Managing EMI in backend semiconductor manufacturing

High-frequency noise, often called electro-magnetic interference (EMI), which is found in abundance on power lines and ground in manufacturing facilities, may cause many problems.

The key problems are electrical overstress (EOS), test errors and problems in the operation of equipment.

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EMI's nature, effects and mitigation
We will examine the nature of EMI, its effects and how to mitigate its effects in device manufacturing.

The operation of electrical equipment inevitably causes electrical disturbances on power lines and ground. Simply turning equipment or a light on and off creates a spike on the power line.

Switched-mode power supplies, which are ubiquitously present in all equipment, generate pulses with repetition rates between 40-200kHz.

The biggest offenders
Servo motors and variable frequency drives (VFDs) used in all equipment with automated motion are arguably the biggest offenders because they produce continuous strong pulses with a repetition rate of 8 to 20kHz. Plenty of equipment generates transients synchronized with 50/60Hz power-line frequency.

Power transmission lines are conductors of EMI.

Noise transmitted through leakage
Through capacitive and inductive leakage, this noise is transmitted to the ground making it no less noisy than the power line.

Now let's examine how EMI specifically affects equipment and devices. According to Intel's Manufacturing Enabling Guide, "EOS is the number one cause of damage to IC components."

Catastrophic damage from EOS
Besides catastrophic damage, EOS tends to weaken the structure of the device. While this may not show failure during test, it leads to latent damage. ***See next page***

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In the presence of high levels of EMI there is often a substantial voltage difference between different grounded points within the tool.

Even low voltage may be dangerous
Since it is ultimately current that damages devices, even a low voltage difference on ground can be dangerous.

IPC-A-610, the most fundamental standard governing PC board assembly and, by extension, relevant to device manufacturing, limits voltage of any kind but with emphasis on "spikes" applied to sensitive devices, to no more than 0.3V.

Smallest pulses like a "jackhammer"
It doesn't take much current to damage the device. Since most of EMI in the equipment are pulses, even the smallest current pulses act as a jackhammer repeatedly supplying device with the energy.

ESD Association STM13.1 limits EOS current from the tip of a soldering iron to no more than 10mA which relates to device manufacturing as well as PC board assembly.

Any metal to metal contact is capable of injection of high current into the devices. At high frequencies, however, metal-to-metal contact may not be necessary.

Capacitors conduct high frequency
Capacitors are very good conductors for high-frequency currents, just like a wire. A device's die or its leadframe positioned close to a metal surface at high frequencies might as well be simply wired to it.

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There are several steps in device manufacturing where metal-to-metal or metal-to-equivalent capacitive contact with the device takes place. Among them:

Wafer-level test
Probe physically connects to the pad or other contact of the device; the die itself has high capacitance to the wafer chuck

Singulation
Metal blade or die comes in contact with the leads of the device while other leads can be connected elsewhere or the die could have capacitive coupling to other metal parts of the tool

Wire bonding
Bonding wire is connected to one grounding point in the tool; the die is capacitively coupled to another one.

Die attach
Often the conductive tip of a nozzle will touch the die, and the die itself has high capacitance respective to the metal of the tool.

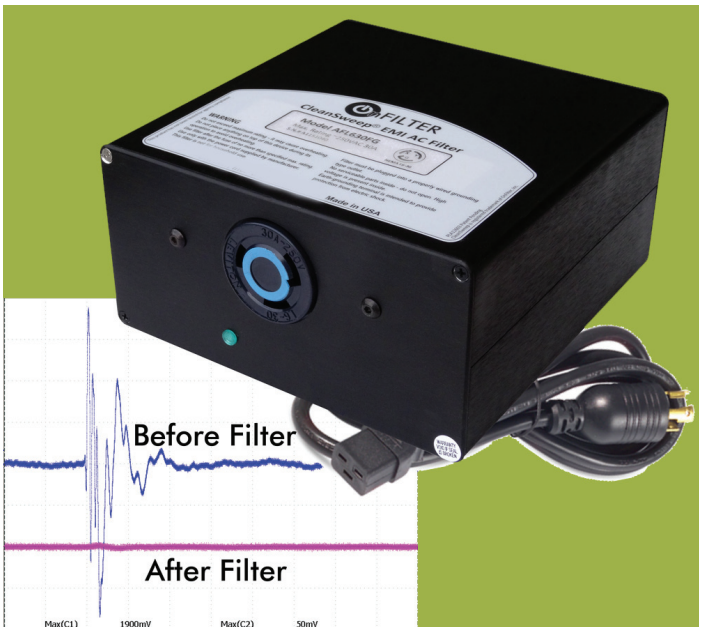
IC handling/test
A typical IC handler places IC several times on the shuttles and once on a test socket. Nozzle has capacitive coupling with the die and leadframe; the pins of the device touch metal.

Strong transients inject signals into data lines and create false pulses that lead to errors in equipment operation. In the worst cases, equipment locks up or behaves erratically.

In milder cases, EMI distorts test results and causes either false positives or false negatives—neither is good.

Such EMI problems are notoriously difficult to debug. Test engineers may spend significant amounts of time trying to catch and eliminate the problem which is often intermittent.

Equipment and EMC Regulations
Don't EMC (electromagnetic compliance) regulations, such as FCC, CE (look at the label on the back of your equipment for a logo) or others require equipment manufacturers to keep noise below certain limits? If so, then why worry about EMI in the facility?



AC power line EMI filter provides substantial suppession of EMI in actual installations

The problem is one of specifics
The problem is that EMC regulations are quite specific, addressing only some types of signals, but not all, and specifying compliance test in the artificial setting of an EMC laboratory.
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Not going into specific details, equipment can generate very high levels of electrical noise and still be fully-compliant with EMC regulations.

The easiest and most conclusive solution to EMI problems is to prevent EMI propagation.

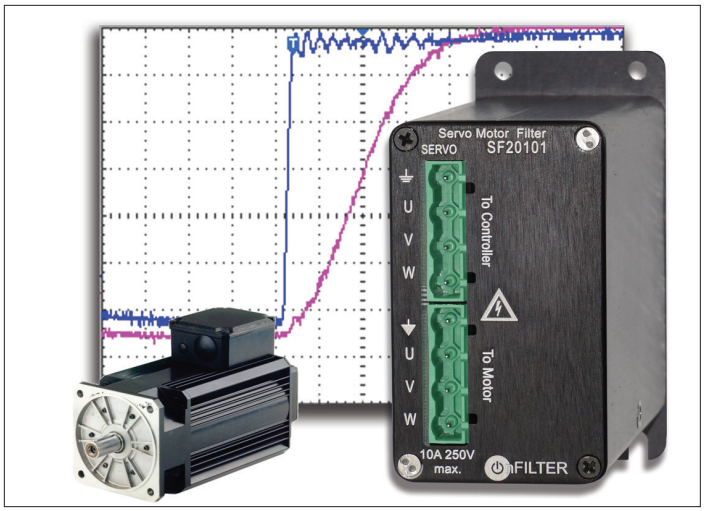
Buyer beware

To further complicate this, there are no current regulations on EMI levels inside the equipment, and the bottom line is *caveat emptor,* or let the buyer beware.

Unfortunately, reducing the EMI generated by equipment may be an arduous task which is practically impossible for the equipment users.

Block high-frequency noise

Blocking the propagation of high-frequency noise within the tool is realistic, effective and permanent. Most importantly, this can be done on already-installed equipment, whether old or new.



Servo motor EMI filters modify the edge of drive pulses, reducing ground EMI current.

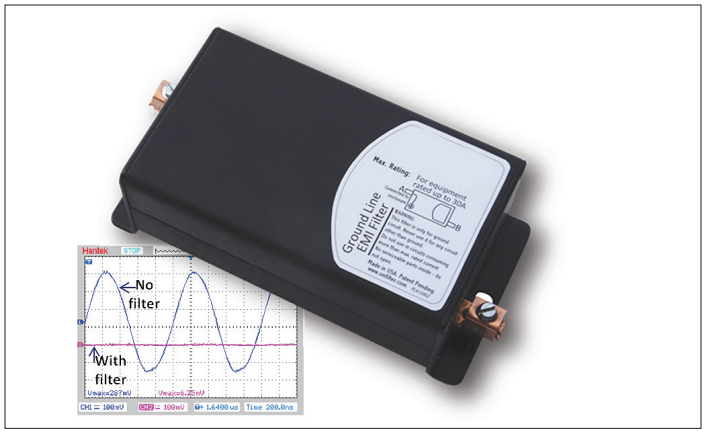
Facility pollution

Since, the power and ground connect all of the equipment in the facility together, noise originated by one tool pollutes the entire facility. When properly designed, AC power line EMI filters can block noise from reaching equipment or sensitive processes.

Provides substantial EMI suppression

It is specifically designed to provide substantial suppression of EMI in actual installations, not just in a laboratory environment.

The filter, which is available with different types of outlets and voltage and current ratings, is plugged into facility's outlet and the equipment is plugged into the filter's outlet.



Facility ground EMI filter

Works for power lines and ground

This filter provides EMI suppression in both power lines and ground. It also reduces noise in the "upstream" direction preventing noisy equipment from polluting the facility's AC power lines.

Some facilities have separate grounding which usually runs in a subfloor. High-frequency leakage currents propagate through such wiring from one tool to another.

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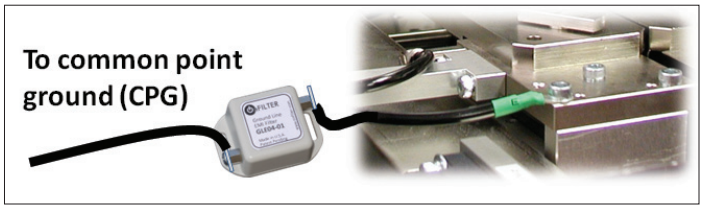
shown, effectively block high-frequency currents while preserving necessary properties of grounding.

Special grounding filters effectively block high-frequency currents while preserving the necessary properties of grounding.



This filter is designed for grounding inside equipment.

Electrical overstress
inside equipment noise generated by servo motors, relays and switches and other sources creates voltage difference between different ground points resulting in electrical overstress.

Small ground filters, above, block high-frequency currents between different ground points while maintaining the proper ESD ground.

Pulse-driven motors are one of the worst EMI polluters. Sharp edges of drive pulses cause significant ground currents. Special servo motor filters modify the edges of these pulses reducing ground EMI current 80 to 100 times.

Conclusion
Special EMI filters for power lines, ground and servo motors are the only realistic way to manage EMI in equipment and in the facility. They provide significant reduction in EMI reducing electrical overstress and improving equipment operation and test.

Mr. Kraz is a founder and president of OnFILTER, a manufacturer of EMI filters, and also does EMI/ESD consulting via his BestESD Technical Services company.

He has 40 years of experience in the electronics industry. During his career, he has designed state-of-the-art equipment for wireless and wired communication, medical, industrial control and other industries, as well as ESD, EMI and EMC solutions.

He holds 23 U.S. patents with more patents pending and is an author of numerous articles for technical publications, papers at ESD Symposia and other forums both in the U.S. and abroad. He has taught classes and conducted seminars on the subject of ESD, EMI and EMC around the world.

He earned two master's degrees in Russia, one in mechanical engineering and the other in electrical engineering. He also chairs the SEMI EMC Task Force.