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TUTORIAL 4991

Oops...Practical ESD Protection vs. Foolhardy Placebos

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Abstract: Electrical overstress (EOS) and electrostatic discharge (ESD) are dangerous to integrated circuits. Foolish humans make excuses, employ placebos, and hope that the laws of physics will not apply to them. This article exposes the folly of that thinking and suggests practical ways to protect electronic systems.

Introduction

Electrical overstress (EOS) and electrostatic discharge (ESD) present real dangers to electronic circuits. In fact, EOS and ESD are the top causes of preventable IC failures. Some people discount the seriousness of the damage that EOS and ESD can cause. We have heard many excuses about why it is not necessary to take proper precautions:

A. "I don't believe in all that hocus pocus (i.e., sleight of hand)."
B. "I am an engineer, have been doing this years without problems."
C. "The humidity is high here."
D. "We already built ESD protection into the printed circuit board (PCB)."
E. "All ICs have built-in ESD protection."
F. "Statistically the odds are that nothing will happen."

This application note exposes the folly of this misguided thinking and suggests practical ways to protect electronic systems.

The Laws of Physics and EOS/ESD

We begin by revisiting these familiar excuses for the absence of proper EOS and ESD protection.

A. Unfortunately, a belief—even a firm belief—usually has little or nothing to do with the laws of physics. Placebos can work in medicine because the human brain has more control than we expect. All the believing that gravity would stop, does not keep us from stumbling and falling. However one thinks about "hocus pocus," when it comes to engineering, the laws of physics will always apply.

B. The laws of physics exist regardless of a person's occupation. Consequently, if a part does not instantly burn up in a cloud of smoke, it does not mean that there was no EOS or ESD present. Nor does apparent functionality mean that the parts were not damaged and will not die later.

C. High humidity does, indeed, reduce the ESD voltage. However, remember that the building's air-conditioning system is removing humidity to make us comfortable. It is simply quite true that humans are not very good at guessing relative humidity levels.

D. Board ESD protection is like air bags in our cars—they are there for accidents not for daily use. Built-in ESD protection reduces the chances of damage but does not totally remove the possibility for injury.

E. While most ICs integrate ESD protection, the ESD structures are made of tiny components. Again they are for accidents not daily use.

F. "Statistically, it will not happen to me." If it is true that statistically most automobile accidents occur within 25 miles of home, will there be no accidents farther away? Remember that numbers do not lie and will not subvert the laws of physics

Credible ESD Protection Obeys the Laws of Physics

A normal ESD wrist strap is a conductive band with a series (current-limiting) resistor connected through a wire and alligator clip to a ground or reference point. Most companies test the effectiveness of this ESD protection several times a day. The person wearing the wrist band goes to the ESD test station and attaches the alligator clip to the ground terminal. While the person touches a finger to another test metal plate, the machine adds an electrostatic potential to the person's body. If the voltage rises, the wrist strap has failed; if the ground effectively keeps the voltage down, the strap is good for continued use.

The proven process follows the laws of physics and is reliable. But still there are sources that subvert the process and convert the effective ESD wrist strap into an ESD placebo. This is the ESD hocus pocus in item A above. For example, take the same wrist strap above and do not connect the alligator clip to the ESD tester ground. Now when the metal plate is touched with a finger, the voltage rises and the wrist strap fails. For many years there have been companies that sell wrist bands without ground wires or claim that the ground wire is optional. In 2005 the *ESD Journal* challenged the wireless wristband manufacturers to performance tests: send in a wireless wrist band for evaluation. If it works, the *ESD Journal* will apologize and give the manufacturer a free advertisement for a year. They had no response to the challenge. The journal continues to claim, "Sorry! Something that sounds too good to be true probably is." Meanwhile, ESD Systems was asked if wireless ESD straps work? Their short answer is "no." (www.esdsystems.com/QuestionsAndAnswers/ShowQuestion.aspx?i=17)

This wireless wrist strap sham sounds foolish, even like a joke, but it is not. Several years ago a friend at another semiconductor company related a story. They had been buying product from a large offshore manufacturer for years, but suddenly something changed. They were finding ESD damage in the imported parts. When questioned, the offshore source said that nothing had changed and that they had stringent ESD safety precautions in place. Finally the semiconductor company flew an ESD expert to the manufacturer's location. Immediately upon walking into the plant, the expert saw wireless wrist straps everywhere. The ESD problem was resolved by replacing the grounding wires and the number of ESD-damaged parts plummeted.

EOS/ESD Protection in an IC

How do we protect electronics from ESD and EOS?

The ESD structures inside an IC are designed to protect the part before the customer mounts it on his

products PC board. Because the ICs are limited in size, they cannot withstand system ESD events. At the board level, however, inputs and outputs can have more robust ESD structures. These external discrete components tend to be physically larger and carry larger currents than the ICs' internal ESD protection.

PC boards are protected from ESD by a combination of discrete silicon (small signal or reference), Schottky diodes, avalanche (zener) diodes, transient voltage suppression (TVS) diodes, gas-tube discharge devices, resistors, inductors, and metal oxide varistors (MOVs). Series resistors and inductors along with capacitors to ground can act as a lowpass filter. The rise time of a spark is very fast, so any way that we can slow it down will reduce the peak voltage.

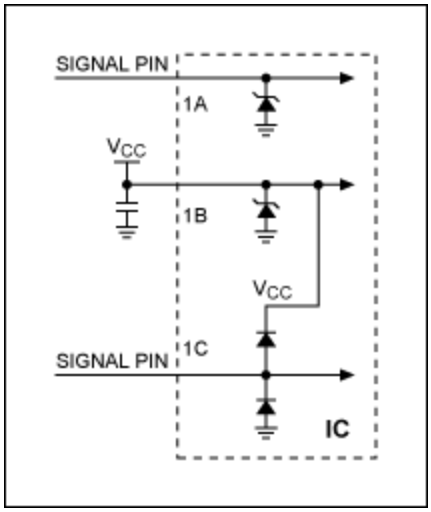

Figure 1. Typical internal IC ESD structures.

The ESD structures of **Figure 1** are internal to the ICs. Figure 1C is the most common design with two diodes used on input and output signal pins. Most IC data sheets will specify that a pin like this will have voltage maximums from -0.3V, if ground is the lowest voltage, to V_{CC} (power supply) plus 0.3V. These are silicon diodes with a forward voltage drop of 0.6V, so why does the data sheet say 0.3V? The answer is because at high temperatures the diode starts leaking significant current. The operation of diode to ground is generally obvious. The diode to V_{CC} requires that the power be low impedance to be effective. Unless the power supply is very close, the low impedance is handled by the decoupling or bypass capacitors.

In Figure 1B the power pin does not have a higher voltage to connect, so a zener diode will protect this pin. The zener on Figure 1A is seen on pins with a hidden use. For example, a part, especially the digital part of the IC, may have special test or trim modes for automatic factory test. To enter this mode the pin can be pulled a diode drop higher than V_{CC}. After the test, power is removed from the IC to exit the test mode.

In addition to the ESD protection build into most Maxim products, Maxim makes specialized ESD-protection and other fault-protected devices (www.maximintegrated.com/products/protection/) which include ESD protection diodes, analog switches and multiplexers, switch debouncer/protectors, overvoltage protection (OVP) controllers, signal-line protectors, lithium-ion (Li+) battery protectors, and current-limit and USB power switches.

Reference Information
Maxim application notes discuss ESD, EOS, and other protection methods:
Application note 639, "Maxim Leads the Way in ESD Protection"
Application note 651, "ESD Protection for I/O Ports"
Application note 4032, "HFTA-16.0: ESD Protection for Bipolar Integrated Circuits"
Application note 1167, "Practical aspects of EMI protection"
Application note 4035, "Overvoltage Protection (OVP) for Sensitive Amplifier Applications"

Application note 4353, "Robust Contact Monitor Simplifies Design of Body Control Computers," discusses the MAX13362, a 24-channel automotive switch monitor. The device interfaces to remote switches in a vehicle and is directly subjected to all the transients observed in the wiring harness of an automobile. The MAX13362 can protect against lost ground/power connections, reverse-battery condition, and ground and power-supply shifts.

Application note 4240, "Active High-Voltage Transient Protectors Trump Conventional Approaches in Automotive Electronics," contrasts active and passive protection methods.

Unfortunately, human nature and common sense do not always coincide. But ESD and EOS always obey the rules of physics, no matter how hard we wish it were otherwise sometimes.

Links for More ESD Information
ESD Journal has many fine articles at: www.esdjournal.com/

The ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge. (www.esda.org/ and https://www.esda.org/about-esd/esd-fundamentals/).

The Silicon Valley EOS/ESD Society discusses electrical overstress (EOS) and electrostatic discharge (ESD) at: www.esdiscovery.org/

Related Parts		
MAX13362	24-Channel Automotive Switch Monitor	Free Samples
MAX1480E	±15kV ESD-Protected, Isolated RS-485/RS-422 Data Interfaces	Free Samples
MAX1488E	±15kV ESD-Protected, Quad, Low-Power RS-232 Line Driver	Free Samples
MAX1490E	±15kV ESD-Protected, Isolated RS-485/RS-422 Data Interfaces	Free Samples
MAX16013	Ultra-Small, Overvoltage Protection/Detection Circuits	Free Samples
MAX16014	Ultra-Small, Overvoltage Protection/Detection Circuits	Free Samples
MAX253	1W Primary-Side Transformer H-Bridge Driver for Isolated Supplies	Free Samples
MAX3080	Fail-Safe, High-Speed (10Mbps), Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX3083	Fail-Safe, High-Speed (10Mbps), Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples

MAX3088	Fail-Safe, High-Speed (10Mbps), Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX3188	1Mbps, 1µA RS-232 Transmitters in SOT23-6	
MAX3190E	±15kV ESD-Protected, 460kbps, RS-232 Transmitters in SOT23-6	Free Samples
MAX321	Precision, Dual Supply, SPST, Analog CMOS Switches	Free Samples
MAX3223E	±15kV ESD-Protected, 1µA, 3.0V to 5.5V, 250kbps, RS-232 Transceivers with AutoShutdown	Free Samples
MAX3225E	±15kV ESD-Protected, 1µA, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3226	1µA Supply Current, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3228	+2.5V to +5.5V RS-232 Tranceivers in UCSP	
MAX3244E	±15kV ESD-Protected, 1µA, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3245E	±15kV ESD-Protected, 1µA, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3311E	±15kV ESD-Protected, 460kbps, 1µA, RS-232-Compatible Transceivers in µMAX	Free Samples
MAX3313E	±15kV ESD-Protected, 460kbps, 1µA, RS-232-Compatible Transceivers in µMAX	Free Samples
MAX3387E	3V, ±15kV ESD-Protected, AutoShutdown Plus RS-232 Transceiver for PDAs and Cell Phones	Free Samples
MAX3388E	2.5V, ±15kV ESD-Protected RS-232 Transceivers for PDAs and Cell Phones	Free Samples
MAX3443E	±15kV ESD-Protected, ±60V Fault-Protected, 10Mbps, Fail-Safe RS-485/J1708 Transceivers	Free Samples
MAX3483E	3.3V Powered, ±15kV ESD-Protected, 12Mbps, Slew-Rate-Limited True RS-485/RS-422 Transceivers	Free Samples
MAX3485	3.3V Powered, 10Mbps and Slew-Rate Limited, True RS-485/RS-422 Transceivers	Free Samples
MAX3490	3.3V Powered, 10Mbps and Slew-Rate Limited, True RS-485/RS-422 Transceivers	Free Samples
MAX4506	Fault-Protected, High-Voltage Signal-Line Protectors	Free Samples
MAX4551	±15kV ESD-Protected, Quad, Low-Voltage, SPST Analog Switches	Free Samples
MAX4558	±15kV ESD-Protected, Low-Voltage, CMOS Analog Multiplexers Switches	Free Samples

MAX4568	±15kV ESD-Protected, Low-Voltage, SPDT/SPST, CMOS Analog Switches	Free Samples
MAX4575	±15kV ESD-Protected, Low-Voltage, Dual, SPST, CMOS Analog Switches	Free Samples
MAX4630	±15kV ESD-Protected, Low-Voltage, Quad, SPST, CMOS Analog Switches	Free Samples
MAX4640	±15kV ESD-Protected, Low-Voltage, Quad, SPST, CMOS Analog Switches	Free Samples
MAX483E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX485E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX487E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX488	Low-Power, Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX491E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX6397	Overvoltage Protection Switch/Limiter Controllers Operate Up to 72V	Free Samples
MAX6398	Overvoltage Protection Switch/Limiter Controllers Operate Up to 72V	Free Samples
MAX6399	High-Voltage, Overvoltage/Undervoltage, Protection Switch Controller	Free Samples
MAX6495	72V, Overvoltage-Protection Switches/Limiter Controllers with an External MOSFET	Free Samples
MAX6496	72V, Overvoltage-Protection Switches/Limiter Controllers with an External MOSFET	Free Samples
MAX6497	72V, Overvoltage-Protection Switches/Limiter Controllers with an External MOSFET	Free Samples
MAX6498	72V, Overvoltage-Protection Switches/Limiter Controllers with an External MOSFET	Free Samples
MAX6499	72V, Overvoltage-Protection Switches/Limiter Controllers with an External MOSFET	Free Samples

More Information
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