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Application Note 108

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Poor Man's Guide to CE EMC Testing

Introduction

To an engineer unfamiliar with EMC testing, faced with meeting EMC requirements of the European Union, the specifications, tests, and jargon of the CE EMC documents can be intimidating. Many EMC specialists seem unable, or unwilling, to describe in simple or even understandable terms what CE EMC tests are all about.

This application note is an overview, a little simplistic to be sure, of what CE testing is really all about. It is based on our company's recent successful CE EMC tests at an outside test house of drives and motors tested to the generic, heavy industrial immunity and emission standards.

Poor Man's Guide

In 1996, the CE EMC specification mandates six EMC tests: five immunity and one emission. One immunity test (50 Hz magnetic immunity, per EN61000-4-8) only applies if there is reason to believe the equipment is sensitive to 50 Hz magnetic fields. Our CE test house decided it did not apply to motors and drives, so this test was not run. The emission test is really two separate tests: conducted line noise and radiated emission. Therefore, there are six CE tests that must be passed for drives and motors.

These tests can be grouped into three categories:

- PC Board Noise Rejection Tests:
  - ESD
  - Radiated RF Immunity
- Cable Shield Tests:
  - Conducted RF Immunity
  - EFT (Burst)
  - Radiated Emission
- Line Filter Test:
  - Conducted Line Emission

PC Board Noise Rejection Tests

ESD (Electro Static Discharge) or sparks

Spec

4 kV contact, 8 kV air, per EN 61000-4-2

Description

This test is 150 pf charged up to few kV and discharged through 150 ohms (or 330 ohms) directly into surfaces that could be touched when the machine is being operated. Each spark produces a controlled current, controlled energy, high dv/dt, nearly unlimited voltage compliance, individual noise pulse. Typically 20 A for about 30 to 50 ns with some ringing. ESD may also radiate some RF energy. The drive needs to ride through without faulting.

Sheet metal or cable shields that are sparked need to bleed this current away from the PC boards to the chassis. A metal chassis is a large sea of free electrons, so it will not change potential much when sparked. Think of it as a local ground that is where the spark current 'wants to go'. Ungrounded small sections of sheet metal, like option panels or DB connector shields, if exposed during the test, will likely get directly sparked, and may very well fault the drive, which is a test failure.

Keys

Buy a spark gun. CE type ESD gun is available from Compliance Design Inc. Spark noise sources can also be homemade fairly easily using a step up transformer. In our experience a spark source is an essential tool for designing noise robust PC boards.

Tip

- If equipment has a known problem to contact ESD, and the equipment is normally run in an industrial cabinet with the door closed, then test it in a cabinet with the door closed. The cabinet prevents the test house from applying the spark directly to the equipment. If the door is closed, ESD is only applied to cabinet walls and components outside the cabinet.

Note: *Spark guns are very useful noise sources and can be used as substitute test equipment for other CE EMC requirements. Consider a spark applied to exposed cable shields. This puts a fast, high current pulse in the shields. The shield current, of course, is not exactly the same as Conducted RF Immunity and EFT, but it is close enough to be useful.*

Note: *A spark gun can also generator RF fields and can become uncalibrated test equipment for Radiated RF Immunity. To get RF fields without currents set the gun voltage high and spark above the board a few inches to a ground strap.*

Radiated RF Immunity

Spec

10 V/m RF field, 80 MHz to 1 GHz, per EN 50140

Description

RF field is impressed on product from an antenna placed a few feet away. Frequency is slowly swept from 80 MHz to 1 Ghz. 10 V/m is considered to be a relatively high level of EMI disturbance.

Keys

Air sparks produce RF fields. Danaher Motion has long employed a strong air spark generator and knows from experience that it is very effective at finding poorly filtered, high Z nodes in fault circuits. The strength of the disturbance within the circuits due to 10 V/m Radiated RF is not known, but our working assumption is that if a PC board tolerates a strong spark a few inches in the air over it, then it will pass this test.

Cable Shield Tests

Conducted RF Immunity

Spec

10 V from 100 ohm source (or 2 V from 4 ohm source), 150 kHz to 80 MHz with 1 kHz modulation, per ENV 50141

Description

RF disturbance is injected into line wiring and cable shields using various impedance couplers. High Z couplers inject 10 V max, 100 ma max, and low Z couplers 2 V max and 500 mA max. The cables from drive to the motor were put through a 5:1 step down transformer that transformed the 10 V, 100 ma source to 2 V, 500 mA.

Keys

Basically this is a test of shields and shield terminations of EXTERNAL cables. About 500 mA of continuous current is injected into the cable shields (2 V max) and the frequency is swept from 150 kHz to 80 MHz. If the shielding is good, you pass.

RF currents are injected into the equipment through the line wiring. You use a line filter with a motor drive (see Conducted Line Emission below), so the disturbance just goes into the line filter. If the filter is RF grounded to the drive, it handles the RF current. To RF ground the filter to the drives mount them on the same base plate, and if the plate is painted, scrape the paint under the mounting screws to insure a good RF connection between them.

Note: *The spark gun can be used to check design robustness to this test. Directly sparking cable shields injects current pulses into the shield. While ESD does not produce a continuous shield disturbance, the current amplitude from an ESD gun is much higher than continuous current of this test.*

EFT (Electrical Fast Transient) or Burst test

Spec

2 kV, burst of 50 ns pulses with 5 ns rise time, per EN 61000-4-4

Description

EXTERNAL cables of more than about 1 m or so in length are put in a clamping fixture. The clamp forms a capacitor of maybe 100 pf (could be less) to the cable shield. Generator impedance is 50 ohms so short circuit current for 2 kV is 40 A. Cable shields are probed with pulses of current (between 40 A for 5 ns and 4 A for 50 ns, with ringing).

Keys

Basically another test of cable shields and cable shield terminations. Like RF immunity except with pulses. If you have good shields and good shield terminations, you pass. Like RF immunity it is also applied to the line cable, but a line filter that is RF grounded blocks it.

Note: *The spark gun can also be used to check design robustness to this test. Directly sparking cable shields injects individual current pulses into the shield with current amplitudes and rise times about the same as the current bursts from the EFT cable clamp.*

Radiated Emissions

Spec

Industrial, generic, class A, field strength of 30 db µV/m at 30 m in the range 30 MHz to 230 MHz (37 db µV/m at 30 m in the range 230 MHz to 1 Ghz)

Description

An antenna looks at how much the equipment is broadcasting. To pass the equipment has to be radiating quite a bit less than the local FM radio stations. The pass/fail limit of a typical biconical antenna (30 MHz to 300 MHz) positioned 3 m from the product, when coupled directly to a spectrum analyzer is in the range of 30 µV (30 db µV) to 100 µV (40 db µV).

Information about the source of the noise is available from the spectrum analyzer. If the emission extends over broad frequency band(s), the likely source is a switching power supply. If the emission shows as narrow frequency spike(s), the source is likely a crystal controlled logic clock.

Key

This can be a difficult test to pass. To a large extent, this is another test and probably the most difficult test of cable shields and cable shield terminations. Cables are the antennas for the radiation (up to about 300 MHz). Shields with good RF connections to the CHASSIS (or local RF ground plane) prevent wires inside the cable from radiating. How shields are connected is VERY important. How cables are routed can also be important.

Tips

- Direct grounding of cable shields to the product chassis (preferred) or the mounting plate using metal cable clamps is the most effective shield grounding technique for reducing cable radiated emissions. This technique can easily be the difference between passing and failing this test. If there is excess radiation from a cable, try the following: strip off an inch or so of the outer jacket to expose the outer shield within about two feet from the cable termination at the drive. Then place a metal cable clamp over the cable to ground the shield using a screw of the product or to the cabinet mounting plate. There should be no paint under the cable clamp or the drive mounting areas.
- Use shielded cables that have an outer *braid* shield. It is not practical in production to clamp foil shields to ground, but it can be done if necessary during EMC testing.
- While cable shields are the primary means to reduce radiation, other techniques are also available to attenuate RF emissions. Ferrite over the cable absorbs RF energy (3 to 8 db), and bypass caps on cable wires are used to bleed away RF currents to the chassis.
- Since seemingly small changes in shield grounding and cable routing can make a big difference in the emissions, it is very useful to have available in-house a spectrum analyzer and antenna so you can do some pre-compliance testing. Simple equipment does a surprisingly good job.
- A good investment is an inexpensive spectrum analyzer and biconical antenna. A spectrum analyzer with a range of 500 kHz to 500 MHz is acceptable, 150 kHz minimum is better because it allows the spectrum analyzer to also check conducted line emissions. A 150 kHz to 500 MHz spectrum analyzer is available from Hameg or ComPower. Mate this with a biconical antenna (30 MHz to 300 MHz) from ComPower. This antenna has a relatively flat frequency response and requires no adjustments. The antenna couples directly to the spectrum analyzer.
- The main difficulty in testing in-house is background RF noise. This equipment was successfully used in a busy engineering lab with the antenna at 3 meters. On/off tests help separate product radiation from the background RF noise. It may be necessary to do some testing in the evening when the background can be quieted by turning off other equipment. Computers and scopes in the lab were no problem and a burn-in room about 60 feet away was an acceptable neighbor. A parking lot can be used as an open field test site.

Line Filter Test

Conducted Line Emission

Spec

Class A, industrial, 150 kHz to 30 MHz (66 db µV av in the range of 150 kHz to 500 kHz), per EN55011

Description

An device called a LISN (Line Impedance Stabilization Network) is placed in each leg of the power line. A LISN is a combination of RLCs (basically a 50 uh inductor in parallel with a 50 ohm resistor) that stabilize the impedance of the line above 150 kHz at 50 ohms. The voltage above 150 kHz across the 50 ohms is measured with a spectrum analyzer. The CE industrial limit is equivalent to a few mV of high frequency noise on the 50 Hz line sinewave.

Keys

Drives have intrinsically high conducted line noise. The reason is there is high capacitance from the inverter to earth ground in the motor cable and inside the motor, and this capacitance is charged and discharged at the PWM rate. This capacitance is not easily screened.

If a drive is to pass this test, a high performance line filter is MANDATORY. Without a line filter, a drive might be 40 db (factor of 100!) over the industrial limit. The line filter protects the mains by coupling the cable and motor capacitive current (amps) from earth ground back to the inverter.

It is important to select the right commercial line filter. Luckily, virtually all line filter data sheets spec the filter attenuation assuming a 50 ohm line, which is the impedance of the line that the LISN creates during CE tests. The key filter specification is the line-ground (sometimes called asynchronous, or common mode) attenuation at 150 kHz. The reason for this is that the 150 kHz spec drives the pole locations of the filter and the wrong filter typically fail the worst at or near 150 kHz. A filter rated for at least 50 db attenuation at150 kHz line-gnd may be adequate, but a filter with a line-gnd spec of 60 to 65 db at 150 kHz is recommended. The latter is a high performance line filter usually built with two baluns.

Tip

- The key to passing this test is to select the right line filter. This filter should have a line-gnd spec of 60 to 65 db at 150 kHz.

Note: *Motor cables longer than 40 ft present special problems. The high capacitive current of a long cable can saturate an inductor in the line filter, seriously degrading its effectiveness.*

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