Effective qualification of soldering iron performance criteria

Introduction

Quality managers and line supervisors are routinely tasked with the responsibility of ensuring that the hand soldering process is under control. The method most commonly used is to measure the idle tip temperature of the soldering station and to use this reading as a benchmark of system compliance. This method, although popular is now being seriously questioned by many industry professionals as being irrelevant in qualifying true system process control.

This document aims to present a practical view of what factors are important for successful hand soldering and to suggest an alternative procedure for qualification that is simple, repeatable and directly related to the effectiveness of the soldering station.

1) Understanding the conduction soldering process

Before we consider alternative test methods, it is first necessary understand what is truly important in the hand soldering process. In general, we are concerned about the following factors:

a) **Solder Joint Connection Quality**
If too much thermal energy is delivered into the solder joint the temperature will become too high resulting in compromised metallurgy and a significant risk of damage to the PCB laminate. Too little thermal energy will lead to unsoldered joints or faults such as insufficient wetting.

b) **Throughput**
Productivity is a primary objective for any business. The desired speed is one that facilitates fast solder joint formation without compromising metallurgy or PCB laminate integrity.

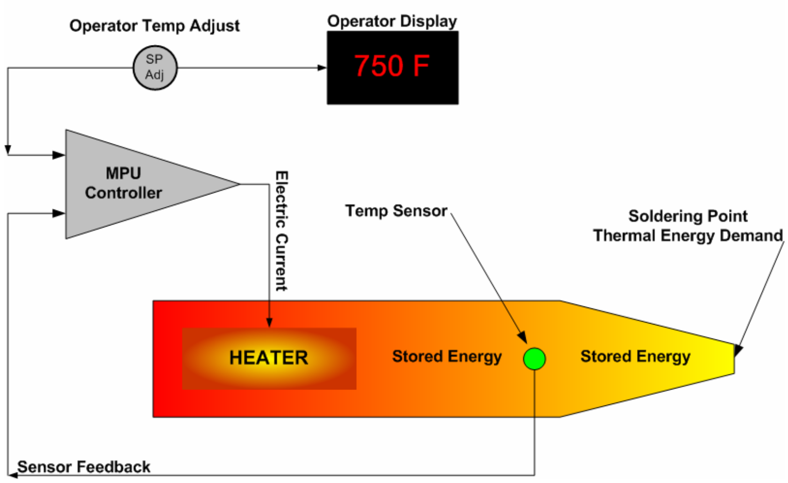
c) **Process Consistency (or repeatability)**
A successful process is one that yields high quality connections consistently. In hand soldering there are many variables ranging from operator use to materials, to soldering stations. In this case we are concerned with ensuring that the soldering station performs consistently throughout the life of the systems and the life of the tips.

All of these factors depend upon the efficient and effective transfer of thermal energy. Simply put, we are trying to deliver the correct amount of energy from the soldering tip to the solder joint within an optimal time period. In this process, it is critical that the energy delivery be controlled as too much or insufficient thermal energy will impact either reliability or productivity.

2) Alternative methods of process control in soldering systems

Control of thermal transfer using conventional microprocessor based systems
Figure 1 shows the major components of a typical Microprocessor (MPU) based temperature controlled hand piece. The system includes the tip (the surface that contacts and transfers the thermal energy to the pad), the heating element that supplies external thermal energy into the system, and the thermal mass which serves to both store and couple the thermal energy from the heater to the tip end. Also included is a temperature sensor, located at between the heater and the tip, which provides temperature information (not thermal energy) to the microprocessor. The MPU then compares the signal from the sensor to the desired tip temperature and applies electrical energy to the heater based upon the differential between the actual temperature reported by the sensor and the set point control set by the operator.

Figure 1 - Conventional MPU Based Conduction Soldering System



The most significant element associated with the proper delivery of thermal energy to the work is the size of the thermal mass. (i.e. the tip & the heating element) This thermal mass both <u>stores and transfers the thermal energy</u> from the heater to the tip. When both ends of the thermal mass are at the same temperature, there is no flow and all the energy is stored. Anytime the temperature at one end of the thermal mass is higher than the temperature at the other end, thermal energy will flow. This energy flow takes some time (it is like a line of people passing buckets of water from one end to the other). As we will illustrate, it is the management of these thermal time constants that becomes the key factor in controlling the process effectively.

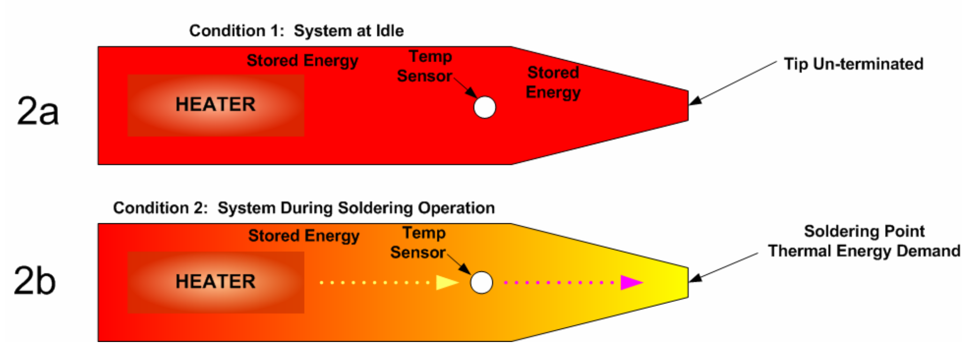
Finally, it is important to segregate the two control system modes – **standby mode and soldering mode**.

In the **standby mode** shown in Figure 2a, the tip is floating in free space and there is virtually no energy flow (but for the insignificant thermal losses into the surrounding atmosphere). In this state, nearly all of the energy is stored and the temperature of the tip is nearly equal to the temperature of the heater.

In the **soldering mode** shown in Figure 2b, the following series of actions are initiated instantly as the operator touches the tip of the soldering handpiece to the solder pad:

1. As the tip meets the solder pad, the tip temperature drops instantaneously and the stored thermal energy (in the system mass) is quickly delivered to the solder pad.
2. As the stored thermal energy flows into the pad a few seconds later the temperature sensor, located midway between the solder pad and heater, detects the drop in temperature instructs the MPU to send electrical current into the heater.
3. The MPU reacts nearly instantaneously and sends current to the coil of the ceramic heater. This thermal energy from the heater will flow down the thermal mass conduit, passing token style, toward the tip arriving a few seconds later.
4. Along this path lies the temperature sensor. It will sense an increase in temperature before the thermal energy arrives at the tip (but still satisfying the operator set point) and inform the MPU that the desired set point has been achieved. The MPU will then interrupt current to the heater again before the energy has arrived at the tip.

Figure 2 Conventional Technology



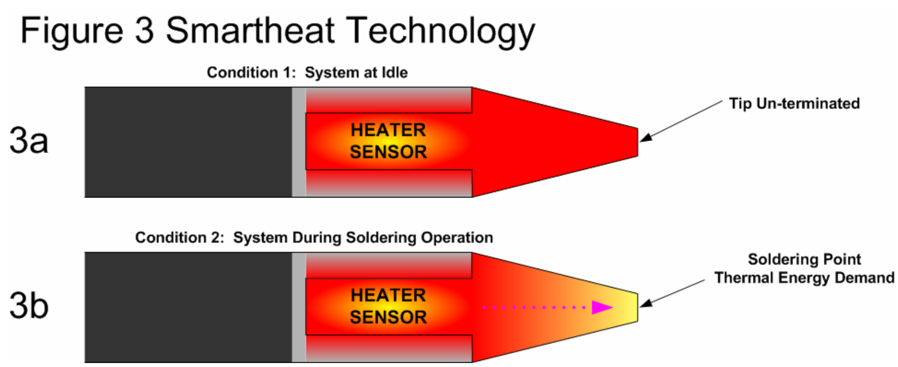
Given that the successful execution of the soldering operation depends upon the controlled delivery of thermal energy, it can be seen from this analysis that the energy transfer delay (latency) is a major challenge to the control of the soldering process.

In the case of conventional technology there are actually regions in the thermal mass that create this latency- the thermal latency between the sensor and the heater, and the latency between the sensor and the solder pad at the tip. So how do we eliminate these latencies?

Control of thermal transfer using SmartHeat technology systems
In contrast to the traditional conduction soldering tool, SmartHeat technology and design addresses both factors and virtually eliminates both latencies.

Referring to figure 3a, with a proprietary integrated heater- sensor, there is no thermal mass between the heater and the sensor (they are actually the same physical device) and therefore no latency between heater and the sensor. In fact, the heater sensor, if sliced into an infinite number of slices is in reality an infinite collection of integrated heater-sensors each precisely responding to the thermal demand imposed.

Secondly, the unique design of the Metcal heater-sensor permits the heater-sensor to be positioned very close to the solder pad providing unprecedented reduction of thermal mass. This provides the most direct coupling of the heater power to the solder pad. Stored energy is dramatically reduced and cannot be compared to conventional designs using traditional ceramic heating elements.



The net result is a soldering tool that directly controls the power to the solder pad by eliminating one source of thermal latency and dramatically reducing both the stored energy and tip geometry latency as is shown in Figure 3b. The benefit is reliable, repeatable direct process control.

3) **Solder station qualification using power measurement**

It should be clear from the previous analysis that the measurement of tip temperature when the system is in the standby mode is unrelated to either control system compliance or system performance when the soldering mode. In contrast, the quantification of system energy transfer (power delivered over time) provides a direct correlation of both system conformance as well as performance.

Metcal technology, as discussed previously, is designed to manage and control the transfer of thermal energy to the solder connection. Several additional factors are contributory to the irrelevance of idle tip temperature measurement:

- The physical measurement of the tip temperature is highly dependent upon the technique deployed. The cleanliness of the tip, including minor common oxidation, and the positioning and seating of the tip to the instrument sensor will dramatically affect the resultant measurement.

- The actual temperature at the tip of the tool will differ from the heater temperature by an amount that is highly dependent upon the mass of the measuring sensor and the geometry of the tip. Larger masses and longer-thinner geometries will result in greater errors.
- Several conventional MPU technology systems provide temperature indicators on their power units. It should be noted that the display is an indication of the operator set point (directive to the MPU) not the actual temperature measured by the internal thermocouple sensor and as such do not represent a temperature value representative of the actual tip temperature – idle or under load.

Alternatively the observation of the handpiece power level into a fixed mass will provide a meaningful indication of both system and heater-tip operation. The attached Heater-Tip Certification Process / Procedure outlines the process and can be incorporated into operational quality manuals. In association with an in-line power meter (available from Metcal), the procedure will quickly certify the performance of the entire system including the replacement heater-tip, or if desired, characterize the actual soldering process. The procedure is both simple and repeatable with easily observed accept / reject criteria.

Conclusion

It is a commonly accepted and promoted belief that the measurement of tip idle temperature is an accurate means to quantify the compliance of convention soldering systems. It has been shown that the relevance of this measurement is unassociated with the process, and the concerns of the personnel associated with control of the process. Additionally, the measurement itself is difficult to perform accurately and repeatability. In contrast, the power delivery characterization is relevant, repeatable, and simple to execute.

Related procedure: Suggested ISO 9000 compliance procedure using power management

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