TECHNICAL NOTE

HAND SOLDERING: ELECTRICAL OVERSTRESS AND ELECTROSTATIC DISCHARGE

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ABSTRACT

This note discusses:

- Definitions of common Electrical Overstress (EOS) and Electrostatic Discharge (ESD) terms.
- The effects and hand soldering causes of EOS damage.
- Metcal's approach to EOS and ESD.
- EOS and ESD MIL-STD requirements.
- Basic test methods for determination of ESD/EOS parameters measured in hand soldering.

This paper will give the reader a general understanding of EOS and ESD phenomena. It specifically addresses hand soldering's role in EOS and ESD and how to protect against and test for potential problems. It discusses how Metcal Systems address EOS and ESD concerns and how they differ from conventional soldering systems.

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INTRODUCTION

Electrical Overstress (EOS), and a subset of EOS, Electrostatic Discharge (ESD), have become major sources of concern over the past 10-20 years. Organizations such as the EOS/ESD Association are beginning to standardize this phenomena. While manufacturers, realizing that ESD and EOS are important, specify ESD protection when purchasing equipment, the method of ESD protection is left up to the supplier. Companies which must meet the MIL-STD often do not fully understand the requirements of the standard. As a result, costly procedures and processes are often implemented that do little to address the actual problem.

EOS/ESD

Many in the electronics industry use the acronyms ESD and EOS interchangeably. However, ESD is a specific subset of EOS, and is generally considered a handling and packaging problem. Electrical overstress (EOS) is a broad definition encompassing many potential sources and failure modes. There are two types of failures: catastrophic, which can usually be identified by testing prior to shipment, and latent, which is a malfunction caused by electrical overstress occurring during normal operation. Latent electrical overstress does not cause catastrophic failure, but is severe enough to actually weaken the part, diminishing the life of the assembly.

COSTLY PROCEDURES AND PROCESSES ARE OFTEN IMPLEMENTED THAT DO LITTLE TO ADDRESS THE ACTUAL PROBLEM

An integrated circuit (IC) has three primary failure modes: metal burnout, junction shorts, and dielectric breakdown. All three failures are caused by excessive current in the IC, which heats the metal through resistance heating. Voltages exceeding the specific breakdown level of the gate oxide send current through the oxide, damaging metal oxide semiconductors (MOS). Any amount of current in the oxide causes sufficient heating to cause damage. This type of voltage sensitivity has resulted in “on chip” protection for most IC’s that use MOS technology.

POTENTIAL EOS SOURCES

STEADY STATE ELECTRICAL ENERGY

Steady state electrical energy may be present on the soldering tip when the alternating electrical current passing through the heater couples with the tip.

TRANSIENT ELECTRICAL ENERGY

Transient electrical energy can be caused by both internal and power line transients. In soldering irons, this can be caused by intermittent ground or by switching power to the heater (in a conventional iron). Most conventional irons now use zero voltage switching. Zero voltage switching attempts to switch power to the heater when the power cycle is essentially at zero voltage.

THERMOCOUPLE EFFECT

Different materials brought into contact under soldering temperatures can generate substantial DC voltages of up to several millivolts, depending on the material. This voltage is of primary interest when testing soldering irons for MIL-STD compliance. See “Testing Methods”, page 3.

ESD

ESD damage is often caused by component handling and assembly during manufacture. An insulative workpiece rubbed against the cord can generate up to 5000V. Most ESD-controlled shops use items such as ground straps, conductive floors, static dissipative clothing, and ionizers to control ESD.

MILITARY STANDARDS

This section is intended to clear up some misconceptions concerning the relevance and requirements of MIL-STDs. For a more detailed description concerning a particular application of the standards, read the MIL-STD.

MIL-STD-2000A FOR EOS PROTECTION

Section 5.1.2.2 reads, in part:
“Resistance between the tip of the hot soldering iron and the workstation ground shall not exceed 5.0 ohms. The potential difference between the workstation ground and the tip of the hot soldering iron shall not exceed 2 mV RMS.”

MIL-STD-2000A FOR ESD PROTECTION

Section 5.1.1 reads in part:
“Electrostatic discharge (ESD)...shall be in accordance with MIL-STD-1686.”

In general, MIL-STD-2000 covers EOS and is concerned primarily with steady state and transient electrical energy. By specifying a tip-to-ground resistance, MIL-STD-2000 insures a greater margin of protection against voltage transients. The 2 mV RMS is a secondary check for current leakage. Metcal systems meet both of these specifications. Recommended test methods are specified in MIL-HDBK-2000 (see Testing Methods). The 2 mV RMS is met by most soldering irons, but is considered by many to be restrictive. Most agree that damage cannot occur below 100 mV.

MIL-STD-1686A

MIL-STD-1686A deals primarily with classifications of parts and assemblies. It makes it necessary for contractors to maintain some control over the voltage level in the handling of ESDS items. MIL-STD-1686A makes reference to DOD-HDBK-263 for guidance. It is up to the contractor and their suppliers to develop the optimum method for voltage control in the handling and assembly of ESDS items.

TESTING METHODS

TIP POTENTIAL

Tip potential measurements are usually made in order to comply with the 2 mV requirement given in Section 5.1.2.2 of MIL-STD-2000A, but a variety of test methods are utilized. To obtain accurate results, the user should follow the test method given in Appendix A of this note or use the suggested method given in MIL-HDBK-2000, Section 5.1.6. The two key elements which can greatly influence the test are thermocouple effects and radiated noise outside the 50-500 Hz frequency range.

THE TWO KEY ELEMENTS THAT CAN GREATLY INFLUENCE THE TEST ARE THERMOCOUPLE EFFECTS AND RADIATED NOISE

Thermocouple effects are DC voltage. They may be eliminated by using an AC voltmeter. The MIL-STD requires a tip potential equal to or less than 2 mV RMS. MIL-HDBK-2000 specifies that this voltage be measured in a specific frequency range (50-500 Hz). A meter sensitive to DC voltages (0 Hz) or AC voltages outside this range should not be used. If a TRMS meter with an expanded frequency response is utilized (HP3400A @ 10 MHz), measurements greater than 2 mV RMS will often result. Local AM radio stations can induce 2 mV (at 1.2 MHz) or more depending on the system layout. A hand-held meter like the Fluke 8060A multimeter provides adequate frequency response, but will not pick up potential sources of error such as local radio stations. Filters can be incorporated to limit the frequency response of a given meter (see Appendix A). Be aware that Metcal Enhanced Systems utilize 10 mA DC current, which results in 1 mV DC potential at the tip. This should not affect results if proper procedures are followed.

TIP-TO-GROUND RESISTANCE

Similar precautions need to be taken when measuring tip-to-ground resistance as specified in Section 5.1.2.2 in MIL-STD-2000. Thermocouple effects also need to be taken into consideration when performing this test. Appendix B provides a method for measuring tip-to-ground resistance.

SURFACE RESISTIVITY MEASUREMENT

Measurement of surface resistivity has been the subject of some discussion. Metcal tests incoming materials per ASTM D257, DC Resistance or Conductance of Insulating Materials. The reader will note that this specification is primarily used for measurement of insulating materials, but it is also the accepted standard for many manufacturers of test equipment. Metcal uses a Monroe Electronics Portable Surface Resistivity Meter for conformance testing of material coupons.

METCAL'S APPROACH TO EOS AND ESD

The primary concern when considering EOS/ESD protection in soldering systems is to limit steady state and transient electrical energy. Metcal offers superior protection in this area. Because Metcal systems deliver continuous current, they cannot generate switching transients. Metcal's cartridge tip and hand cord assembly guarantee good ground path with little maintenance. This keeps the tip current leakage and tip potential at a minimum. Typical values for tip-to-ground resistance and tip potential are 0.8 ohms and 1.0 mV, well within the MIL-STD specification.

Metcal also offers extra protection against potential ground faults in its Enhanced Systems with an Auto-Off feature. This feature senses the DC continuity (resistance) of the output cable and handle assembly through the cartridge. If the resistance of the output circuit exceeds a preset reference level, the system is turned off. This is fail-safe protection against any ground loss.

Metcal also protects against ESD by making static dissipative (10^5-10^{12} ohms/sq surface resistivity) all surfaces that are in direct contact with soldered components static dissipative. And where possible, Metcal uses static dissipative materials with the stricter surface resistivity of 10^5 - 10^9 ohms/sq. This limits the opportunity for any substantial static charge build-up.

However, the user concerned with ESD protection must still insure that the work surface is made of static dissipative material and is properly grounded. A static dissipative surface insures efficient, but controlled, dissipation of static charges. Dissipative surfaces will also distribute the charge over the entire surface, limiting the possibility of point charge buildup. For information on how to check static dissipative material for surface resistivity, see Testing Methods.

APPENDIX A: DEFINITIONS

ANTI-STATIC

The triboelectric charge inhibiting property of a material.

CONDUCTION CHARGING

The charging process which occurs between two conductors, one of which is initially charged. Charge transfer happens at the time of contact and results in new body potentials after separation.

CONDUCTIVE

A material that has a surface resistivity less than 10^5 ohms/sq or a volume resistivity less than 10^4 ohm-cm. See Figure 1.

ELECTRICAL OVERSTRESS (EOS)

Any electrical energy that damages or causes possible failure to an electrical device.

ELECTROSTATIC DISCHARGE (ESD)

The transfer of an electrostatic charge between bodies at different electrostatic potentials. A subset of EOS.

ESDS

Electrical and electronic parts, assemblies, and equipment that are ESD-sensitive. As defined in MIL-STD-1686, parts sensitive to voltages of 16,000 volts or higher are non-ESD sensitive.

INDUCTION CHARGING

The charging process that occurs when a neutral conductor is brought into the vicinity of the electric field produced by another charged body.

INSULATIVE MATERIAL

A material having a surface resistivity greater than or equal to 10^{12} ohms/sq or 10^{11} ohm-cm volume resistivity. See Figure 1.

STATIC DISSIPATIVE

A property of a material having a surface resistivity of at least 10^5 ohms/sq or 10^4 ohm-cm volume resistivity, but less than 10^{12} ohms/sq surface resistivity or 10^{11} ohm-cm volume resistivity. See Figure 1.

SURFACE RESISTIVITY

The ratio of DC voltages to the amount of current passing across the system's surface, or the resistance between two opposite sides of a square independent of the square's size or dimensional units. Units: ohms/sq.

TRIBOELECTRIC CHARGING

The charging process which occurs when two different materials come into contact, and then separate. One or both materials are generally an insulator.

VOLUME RESISTIVITY

The ratio of the DC voltage per unit thickness to the amount of current per unit area passing through a material. Units: ohm-cm.

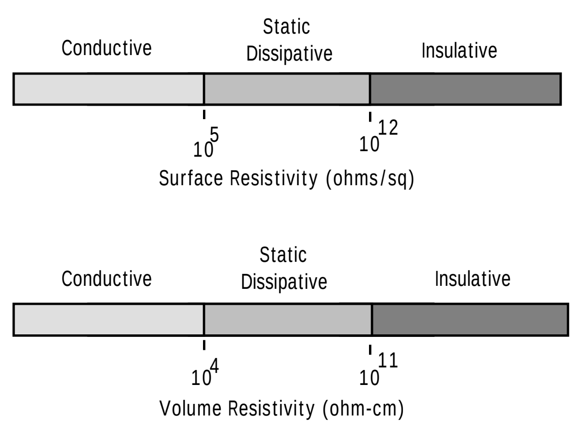

FIGURE 1: RESISTIVITY

APPENDIX B: TIP POTENTIAL TESTING METHOD

EQUIPMENT LIST

TRMS voltmeter, three (3) cables (shielded, BNC to alligator), ground clip, conduction plate (copper shim stock), and solder.

PROCEDURE

1. Remove any dirt and corrosion from the conduction plate. (See Figure 2)
2. If sufficient solder pool is not already present, bond a small pool of solder to the conduction plate.
3. Attach BNC connector to the input of the voltmeter.
4. Attach the ground clip probe to the ground pin on the AC wall receptacle. (See Figure 2)
5. Plug voltmeter and soldering iron into the same AC power strip.
6. Connect the positive and negative cable wire alligator clips to the conduction plate. (See Figure 2)
7. Connect the ground clip to the conduction plate.
8. Turn on power to voltmeter and soldering iron and allow 1 min for warm-up.
9. Record voltmeter value (V_1).
10. Remove the negative cable wire alligator clip and ground clip from the conductive plate.
11. Connect the negative cable wire alligator clip to the ground clip.
12. Remove the soldering iron from holder and press the soldering tip against the solder pool on the conduction plate. Allow approximately 15-20 seconds for stabilization.
13. Record voltmeter value (V_2).
14. Calculate the potential difference (P) between earth ground and the tip of the iron by subtracting the first reading (V_1) from the second (V_2).

$$P = V_2 - V_1$$

Test Frequency: 50-500 Hz.
If using HP3400A or equivalent, see Figure 3.

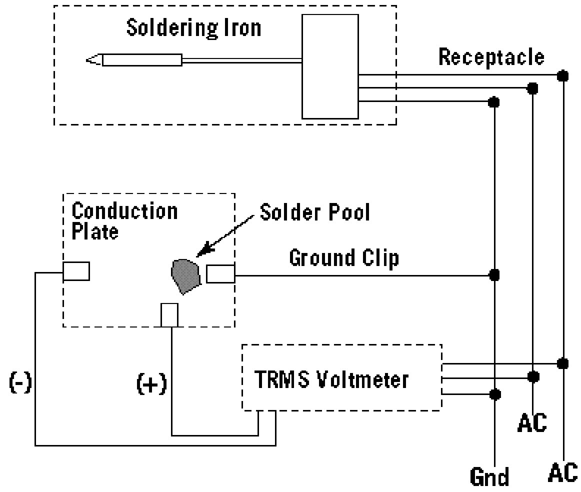

FIGURE 2: INITIAL TEST SET-UP

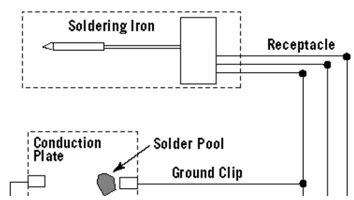

FIGURE 3: 500 HZ FILTER FOR HP3400A OR EQUIVALENT

APPENDIX C: TIP TO GROUND MEASUREMENT

EQUIPMENT LIST

Ohmmeter (consider the resolution and the supplied constant current. The smaller the current, the more susceptible the measurement will be to system oxide effects), Electrical Probe

PROCEDURE

1. Calibrate the test equipment by connecting the connector end of the ground wire into the meter ground and the probe into the meter signal input. Next, determine the resistance of the wires and probes. Connect the ground wire to the probe. The resulting resistance is the total resistance of the two wires. Subtract the wire resistance from the resistance readings made with the soldering system.

2. Secure the tip in the soldering system.

3. Connect one input of the ohmmeter to ground at the same location the system's ground is connected at the plug.

4. Connect the other input to the probe that is to be placed on the hot soldering tip. The tip should be at a temperature greater than the reflow temperature of the solder used. This procedure reduces the electrical contact resistance between the tip and the probe. A soldering system holder may be used to maintain a constant pressure and angle for the probe-to-tip interface. This practice provides consistent readings.

5. Take the resistance reading and record the highest reading observed. Resistance should be measured within the first 10 seconds after the tip is in contact with the probe.

6. The thermoelectric effect also effects resistance readings. This can be negated to some degree by the following procedure:

   a. Make resistance readings with above configuration. Note reading R_1.

   b Reverse leads

   c Take a second resistance measurement. Note reading R_2.

   d. Average the absolute values or simply

$$R_{actual} = \frac{|R_1| + |R_2|}{2}$$

Procedure xcerpted from EMPF (Electronics Manufacutring Productivity Facility) "Process Handbook: Conductive Point-to-Point Soldering" June 1989