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EOS Safe Soldering Iron Requirements

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EOS Safe Soldering Iron Requirements

Introduction

Soldering iron requirements to prevent electrical overstress (EOS) vary throughout the world. EOS issues related to soldering irons have not been researched based on device physics or sound electrical engineering practice. In the United States the most prominent standard has been the MIL STD-2000 series documents that contain soldering specifications. (MIL STD-2000 is now cancelled without replacement as the Military is using civilian documents.) ESD documents often consider the soldering iron requirements part of electrostatic discharge (ESD) protection, but the soldering iron requirements are really intended to control one of the many forms of EOS, not ESD. An underlying, but misguided concern is the possibility of causing a latent defect that would become a latent failure. This issue has been addressed^{1, 2} and it has been shown that a latent failure is highly improbable, therefore latency is not an issue, even with a faulty soldering iron. The ESD Association is working on a replacement soldering iron standard that is based on the information in this technical report.

The soldering iron requirements seem arbitrarily based on the lowest voltage that could be measured in a laboratory setting. The present requirements are in the noise level and do not detect actual leakage currents or changes in leakage current with time. Calculations show that the actual leakage currents, for most soldering irons, are far below the level of the millivolt readings that are being recorded and below the specification value required by the present day MIL STD-2000 standard. The tip resistance to ground also appears to be arbitrary and varies from document to document. The soldering iron requirements must be based on the sensitivity of the most susceptible devices that are to be soldered.

There are many EOS issues related to soldering irons. Soldering iron switching circuits and external line transients are hard to specify and difficult to measure. Line transients are hard to predict or control. Also, a tribocharged device or board may cause a device to be damaged when contacted by a soldering iron. In the case of a charged device or board, the amount of charge available to cause damaging current cannot easily be measured. The current is not related to hand held charge locator measurements³ because most of the charge on an insulator may not flow from the insulator to produce device damage. The potential for damage cannot be easily assessed for these situations. There are also special conditions related to disk drive magnetic recording soldering operations, or some other sensitive items. These conditions and special situations are not addressed in this technical report.

History

The MIL-STD-2000 specification for tip voltage of 2 millivolts is not acceptable to everyone for many reasons. The tip voltage requirement always has been a controversial issue because the requirements were never based on semiconductor physics. Also, it seems that measurement problems related to instrumentation required outside of a laboratory and in a manufacturing

environment were not considered. The measurements to verify compliance are very time consuming, especially for those contracts that require soldering irons to be checked daily.

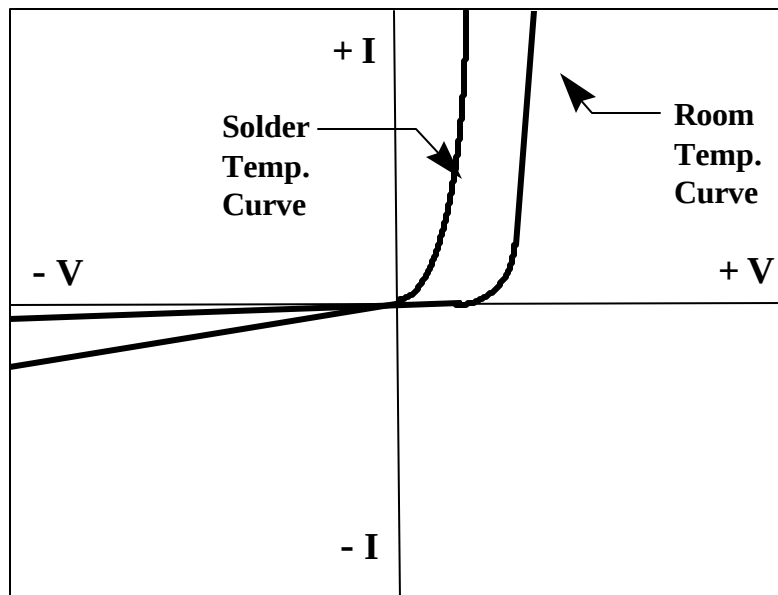
There are many voltage sources in the workplace that are above the 2 millivolt specification, such as thermocouple voltages produced by a contact of dissimilar metals of the soldered item and the iron tip. Potentials of several volts can be measured between the work surface and EGC due to induced voltages from power line to lamps, instrumentation, and other equipment. These sources have been known for a long time, but have not caused a change in the requirements, although some years ago M.D. Frederickson of the Navy EMPF Soldering School proposed a 100 millivolt requirement. Recently measurements and analysis of several soldering iron types have been made for the development of the ESD Association's Soldering Iron Standard - EOS/ESD WIP-13.0. This work showed that the values being measured for current standards are excessive and incomplete. Also, the values measured are not due to the inherent leakage current, but are due to noise sources and measuring instrument limitations.

Iron Tip Requirements

A safe steady-state power level requirement, is needed to determine the prevention of EOS by soldering irons. To prevent EOS damage or degradation, the transistor device must withstand both the tip voltage and the applied power in a steady state situation. Therefore, the available power, not tip voltage, needs to be controlled by the specification.

Device Type Based Requirements

Voltage sensitive type of devices, unprotected MOS (metal oxide semiconductor), have gate oxide breakdown voltages that are much higher than the tip voltage that could cause EOS in an energy type of device.³ A low applied voltage to an energy sensitive type of device, P/N junctions and "on chip" protected MOS, passes a small current before the forward turn-on voltage is reached. This current increases many fold for the given voltage when the junction's temperature rises because the device is being soldered. (See Figure 1) Gate oxide breakdown voltages are relatively high compared to any tip voltage that would damage a low impedance energy sensitive device being soldered. When compared to a voltage sensitive device, there will be only a minuscule current through very insulative oxide, if the breakdown voltage is not exceeded. Therefore, energy devices set upper limit for tip voltages, not voltage sensitive type of devices. In other words, for a grounded iron, very sensitive energy devices will be damaged before voltage sensitive devices reach the gate oxide breakdown voltage. This is contrary to the popular myth that soldering iron tip voltages can easily damage unprotected gate oxide.



Diode I/V Curve
at
Soldering Temp.
Fig. 1

If voltage sensitive gate oxide devices would have a breakdown voltage in the range that would be damaged by a poorly grounded iron, they could not be assembled by automatic equipment or by hand because it takes so little energy to damage a oxide device once the breakdown voltage is reached.³ Even the most sensitive gate oxide devices have breakdown voltages that are very high, many volts, compared to the millivolts of a grounded tip. Voltage sensitive devices have to have breakdown voltages above the tens of volt range, even if there is a good ESD protection program in place.⁴

The vast majority of MOS ICs have “on chip” protection circuits and they respond to EOS just like PN junction devices. Therefore, some of the soldering iron’s leakage current may pass through the grounded MOS device when it is soldered. Increasing the HBM energy level classification by making the device’s protection circuit more robust also hardens the device to EOS, in most cases. The protection levels of most present day MOS computer chips are above a 2 kV human body model (HBM) energy level. This is contrary another myth, that as devices become smaller, they become more sensitive. Very few devices become more sensitive as they become smaller. Competing manufacturers just cannot afford to have their devices fail at low levels of ESD. ESD “on chip” protection improvement have been reported in numerous EOS/ESD Symposium papers over the years.

Semiconductor Based Analysis

The present 2 millivolt specification is unreasonably stringent and not related to EOS of semiconductor devices. Besides lacking any relationship to device damage, the specifications are also impractical to maintain in the workplace. This should be obvious, particularly when

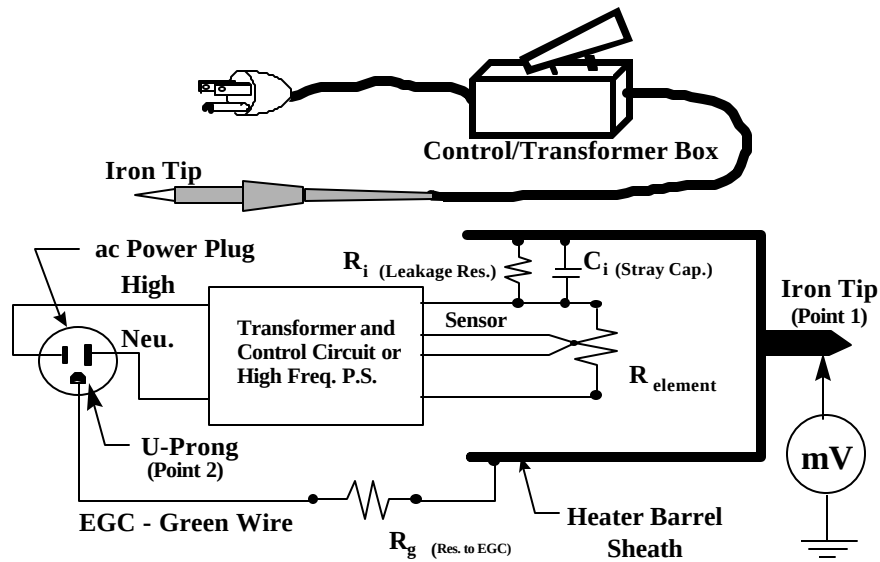
dealing with solder irons since thermocouple effects can easily generate 2 millivolts at soldering temperatures. Workstation mats also can have several volts of induced ac from power cords. Though the 2 millivolts specification is shown to be unreasonable for many reasons, at issue is, what soldering iron tip power (voltage and current) level is safe for the most ESD susceptible device that will ever be soldered?

There are many possible threats to sensitive electronics as a result of applying a soldering iron. The first is that the iron is carrying an unwanted charge, which upon touching the lead of an electronic package can discharge through the electronics to the ground of the system. This is the **static charge** threat and is easily taken care of by “grounding” the soldering iron tip or heater barrel metal sheath to the equipment grounding conductor (EGC). By requiring that the iron tip be connected to EGC with a resistance that is very low, a near equal potential is maintained between the iron tip, the EGC and the ESD workstation surface. The ESD workstation surface or portable mat is connected to the same common ground (EGC).

Another threat is the presence of a charge on the device. The concern is that suddenly discharging an already charged device will result in a damaging current. While a low resistance protects the iron from having unwanted charge, it does not protect against the possibility of a high current discharge from a charged device that is being soldered. In this case, the low resistance specification results in the possibility that a very susceptible device may be damaged. This sudden discharge can produce a large current for a short period of time. Some devices can be sensitive to such sudden discharges. To prevent this scenario two approaches can be pursued. The first is to ensure that the item being soldered is fully discharged. The second approach is to require that the soldering iron tip is isolated from ground with at least 1×10^6 ohm resistance. This will cause the iron to discharge any charged devices more slowly assuming that the initial peak power discharge into the iron tip’s capacitance is sufficiently low. Even with an isolated tip, the inside metal heater sheath must still have a low resistance to the EGC. A change in the tip resistance to EGC has ramifications in soldering iron design. A high tip to EGC resistance, in the megohms range, is an issue for USA standards, but no recommendation can be made at this time, because the magnitude of the charged device problem is not known.

Soldering Iron EOS Analysis

EOS is the main threat that is of concern and is addressed in present USA soldering iron standards. The ac power source due to a faulty soldering iron can be a source of the EOS. The ac coupling capacitance and leakage current for a properly designed and functioning soldering iron will deliver very little electrical power and store very little energy, but it will never be totally zero. A diagram of pertinent parameters is shown in Figure 2.



Soldering Iron Schematic

Fig. 2.

The Figure 2 generalized soldering iron representation of the ac power source that shows the components that deliver power to the grounded tip. The maximum resistance R_g of the tip is specified by various soldering iron specifications and is not the same in all the soldering standards. R_i and C_i are established by soldering iron design. Typically R_i is greater than 10 megohms and assumed to be due mainly to the leakage current from the heater element R_h . While C_i is usually around 50 picofarads, filter capacitors across on the ac line may produce additional current into the EGC ground wire. At around 50 picofarads, the capacitance reactance is about 50 megohms. Transformerless soldering irons will have a much greater capacitance that is distributed along the EGC wire of the power cord. (See Appendix Table 1 values for cords and transformerless soldering irons.) Transformerless soldering irons can be much more dangerous to sensitive devices than transformer units, if the EGC line opens. An open EGC at the ac outlet is most common soldering iron problem because of a broken wire or the EGC is not connected to ac neutral at the utility service entrance. An open line is often due to miss-wired EGC at the ac outlet. The ac outlet should conform to the ESD Association's Grounding Standard - EOS/ESD 6.1

The impedance Z_i (the parallel combination of R_i and X_{Ci}) for the iron of Figure 2 is given by:

$$[1] \quad z_i = \frac{R_i}{1 + 2\pi f R_i C_i}$$

The applied ac voltage V_a results in an iron tip voltage V_t given by equation [2].

$$[2] \quad V_t = \frac{R_g V_a}{z_i + R_g}$$