-3 in the second environment, with restricted distribution. There is some risk of disturbance to other equipment, and in this case the user and supplier of the drive system must jointly take responsibility for correcting any problem which occurs.**

IEC 61800-3:2004 and EN 61800-3:2004

The 2004 revision of the standard uses different terminology to align the requirements of the standard better with the EC EMC Directive.

Power drive systems are categorised C1 to C4:

Category	**Definition**	**Corresponding code used above**
C1	intended for use in the first or second environments	R (not available)
C2	not a plug-in or movable device, and intended for use in the first environment only when installed by a professional, or in the second environment	I
C3	intended for use in the second environment, not the first environment	E2U
C4	rated at over 1000V or over 400A, intended for use in complex systems in the second environment	E2R

Note that category 4 is more restrictive than E2R, since the rated current of the PDS must exceed 400A or the supply voltage exceed 1000V, for the complete PDS.

Recommended filters

	Control Techniques part number	
Drive	**Manufacturer Schaffner**	**Manufacturer Epcos**
1401 - 1404	4200-6315	4200-6313
1601 – 1604	4200-6316	4200-6314

Filters for parallel systems and multiple drives are also available. Please contact your drive supplier for details.

- WARNING -
These filters and the internal filter have earth leakage current exceeding 3.5mA. A permanent fixed earth connection with cross-section exceeding 10mm^2 is necessary to avoid electrical shock hazard.

Example conducted emission test data

The conducted emission from a SPMD1404 operating with filter part number 4200-6315, at 3kHz switching frequency with 100m motor cable, which is the worst case tested, is shown in the emission plot in Figure 10.

Note on ungrounded supply systems (IT systems)
Care is needed when using inverter drives with RFI filters on ungrounded supply systems. The recommended filters are designed to operate safely with an earth fault on the supply. However damage could occur to the filter if an earth fault occurs in the driven motor, as the drive might not trip, and excessive high-frequency current could flow into the filter. Observe the following caution:

- Caution -
Neither the internal nor external filters must be used with an IT supply unless an earth leakage relay is fitted at the drive output, arranged to trip the drive in the event of excessive earth leakage current caused by a motor earth fault. Typical relay setting is 150mA.

Note on shared external filters for multiple drives
When more than one drive is used in the same enclosure, some cost saving is possible by sharing a single filter of suitable current rating between several drives. Tests have shown that combinations of drives with a single filter are able to meet the same emission standard as a single drive, provided that all filters and drives are mounted on the same metal plate. Because of the unpredictable effect of the additional wiring and the need for separate fuses for the drives on the drive side of the filter, this arrangement is not recommended where strict compliance with a specific standard is required, unless emission tests can be carried out.

Related product standards
The conducted emission levels specified in the generic emission standards are equivalent to the levels required by the following product specific standards:

Conducted emission from 150kHz to 30MHz		
Generic standard	**Product standard**	
EN 61000-6-4 EN 50081-2	EN 55011 Class A Group 1 CISPR 11 Class A Group 1	Industrial, scientific and medical equipment
	EN 55022 Class A CISPR 22 Class A	Information technology equipment

RADIATED RADIO FREQUENCY EMISSION
When installed in a standard metal enclosure according to the wiring guidelines, the drive will meet the radiated emission limits required by the power drive systems standard EN 61800-3 for the second environment.

Important note
Compliance was achieved in tests using representative enclosures and following the guidelines given. No special EMC techniques were used beyond those described here. Every effort was made to ensure that the arrangements were robust enough to be effective despite the normal variations which will occur in practical installations. However no warranty is given that installations built according to these guidelines will necessarily meet the same emission limits.

The limits for emission required by the generic emission standards are summarised in the following table:

Radiated emission from 30 to 1000MHz				
Standard	**Application**	**Frequency range**	**Limits**	**Comments**
EN 61000-6-3	Enclosure	30 - 230MHz	30dBμV/m quasi peak at 10m	
		230 - 1000MHz	37dBμV/m quasi peak at 10m	
EN 61000-6-4	Enclosure	30 - 230MHz	40dBμV/m quasi peak at 10m	Standard specifies limits of 30 and 37dBμV/m respectively at a measuring distance of 30m; emission may be measured at 10m if limits are increased by 10dB
		230 - 1000MHz	47dBμV/m quasi peak at 10m	

EN 61800-3 (IEC 61800-3) requires the following, in order of increasing emission level:

As EN 61000-6-3	First environment - unrestricted distribution
As EN 61000-6-4	First environment - restricted distribution
30 – 230MHz 40dBµV/m at 30m 230 – 1000MHz 50dBµV/m at 30m	Second environment – unrestricted distribution

Test Data

The test data is based on radiated emission measurements made in a standard steel enclosure containing a single SPMD1402 drive, in a calibrated open area test site. Details of the test arrangement are described:

A standard Rittall steel enclosure was used having dimensions 1900mm (high) × 600mm (wide) × 500mm (deep). Two ventilation grilles, both 200mm square, were provided on the upper and lower faces of the door. No special EMC features were incorporated.

The drive and recommended RFI input filter were fitted to the internal back-plate of the enclosure, the filter casing making electrical contact with the back-plate by the fixing screws. Standard unscreened power cable was used to connect the cubicle to the supply.

A standard 90kW AC induction motor was connected by 5m of shielded cable (steel braided - type SY) and mounted externally. The cable screen was clamped directly to the back-plate near the drive, and connected to the motor frame by a pig-tail approximately 50mm long. In order to allow for realistic imperfections in the installation, the motor cable was interrupted by a DIN rail terminal block mounted in the enclosure. The screen pigtails (50mm long) were connected to the back plate through an earthed DIN rail terminal block. The motor cable screen was not bonded to the enclosure wall at the point of entry.

A 2m screened control cable was connected to the drive control terminals, and its screen clamped to the drive EMC grounding bracket as recommended in the user guide, but the screen was not allowed to contact the cubicle wall.

The drive was operated at 3Hz, with a switching frequency of 6kHz which is the worst case for RF emission.

No additional EMC preventative measures were taken, e.g. RFI gaskets around the cubicle doors.

The following table summarises the results for radiated emission, showing the six highest measurements over the frequency range 30 to 1000 MHz:

Frequency MHz	Emission dBµV/m	Level required by standard EN 61800-3 *
49.95	44.1	50
51.15	42.9	50
50.4	42.6	50
51.3	41.1	50
65.9	38.4	50
65.1	35.9	50

*****for 2nd environment/unrestricted (category C3) at 10m measuring distance

The results show that the limit for the standard is met with a margin of at least 5.9dB.
The limit for EN 61800-3 (IEC 61800-3) is met for the second environment without restriction.

Enclosure construction

For most installations the enclosure will have a back-plate which will be used to mount variable speed drive modules, RFI filters and ancillary equipment. This back-plate can be used as the EMC earth plane, so that all metal parts of these items and cable screens are fixed directly to it. Its surface should have a conductive protective surface treatment such as zinc plate. If it is painted then paint will have to be removed at the points of contact to ensure a low-inductance earth connection which is effective at high frequency.

The motor cable screen must be clamped directly to the back-plate. It may also be bonded at the point of exit from the enclosure, through the normal gland fixings.

Depending on construction, the enclosure wall used for cable entry might have separate panels and have a poor connection with the remaining structure at high frequencies. If the motor cable is only bonded to these surfaces and not to a back-plate, then the enclosure may provide insufficient attenuation of RF emission. It is the bonding to a common metal plate which minimises radiated emission. There is no need for a special EMC enclosure with gaskets etc. In the tests described, opening the cubicle door had little effect on the emission level, showing that the enclosure itself does not provide significant screening.

WIRING GUIDELINES

The wiring guidelines on the following pages should be observed to achieve minimum radio frequency emission. The details of individual installations may vary, but aspects which are indicated in the guidelines as important for EMC must be adhered to closely.
The guidelines do not preclude the application of more extensive measures which may be preferred by some installers. For example, the use of full 360° ground terminations on shielded cables in the place of 'pig-tail' ground connections is beneficial, but is not necessary unless specifically stated in the instructions.

1. The drive and filter must be mounted on the same metal back-plate, and their mounting surfaces must make a good direct electrical connection to it. The use of a plain metal back-plate (eg galvanised not painted) is beneficial for ensuring this without having to scrape off paint and other insulating finishes.

2. The filter must be mounted above and close to the drive but allowing a space of 100mm as advised in the user guide, to allow free exit of cooling air from the drive.

3. A shielded (screened) or steel wire armoured cable must be used to connect the drive to the motor. The shield must be fixed in direct contact with the metal back-plate of the panel by a suitable clamp.

4. The AC supply connections must be kept at least 4in (100mm) from the drive, motor cable and braking resistor cable.

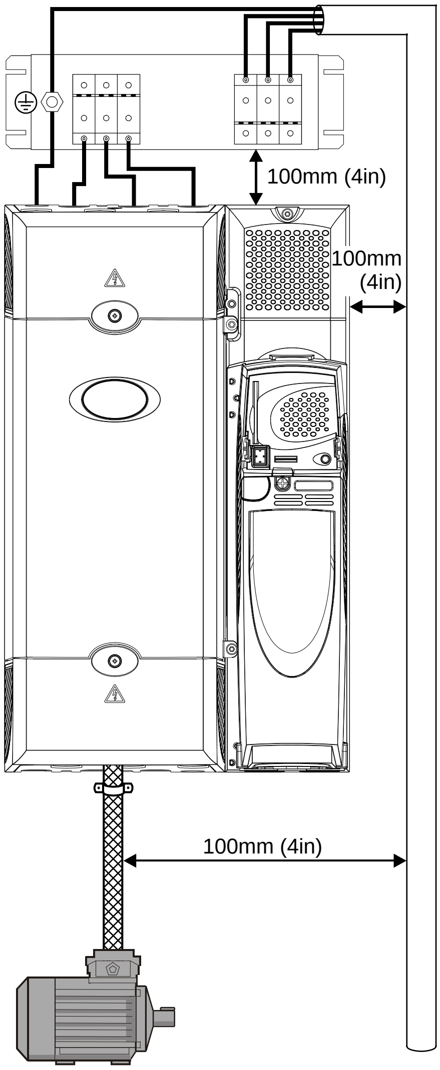

Figure 3: Grounding the drive, filter and motor cable screen: input wiring spacing

Connect the shield of the motor cable to the ground terminal of the motor frame using a link that is as short as possible and not exceeding 50mm (2 in) in length. A full 360° termination of the shield to the motor terminal housing (if metal) is beneficial.

5.

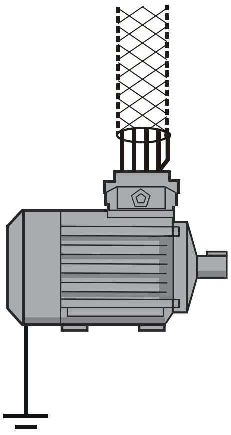

Figure 4: Connecting the motor cable shield at the motor

6. If an additional safety earth wire is required for the motor, it can either be carried inside or outside the motor cable shield. If it is carried inside then it must be terminated at both ends as close as possible to the point where the screen is terminated. It must always return to the drive and not to any other earth circuit.

7. Wiring to the braking resistor should be shielded. The shield must be bonded to the back-plate using an uninsulated metal cable-clamp. It need only be connected at the drive end.

8. If the braking resistor is outside the enclosure then it should be surrounded by an earthed metal shield.

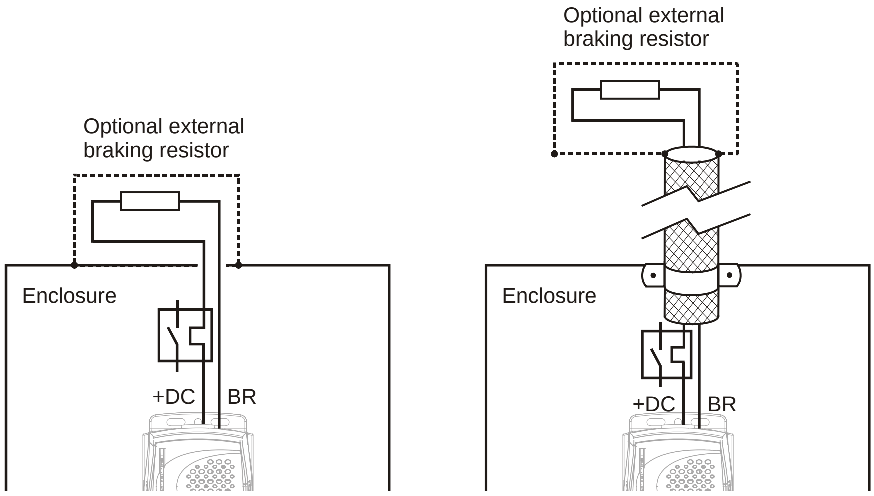

Figure 5: Screening of braking circuit

9. Signal and control wiring must be kept at least 12in (300mm) from the drive and motor cable.

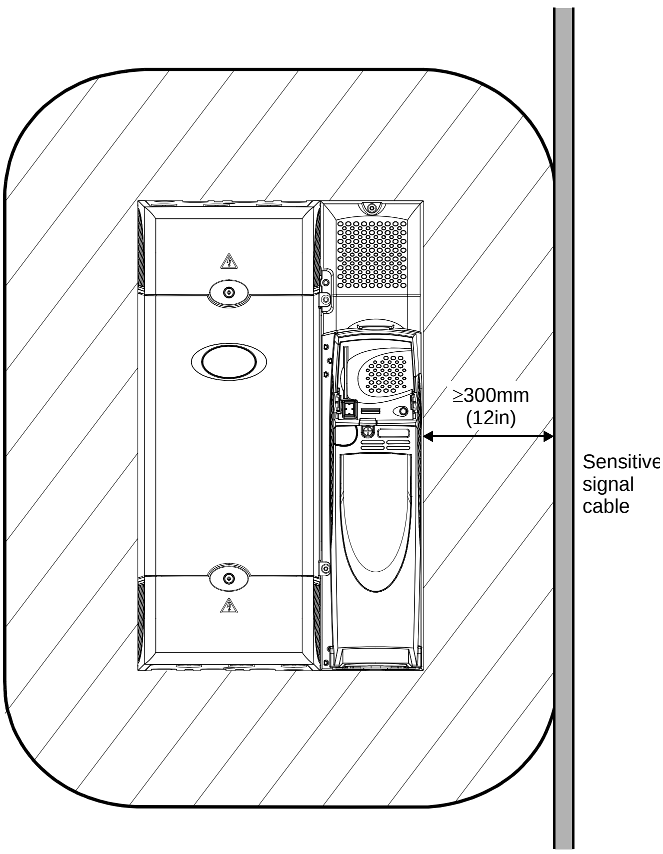

Figure 6: Signal wiring spacing

10. The control wiring “0V” connection should be earthed at one point only, preferably at the controller and not at a drive.

Variations to wiring guidelines

– **Output ferrite ring**

If a ferrite ring is to be used to further reduce conducted emission, it should be mounted close to the drive, and the output power conductors (U,V,W but not E) should be passed through the central aperture, all together in the same direction.

– **If drive control wiring leaves the enclosure**

This includes all control, encoder and option module wiring but not the status relay circuit or the serial port. One of the following additional measures must be taken:

- Use shielded cables (one overall shield or separate shielded cables) and clamp the shield(s) to the grounding bracket provided, as shown in Figure 7.

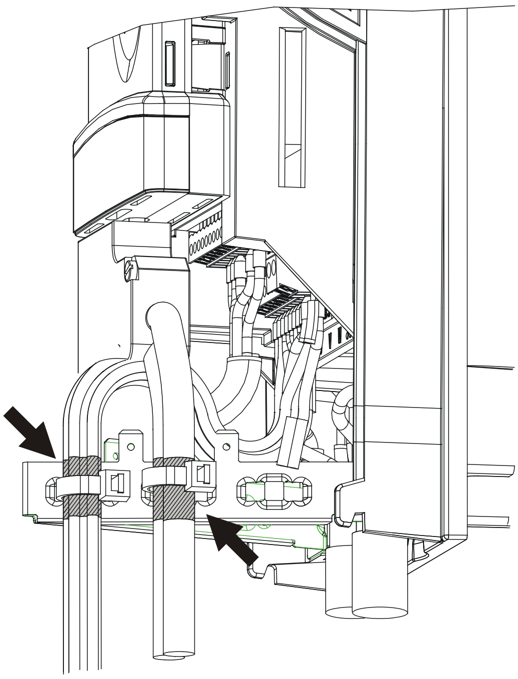

Figure 7: Earthing of signal cable screens using the grounding bracket

or:

- Pass the control wires through a ferrite ring part number 3225-1004. More than one cable can pass through a ring. Ensure the length of cable between the ring and drive does not exceed 125mm (5in).

– **Interruptions to the motor cable**

The motor cable should ideally be a single run of shielded cable having no interruptions. In some situations it may be necessary to interrupt the cable, for example to connect the motor cable to a terminal block within the drive enclosure, or to fit an isolator switch to allow safe working on the motor. In these cases the following guidelines should be observed. The most important factor is always to minimise the inductance of the connection between the cable shields.

– **Terminal block within enclosure**

The motor cable shields should be bonded to the back-plate using uninsulated cable-clamps which should be positioned as close as possible to the terminal block. Keep the length of power conductors to a minimum and ensure that all sensitive equipment and circuits are at least 0.3m (12 in) away from the terminal block.

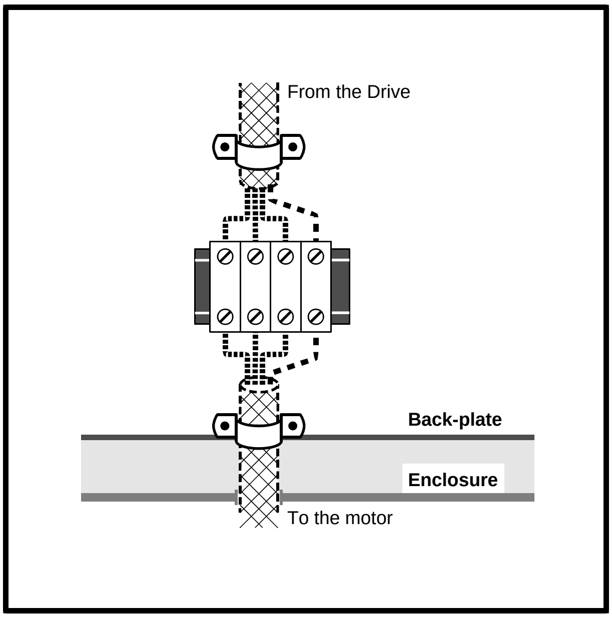

Figure 8: Connecting the motor cable to a terminal block in the enclosure

– **Using a motor isolator switch**

The motor cable shields should be connected by a very short conductor having a low inductance. The use of a flat metal bar is recommended; conventional wire is not suitable. The shields should be bonded directly to the coupling bar using uninsulated metal cable-clamps. Keep the length of power conductors to a minimum and ensure that all sensitive equipment and circuits are at least 0.3m (12 in) away. The coupling bar may be grounded to a known low impedance ground nearby, for example a large metallic structure which is connected closely to the drive ground.

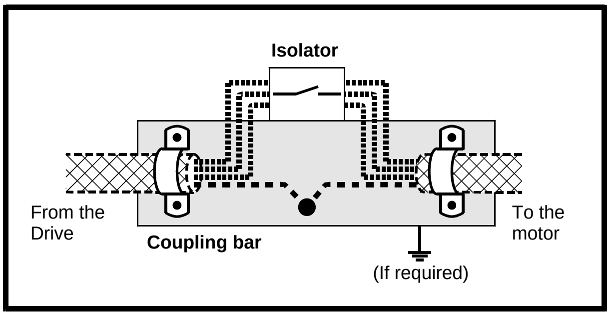

Figure 9: Connecting the motor cable to an isolating switch

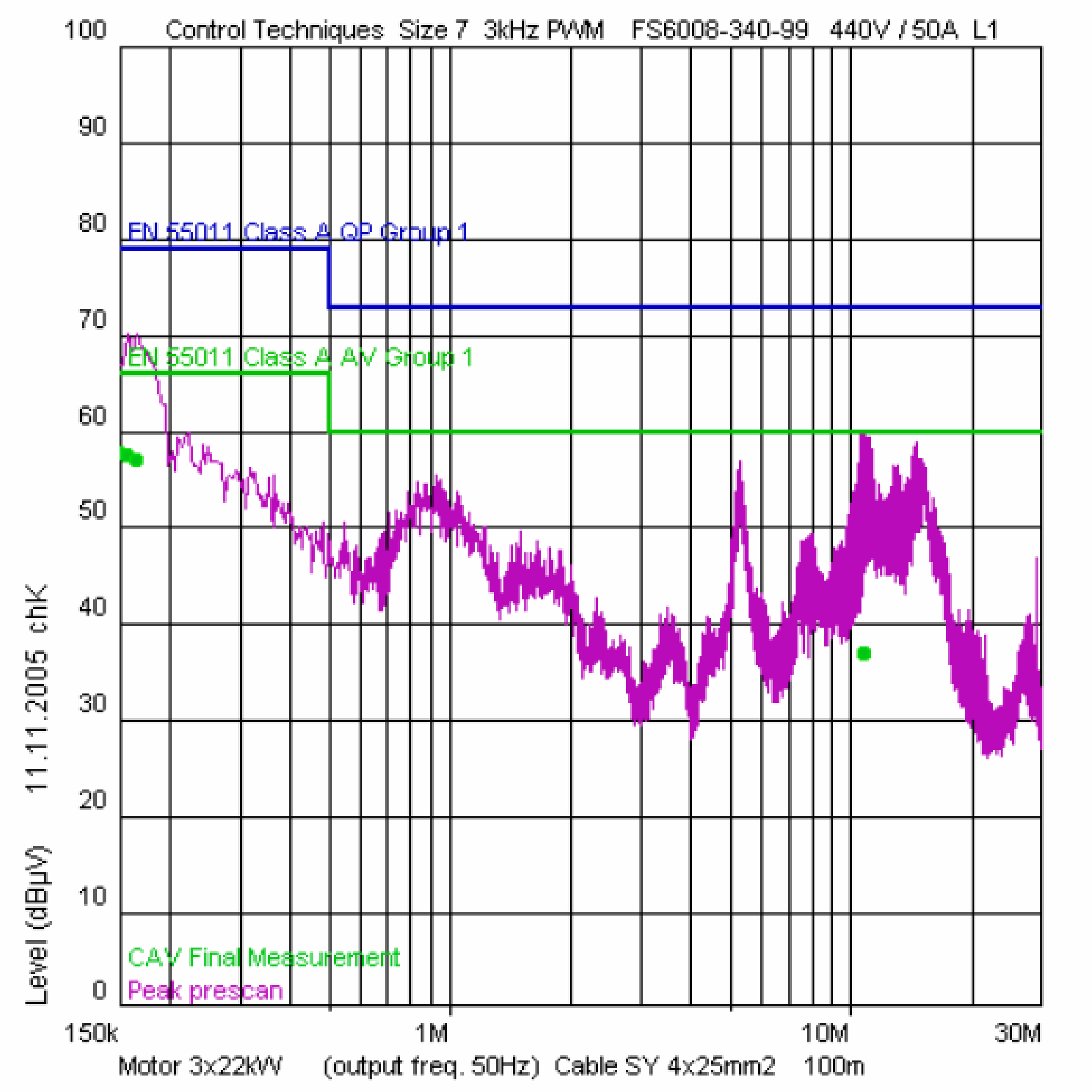

Figure 10: Example conducted emission plot (SPMD1404, 100m cable, 3kHz switching frequency)