Guidelines for Handling Failed Power MOSFETs on PCB Assemblies

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INTRODUCTION

When a power MOSFET fails, the challenge is to determine the root cause of failure and implement a containment plan. However, this is more easily said than done. The complexity of semiconductor technologies and the advanced techniques required to analyze them means that failed components must be handled with extreme care in order to retain all possible failure signatures. Unfortunately the urgencies of the manufacturing environment often lead to short-cuts as a failed component is rushed back to its manufacturer for failure analysis. If this is not carefully done, vital failure signatures can be lost, which adds further difficulties to the already complex task of failure analysis. The end result is further delays or loss of opportunities to correctly identify the root cause of failure.

Typically, failures are reported as In-Circuit Tester (ICT), Functional Test, or Field Returns. The following steps help to ensure that the source of MOSFET failure will be identified while avoiding any further damage or loss of failure signatures:

1. Follow ESD protection procedures throughout handling of the suspect MOSFET.
2. Resistive Test: Use a low-voltage laboratory-grade digital multimeter such as Keithley or HP to measure the resistance between gate and source, gate and drain, and drain and source. Do not use a portable DMM. The 9 V battery supply can easily increase the extent of the damage or even destroy the evidence. It can also lead to conflicting findings with repetitive tests. Thus a MOSFET with damage only in the gate-source region and exhibiting low gate-to-source resistance on the first measurement can later exhibit high resistance and healthy functionality. The result will be no fault found on FA report.
3. De-soldering: After determining that the MOSFET has failed, the next step is to remove the suspect MOSFET from the PB board assembly. The objective here is to remove the part from the PC board assembly without causing any further physical damage and/or loss of evidence. Only uniform, controlled heating should be used for removal of the MOSFET from the PC board assembly. Using standard soldering stations can easily subject the part to non-uniform heating by individually heating up each solder joint. This approach is more likely to alter the failure signature. Do not use standard soldering stations. An advanced soldering station like the Metcal APR5000 is needed to generate a de-soldering temperature profile that is close to the reflow profile for safe removal of the part. Alternatively, a heat gun such as the Steinel model HG3002LCD, which enables air flow with controlled temperature for uniform heating, can be used for safe removal of the part from the PC board assembly.

   By way of an example, here are step-by-step instructions for removing a PolarPAK® power MOSFET from a PCB.

Engineering Lab Set-up:

1. Test PCB used for this experiment (figure 1). See Appendix A for details.

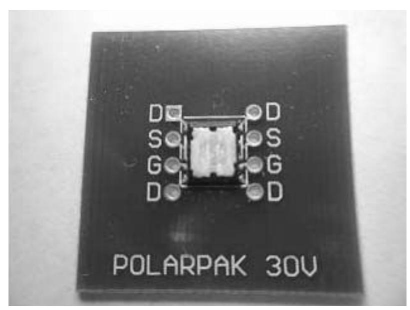

Fig. 1 - PC Board assembly with Soldered Part

2. Steinel Heat Gun with Digital Display, Model HG3002LCD (figures 2, 3a, 3b, 3c, and 3d). See Appendix B for details.

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Fig. 2 - Steinel Heat Gun

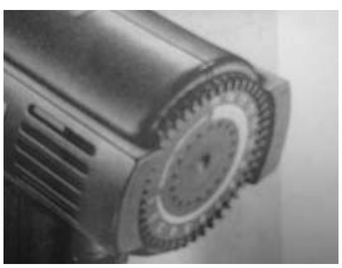

Fig. 3a - Temperature Setting Wheel

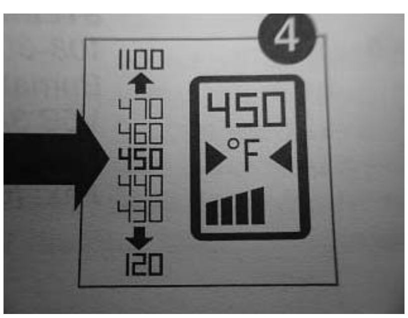

Fig. 3b - LCD Display for Temperature and Air Flow

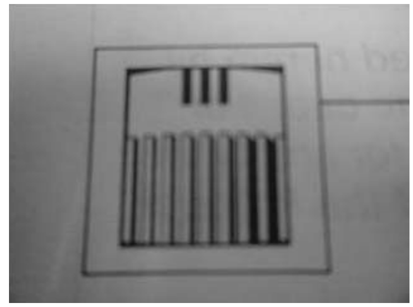

Fig. 3c - Air Flow Control

3. Electronic lab tools, measuring instruments, thermo-couples with temperature indicator, and soldering material.
4. The Steinel Heat Gun, Model HG3002LCD, shown in figure 2, is a calibrated heat gun which has all the features required to work with a SMD part in the laboratory environment. The temperature setting wheel (figure 3a) enables setting the temperature of the air blown by the heat gun. The set temperature is displayed on an LCD panel (figure 3b), which also displays vertical bars to indicate airflow. Airflow can be set with the airflow control knob as shown in figure 3c. The on/off controls switch in figure 3d enables heat gun operation with controlled airflow at a preset temperature.
5. The heat gun can be held upright over the PCB assembly at a distance of 1" to 1-1/2". This can be done manually, but it is more conveniently done with a suitable vertical clamp, if available. The latter can be used as a mechanical fixture. figure 4 shows our lab arrangement, which uses a fixture capable of providing X-Y-Z movement to hold the heat gun in its upper head. The air nozzle of the gun can be lowered over the PCB and kept at a fixed distance.

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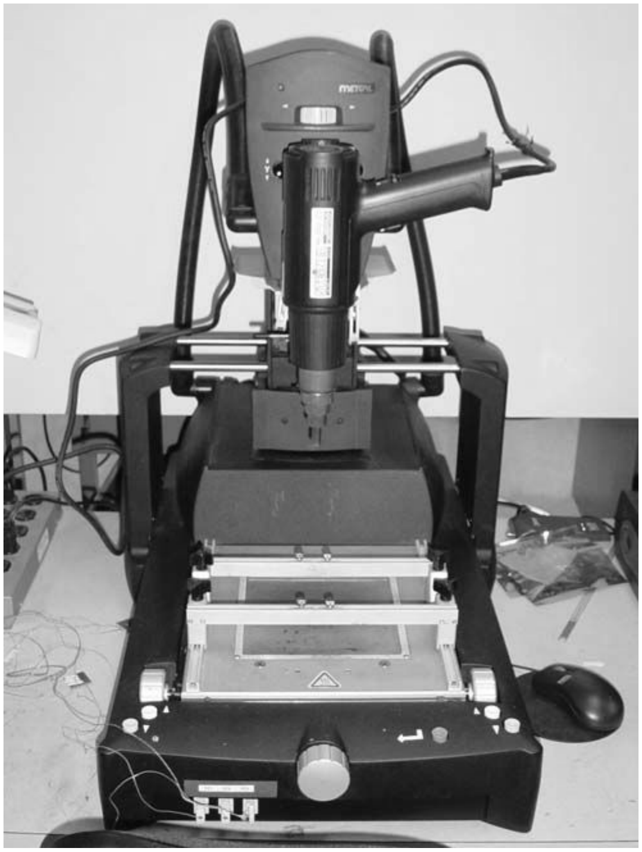

Fig. 4 - A Representative Fixture Setup

Reflow Profile Definition and Development

1. The Vishay reliability manual, available online at www.vishay.com/docs/80126/80126.pdf, covers the recommended basic reflow profile definitions. Graphical representations of the recommended reflow profile in degrees Celsius and in Fahrenheit are shown in figure 5a and 5b respectively. The temperature values indicated by the red line show the maximum values and those indicated by the blue line show the minimum values.

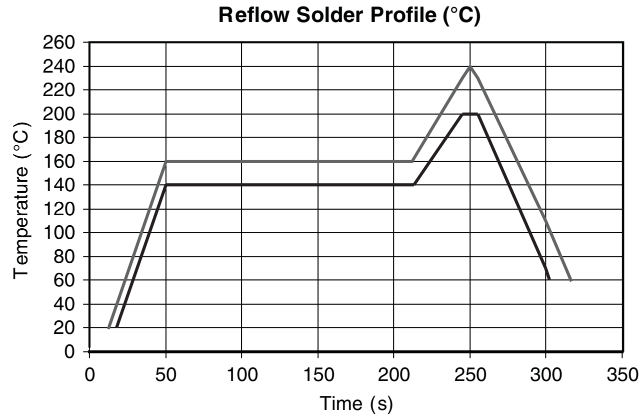

Fig. 5a - Recommended Reflow Profile in Celsius (Red = Maximum Values, Blue = Minimum Values)

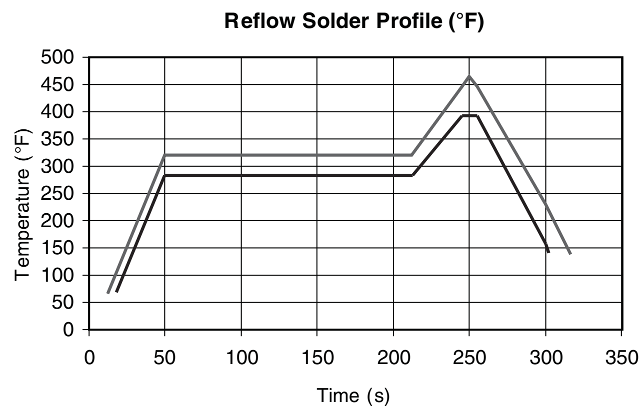

Fig. 5b - Recommended Reflow Profile (°F). (Red = Maximum Values, Blue = Minimum Values)

2. Following the profile is a task in itself, requiring a high degree of experience and skill. There are four interdependent parameters, two of which are the settings of the calibrated heat gun: the temperature and airflow settings. The third parameter is the distance of the air nozzle from the component/PCB assembly. The fourth parameter is the time duration for a given temperature setting. Temperature settings and time durations are controlled dynamically by the operator using a stop watch.

3. Observe the temperature reflow profile in figure 6, which matches the recommendations in figure 5a and 5b.

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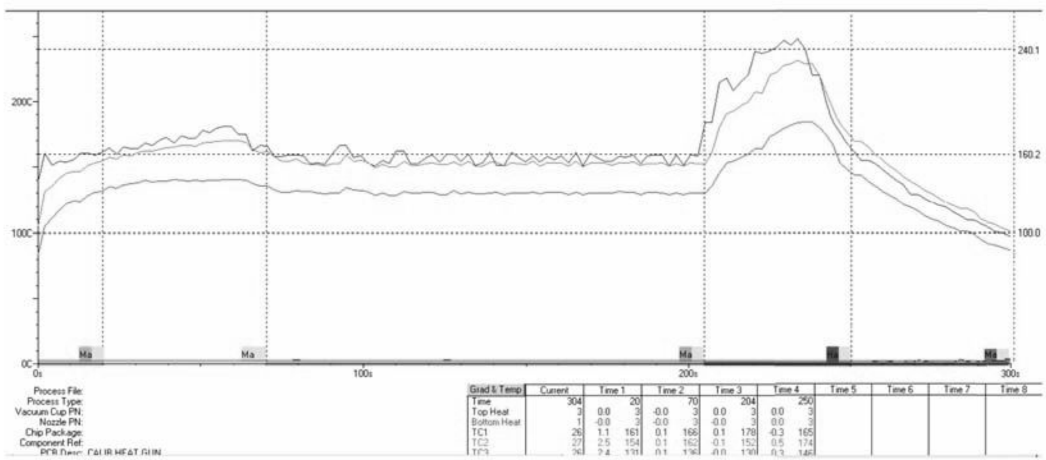

Fig. 6 - Reflow Profile generated by using Heat Gun

Thermo-couple placement:

TC1 - Green Trace - Top of Component

TC2 - Blue Green - Close to lead frame on PCB

TC3 - Pink Trace - Bottom of PCB

De-soldering procedure:

1. The test sample is shown in figure 1 the PCB assembly
2. Air nozzle distance from component: 1" (25.4 mm)
3. Air flow setting: medium
4. Temperature settings and time steps operations:
   (a) 370 °F (180 °C) for 200 s - (pre-heat period)
   (b) 700 °F (240 °C) for 25 to 40 s - (reflow period)
5. At the end of step 2 the solder under the part needs to be checked to see if it is soft enough so that the part can be lifted away. Figure 7 shows a removed part with the PCB.
6. It should be noted that higher temperature settings are required for the heat gun to get the desired temperature on the component and PCB surfaces. This is due to the distance between the air nozzle and the component. The airflow setting also contributes to this difference in the temperature settings.
7. Also take note that this profile is developed for soldering/de-soldering a part on a 1" x 1" (25.4 mm x 25.4 mm) PCB as defined in Appendix A. Different temperature settings and air speeds may be required for different PCBs. However, such changes are easily made by an experienced laboratory technician.

Fig. 7 - Removed Part and PCB

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Appendix A

Standard PCB used for MOSFET Soldering/re-work:

a) Dimensions: 1" x 1" x 0.062" (25.4 mm x 25.4 mm x 1.575 mm)

b) Material: FR4

c) Number of copper layers: 2

d) Copper thickness on both sides: 2 oz. (0.076 mm)

e) Area covered by copper on top side: 20 %

f) Area covered by copper on bottom side: 100 %

Appendix B

Steinel HG3002LCD Heat Gun Specifications

Technical Specifications:

Voltage: 120 V_{AC}

Output: 1500 V

Temperature, Step 1: 120 °F

Temperature, Step 2: 120 °F to 1100 °F

Indicator Range Display: 120 °F to 1100 °F

Blower: Continuously variable

Air Flow: Min. 7 cfm, Max. 17.6 cfm

Weight: 31 oz. with cord and plug

More information at URL: www.steinel.net/products/heatguns/electronic_heatguns.cfm