EMC, CE Mark, IEC801 .....What's it all about?

And new devices to ease the job

by Matt Smith

This article examines **electromagnetic compatibility** (EMC), which has assumed increased formal significance since January, 1996. We discuss here the special requirements and standards that are mandatory for all pieces of equipment entering the market in the European Union (EU), and we consider the requirements for attaining the "CE" *(Communauté Europééne)* mark from an EMC point of view. A new generation of RS-232 products, designed to meet these requirements, exemplifies the measures that have been taken by Analog Devices to achieve EMC at the IC level. These measures include inbuilt protection circuitry to provide levels of immunity far beyond anything previously available; immunity to *electrostatic discharges* (ESD) in excess of 15 kV has been achieved—measured by new and more-stringent test methods. We also discuss protection against overvoltage and *electrical fast transients* (EFT). From the *emissions* point of view, we examine electromagnetic emissions and the measures we have taken in ICs to eliminate costly shielding procedures.

The European Union EMC Directive: In May, 1989, the European Union published a Council Directive, 89/336/EEC, relating to electromagnetic compatibility of products placed on the market within the member states. A later amendment, 92/31/EEC, delayed compulsory compliance until January 1, 1996. The Directive applies to apparatus which is liable either to cause electromagnetic disturbance or itself be affected by such disturbance—and thus to all electrical or electronic products. It goes beyond the more familiar FCC Class B requirement for emissions control since it also addresses *immunity* as well as emissions. While the directive applies only to products marketed within the EU, the standards are likely to be adopted worldwide.

Conformance with the EU Directive on Electromagnetic Compatibility requires that products will

- Have high intrinsic immunity to emissions from other sources
- Keep their undesirable emissions to within very strict limits

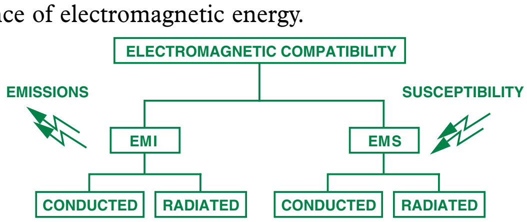
Manufacturers are responsible for meeting the regulations; from January 1, 1996, all electronic products sold in the European Union *must* show conformance by displaying the CE mark.

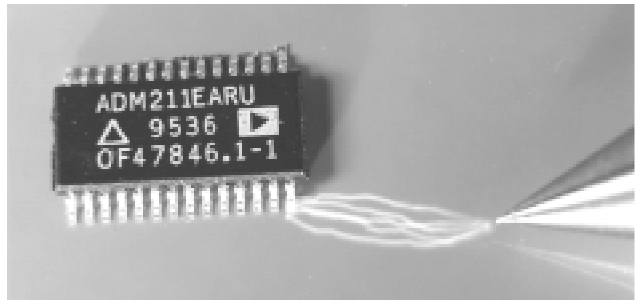
Definitions:

Electromagnetic compatibility (EMC): Ability to operate in, and not overly contribute to, an environment of electromagnetic radiation. When this goal is met, all electronic equipments operate correctly in one another's presence.

Electromagnetic interference (°EMI): Electromagnetic energy emanating from one device causing degraded performance in another.

Electromagnetic immunity, or *susceptibility* (EMS): Tolerance of the presence of electromagnetic energy.





EMC Testing: Thorough EMC evaluation requires testing of both EMI and EMS. Requiring different measurement approaches and test methodologies, they are specified in separate Standards. *Emitted* energy may be *conducted* via the power supply lines or on I/O cables, or it may be *radiated* through space. It can start out by being conducted along cables and then be radiated when shielding is inadequate. Similarly, electromagnetic immunity, or *susceptibility*, must be tested for both conducted and radiated interference. Conducted interference includes *electrostatic discharges* (ESD) and *electrical fast transients* (EFT).

Emissions testing is not new, but only now has *immunity* testing become mandatory on commercial products—a result of the EU regulations. The standards for commercial immunity testing, both conducted and radiated, have evolved over several years

IEC1000-4-x Immunity Specifications: The basic EMC immunity standards in Europe come from the International Electrotechnical Commission (IEC). The content and document numbers have continually evolved over many years. In the latest round, the IEC have assigned IEC1000-4-x to the family of immunity standards previously known as the IEC801-x series. For example, the specification dealing with ESD immunity, previously referred to as IEC801-2, has become IEC1000-4-2.

Nomenclature	Subject
IEC1000-4	Electromagnetic Compatibility EMC
IEC1000-4-1	Overview of Immunity Tests
IEC1000-4-2	Electrostatic Discharge Immunity (ESD)
IEC1000-4-3	Radiated Radio-Frequency Electromagnetic Field Immunity
IEC1000-4-4	Electrical Fast Transients (EFT)
IEC1000-4-5	Lightning Surges
IEC1000-4-6	Conducted Radio Frequency Disturbances above 9 kHz

EMC AND I-O PORTS

It has been estimated that up to 75% of EMC problems occur in relation to I-O ports. The I-O port is an open gateway for electrostatic discharges or fast transient discharges to enter a piece of equipment, and for interfering signals to escape, either by conduction of spurious signals on the I-O lines or by radiation from the I-O cable. Because of this, the EMC performance of the I-O transceiver device connected to the port is crucial to the EMC performance of the entire package.

Electromagnetic Susceptibility of I-O Ports: I-O ports are particularly vulnerable to damage from EMI because they may be subjected to various forms of overvoltage during "normal" operation. Simply plugging or unplugging cables carrying static charges can destroy the transceiver. RS-232 serial ports are especially vulnerable A standard serial port uses an exposed 9-way male D connector. The pins on the connector are all too easily accessible, making them a prime target for accidental discharges. ESD damage can result from simply picking up a laptop PC after walking across a carpeted room.

The traditional method for ensuring immunity against ESD on I-O ports, including RS-232, has been to use some form of voltage clamping structure such as Tranzorbs, or current-limiting resistors. Damage to an integrated circuit is caused by excessive current flow, usually induced by high voltages. Protection can be achieved using *current diversion* or *current limiting.*

Current Diversion: An integrated circuit may be protected by diverting some of the current to ground externally, usually with a structure that provides voltage clamping. The voltage clamp must switch on quickly and be able to safely handle the current that it is diverting away from the IC. Tranzorbs are a popular choice, but they are expensive and space consuming. For example, an RS-232 port has eight I-O lines, each requiring individual protection; the protection components can often take up more area than the transceiver itself. In today's laptop computers, where both costs and board space must be minimized, this is far from ideal. Another disadvantage of external clamping structures is their heavy capacitive loading on the I-O lines. This limits the maximum data rate, and the charging/discharging on data edges contributes to battery drain—another serious drawback in portable equipment.

Current Limiting: Current-limiting protection using simple series resistors is a popular choice where the overvoltages likely to be encountered are relatively low. But for ESD protection, where the voltages can be as high as 15 kV, it is not a feasible option. The resistance value required to keep the current within safe limits (200 mA or so) would be so high as to defeat normal operation of the transceiver. Other current limiting components such as thermistors are occasionally used; but again, protection is achieved at the expense of output impedance. Current limiting is often used in combination with voltage clamping to achieve a good compromise, giving high levels of protection but without degrading normal operating specifications. Still, the external structures are undesirable in portable, low-cost equipment.

EMC Emissions on I-O ports: One might not think of RS-232 ports as likely offenders since the data rates are quite modest. But emissions are indeed a concern, and for a number of reasons.

In recent years, transmission speeds have been pushed up by a factor of 10 over the originally intended RS-232 speeds. The now-common V.34 modems require data rates in excess of 115 kbps. Higher speed modems are now appearing, pushing the rate up to 133 kbps. ISDN pushes this even higher—up to 230 kbps . Higher frequencies, together with high voltages, translate into higher levels of emissions. The move towards single-supply, charge-pump-based transceivers has resulted in on-chip high-frequency clock oscillators. The latest generation of charge-pump-based products uses 0.1-µF charge-pump capacitors in order to conserve board space, but at the price of higher oscillator frequencies, resulting in higher levels of emissions. The high voltage switching (20 V), high frequencies, and the driving of long, often unshielded cables are a recipe for EMI trouble unless great care is taken. The RS-232 cable serves as a very effective antenna, and even low level noise coupled onto the RS-232 cable can radiate significantly.

"FIXES" vs. PREVENTION

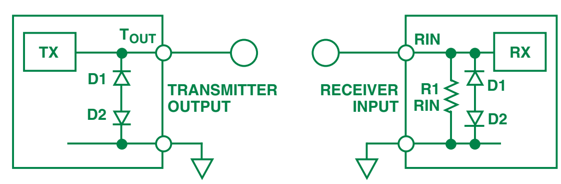
Too often, EMC problems are discovered late in a product design cycle and require expensive redesign including shielding, additional grounding, voltage-clamping structures, etc. Such "Band-Aid" fixes can be time- and space consuming, expensive, and lacking in guarantees of success. It helps to understand and eliminate potential EMI problems, both emissions and immunity, as early as possible in the design cycle.* It will be helpful to include, where possible, products that have already been tested for compliance and characterized so you know just how close to the limits you are running.

The ADM2xxE family† of RS-232 interface transceiver products (*Analog Dialogue* 30-3, p. 19) is an example of devices that have been designed with EMC compliance as an important consideration. High levels of inherent immunity to EMI as well as low levels of radiated emissions make for fewer headaches for the system designer. Benefits include low cost, space saving, inbuilt ruggedness and low emissions.

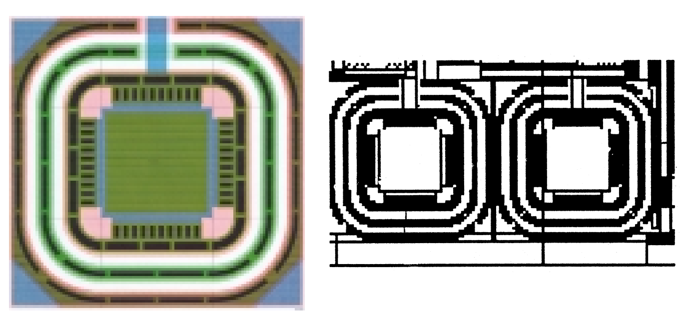
On-chip immunity: On-chip ESD, EFT and EMI protection structures ensure compliance with the requirements of IEC1000-4-2, IEC1000-4-3 and IEC1000-4-4. All inputs and outputs are protected against electrostatic discharges up to ±15 kV, and electrical fast transients up to ±2 kV. This ideally suits the devices for operation in electrically harsh environments or where RS-232 cables are frequently being plugged or unplugged. They are also immune to high R-F field strengths (1000-4-3), allowing operation in unshielded enclosures.

All this inherent protection means that costly external circuitry can be eliminated, saving cost and board space; fewer components means increased system reliability; and data-transmission speed, often compromised by external protection, is maintained.

Protection Structure: A simplified version of the protection structure used is illustrated below. It basically employs two back-to-back diodes. Under normal operating conditions, one or the other of these diodes is reverse-biased. If the voltage on the I-O pins exceeds ±50 V, reverse breakdown occurs and the voltage is clamped, diverting the current through the diodes. Two diodes are required because the RS-232 signal lines are bipolar , usually swinging from –10 V to +10 V. The transmitter output and receiver input use the same protection structure. The receiver input's terminating 5-kΩ resistor also aids in current diversion.



The diodes must be capable of dissipating the energy present in ESD pulses. They must be able to switch at high speed, safely dissipate energy, and occupy minimal die area. The diagram below, which illustrates how this was achieved, is the actual structure



*See "A bibliography on EMC/EMI/ESD", *Analog Dialogue* 30-2 (1996). **Circle 2**

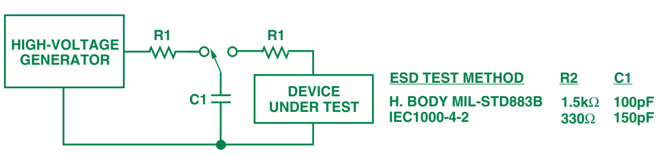
†For technical data, visit our Web site, http://www.analog.com. Data is also available in North America around the clock by Analogfax™, 1-800-446-6212; request **1992** and **1991**; or use the reply card. Circle **3**

used for receiver input and transmitter output. The annular structure around each pad embodies the P-N junction, achieving optimum charge distribution with minimum die area.

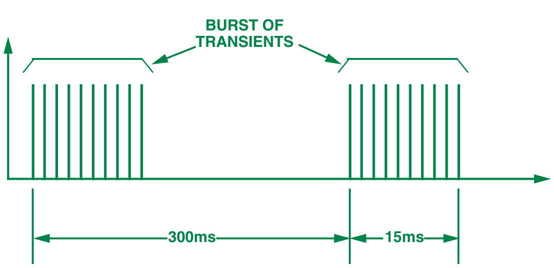
Testing ESD Protection to IEC1000-4-2: This structure meets the test requirements of IEC1000-4-2, which are much more stringent that the more usual MIL-STD-883B or human body model test. Such traditional ESD test methods, used by most semiconductor manufacturers, were intended to test a product's susceptibility to ESD damage during handling and board manufacture. They do not adequately test a product's susceptibility to real-world discharges. Each pin is tested with respect to all other pins, simulating the types of discharge likely to occur during handling or with auto insertion equipment. There are important differences between these tests and the IEC test.

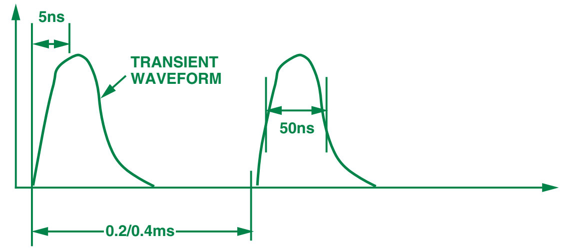
IEC1000-4-2 vs. MIL-STD-883B: The IEC test is much more stringent in terms of discharge energy. Shown below is a simplified schematic of the ESD test generator. Capacitor C1 is charged up to the required test voltage via R1. The energy in C1 is then discharged into the device under test via R2. The peak current and discharge energy are determined by R2 and C1. The table shows that for the IEC test, R2 is decreased from 1.5 kΩ to 330 Ω, resulting in a >4× peak current increase. In addition, C1 is increased by 50% from 100 pF to 150 pF. Furthermore, the IEC1000-4-2 test, applied to the I-O pins, is carried out while power is applied to the device, to check for potential destructive latchup, which could be induced by the ESD transient.

The IEC test therefore better represents a real-world I-O discharge where the equipment is operating normally with power applied. But for maximum peace of mind, both tests should be performed to ensure maximum protection during both handling and manufacture, as well as later during field service.



IEC1000-4-4 (previously IEC801-4) Electrical Fast-Transient Immunity: Electrical fast transients occur as a result of arcing contacts in switches and relays. The tests defined in IEC1000-4-4 simulate the interference generated when, for example, a power relay disconnects an inductive load. An arc is produced, due to the high back EMF (*Ldi/dt*). Because of contact bounce as the switch is opened, the arc is actually a burst; therefore, the voltage appearing on the line consists of a burst of extremely fast transient impulses. The fast-transient burst test defined in IEC1000-4-4 attempts to simulate the interference resulting from this type of event with the waveforms shown here.





The waveform consists of a 15-ms burst of 2.5- to 5-kHz transients repeated at 300-ms intervals. These transients are coupled onto the I-O lines using a 1-meter capacitive clamp. Voltages as high as 2 kV are applied with the fast transition times shown. This can either destroy an unprotected IC connected to the I-O line immediately or cause degradation in performance with delayed failure. The protection scheme described above, used for the ADM2xxE, clamps the overvoltages to a safe level

IEC1000-4-3 (previously IEC801-3) Radiated Immunity: This specification describes the measurement method and defines the levels of immunity to radiated electromagnetic (EM) fields. It was originally intended to simulate the EM fields generated by sources such as portable radio transceivers, that generate continuous-wave radiated EM energy. Its scope has since been broadened to include spurious EM energy, which can be radiated from fluorescent lights, thyristor drives, inductive load, etc.

In tests for immunity, the device is irradiated with an EM field in one of a variety of ways. Integrated circuits are conveniently tested using some form of *stripline cell*, which consists of two parallel plates with an electric field developed between them. A high-power RF amplifier generates the field, which is swept in frequency from 80 MHz to 1 GHz. The device under test is placed within the cell and exposed to the electric field. A field-strength monitor within the cell provides feedback to maintain a constant field level as the frequency changes. Three severity levels are defined, with field strengths from 1 to 10 V/m. Results are classified in a similar fashion to those for IEC1000-4-2.

Emissions: EN55 022, CISPR22 defines the permitted limits of radiated and conducted interference from information-technology (IT) equipment. The objective of the standard is to minimize both types of emissions, such as are produced by switching circuits that involve switching current at high frequencies. For ease of measurement and analysis, conducted emissions are assumed to predominate below 30 MHz, radiated emissions above 30 MHz.

The best and easiest method of minimizing emissions is to reduce them at the source; for example, the charge-pump design used in the ADM2xxE family has a major objective of minimizing switching transients without any additional filtering or shielding components. This eases the system designer's task, saves cost and space by eliminating external filters and other high-frequency suppression or shielding elements, and completely avoids filtered connectors, often an expensive last resort.