

Design Fundamentals

EMI Issues in the Manufacturing Environment

Increased Use of Electronics Introduces New Challenges

by Vladimir Kraz

Electromagnetic environment in today's manufacturing presents serious challenge to normal operation of equipment. Electromagnetic interference causes equipment malfunction, parametric errors and downtime. As the sensitivity of equipment increases with higher content of electronics, its susceptibility to EMI increases accordingly. High-energy tools and their co-location with sensitive equipment influence productivity and associated downtime.

In this article, we discuss in detail the nature of electromagnetic interference in the manufacturing environment, and offer some suggestions for effective EMI management.

Nature of Electromagnetic Interference

Every tool or instrument that uses electricity generates associated electromagnetic fields. Voltage causes electric fields, and currents cause magnetic fields. It is normal to expect presence of electromagnetic fields in any environment. Not all electromagnetic fields are a problem. Wireless communication is possible solely due to electromagnetic fields, for instance. Electromagnetic fields generate voltages and currents in any conductive object just like they do in antennae of mobile phones and radio and TV antennae. Similarly, electromagnetic fields generate voltages and currents in electric circuits of process equipment, which act just like antennae.

When these induced voltages and currents reach the level that can cause undesirable operation of equipment, it is called EMI, or electromagnetic interference. EMI can manifest itself in the following forms:

- Outright equipment lock-up
- Tools do things they weren't supposed to do
- Software errors
- Erratic response
- Parametric errors
- Sensor misreading
- Component damage

All of that causes equipment downtime, loss of productivity and product defects.

Proper management of electromagnetic environment is a complex task, consisting of management of electromagnetic emission sources, propagation path and equipment's immunity to electromagnetic radiation. In this article, we will consider each of these tasks.

EMI Generation

There are several types of generators of electromagnetic emission that can eventually cause interference (thereafter called EMI):

- ESD events (discharges)
- Parasitic emission from equipment
- Intentional emission from equipment that uses electromagnetic fields as a part of the process.

ESD Events

An ESD event is characterized by very rapid drop in static voltage and by equally rapid surge of discharge current. The resulting electromagnetic field is similarly characterized by a very sharp transient nature. The effect on the equipment is

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Feature

determined not only on the voltage that was discharged by the ESD event, but also by the charge that was dissipated during the event and the properties of contact.

Another important parameter in assessing EMI impact of ESD events is the antenna properties of the discharging parts. A more effective antenna leads to a higher magnitude of electromagnetic field.

Parasitic Emission from Equipment

This is a type of emission that is a side product of the normal operation of equipment. Though FCC, the European EMC Directive and similar regulations tightly control parasitic emission, in actual installations it is often higher than levels originally anticipated by the equipment manufacturer. This is

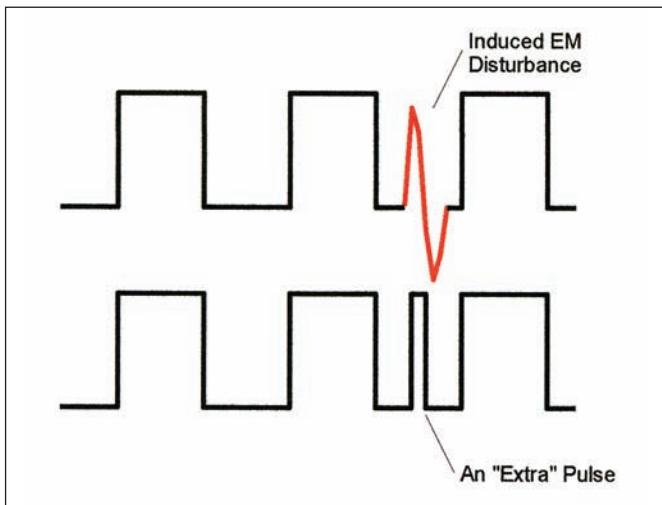


Figure 1: "Extra" pulse due to EMI

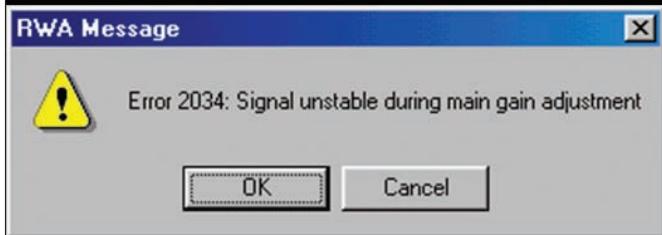


Figure 2: Magnetic head tester under influence of EMI

mainly due to extra long cabling, that may also have partially-engaged connectors and often-open covers that are supposed to, among other things, attenuate the electromagnetic emissions generated inside.

Parasitic emissions may have many characteristics, which are unpredictable and vary from one type of equipment to another.

Intentional Radiation

Some types of tools generate substantial EMI as a part of their normal operation. Special precautions should be taken to isolate such equipment from other tools, including separate power and ground, for example.

Controlling EMI generation is a key component in EMI management.

EMI Propagation

In order for electromagnetic emissions to reach their target, they must have a propagation path. Propagation paths for electromagnetic emissions include:

Radiated

- Electromagnetic fields composed of electric and magnetic fields propagate via air path, just as emissions from a mobile phone would reach the base station
- This field would create voltages and currents in any metal object, i.e. wire, PCB trace, etc.

Conducted

- The most neglected type of propagation
- High-frequency currents move via power, ground and data cables and inject undesirable signals into equipment

Mixed

- Radiated emissions generate signals in wires and cables. These signals are then injected into equipment via conductive path.

Poorly implemented grounding and power distribution networks provide a venue for EMI to propagate from one tool to another. It is not uncommon to witness EMI generated in one corner of a cleanroom manifest itself in another corner.

Controlling propagation path is another key component in EMI management.

EMI Susceptibility

Three basic types of failures can be observed in equipment due to EMI:

Fatal failure due to overstress

- Direct ESD discharge
- Very high EMI-induced signals (EOS)

Latch-Up

- Induced voltages are outside of supply rails
- Often recoverable after power-cycling
- Sometimes causes overheating and failure

Injection of false signals

- Induced signal is comparable to legitimate signals.

Equipment Malfunction

The first two types of failures described above are self-evident when they occur – equipment simply locks up. However, the most problematic is the third type – injection of false signals.

Figure 1 shows how EMI can cause false signal in the tool.

The top waveform of Figure 1 shows how an electromagnetic field creates a signal in a wire or in a trace of a circuit board of a tool. When such a signal passes through the logic gate, it transforms into a pulse which is nearly impossible for the tool to separate from a legitimate signal. This “extra” pulse can cause equipment to perform operations which it wasn’t intended to perform, potentially causing serious damage.

This type of malfunction is very difficult to diagnose. Often, the electronics circuit does not suspect that it was affected by EMI. Today’s high-speed circuits are much more susceptible to ESD-induced high-speed transients. Such equipment malfunctions are frequently blamed on the tool’s software, when the root of the problem can be entirely different. One of the clear indications that the problem has been caused by EMI is difficulty in reproducing the malfunction due to the randomness of the EMI occurrence.

Sensor Misreading

Sensors in the tools may transmit signals at very low levels. EMI can impose sufficient noise on cables and wires to the sensors to alter the signal from the sensors to the degree that the sensors seem to indicate values of the parameters that are different from those that actually exist. In a fully-automated process without safeguards, this may lead to random changes in recipes and product defects.

Some systems can detect abnormal status of their signals and indicate alarm. Figure 2 shows a situation in which a mobile phone induced sufficient signal into sensitive electronics so that the tester recognized the problem and indicated alarm.

EMI and Ground

As technological and process requirements change, the demands for the quality of grounding change, too. Simply complying with the safety standards and conventional ESD grounding standards no longer is enough. We need to examine ground from a different perspective—electromagnetic interference.

While for 50/60Hz and for DC regular long and often coiled ground wires may be sufficient, for high frequency signals they present significant impedance, resulting in significant levels of high-frequency voltage on ground of operating tools.

Figure 3 shows different ways to arrange grounding of the tools. The tool on the left has long coiled ground wire, while the tool on the right has short, braided, straight cable.

But, are these two tools grounded equally well? Existing standards specify properties of grounding mostly at DC and 50/60 Hz. At high frequencies, the situation changes.

With 5 turns of 30 cm diameter, inductance of this coil will be $12.2\mu\text{H}$ which at 100MHz will present impedance of 7.66kOhms . With only 1mA of current at this frequency, the 100MHz voltage on ground of the tool will be 7.66V.

What if the ground wire is not coiled but simply too long? Inductance of a straight 10m wire at 100MHz will be $17.36\mu\text{H}$ which with 1mA of current will produce ground bounce of 10.9V.

Such situations are prone to cause significant EMI problems for the tool.

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Proper EMI Practices

Equipment EMC Compliance

In view of increasingly sensitive processes in manufacturing, it is a prudent practice to buy only equipment that has met appropriate electromagnetic compliance standards, both for emission and for immunity

Installation

Attention must be paid to co-location of equipment, and to avoid placing sensitive equipment near high-energy tools. It is also not advisable to place such tools on the same ground and power lines.

Maintenance

Do not leave tools after maintenance with disconnected grounds, open doors and covers – each of these practices greatly increases probability of EMI-related malfunctions.

EMI Audits

It is advisable to conduct EMI audits in a similar way as ESD audits are conducted. It is outside of the scope of this article to describe the specifics of such audits. However, they are highly effective in understanding EMI environment in

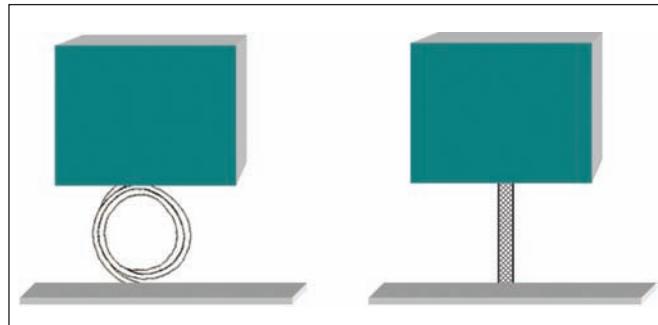


Figure 3: Grounding with High and Low Impedance Path

manufacturing, and they promote a proactive rather than reactive approach to EMI issues.

SEMI E.33 Developments

Some industries, such as semiconductor manufacturing, are paying increased attention to EMI issues. Specific to this industry is SEMI's E.33 standard, which specifies

electromagnetic compliance of semiconductor equipment, and is in its revision phase. (The original E.33 document was issued in 1994, 12 years ago!) Not only have regulatory requirements changed significantly over that time frame, but so to has fabrication technology. Requirements for electromagnetic performance have significantly risen in the past years as well. ■

References

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