Big Board Rework

Joerg Nolte
Ersa GmbH
Wertheim, Germany

Abstract

As indicated in previous abstracts to the rework topic, customer demands in the field of PCB repair are constantly increasing. Lately technical developments like Internet of Things (IoT), smart home, mobile connectivity, and cloud computing as well as intensive telecommunication in general are driving the need for higher network performance and computing power. As a result high end telecommunication and server infrastructure is required. Super computers are designed and installed with many of them equipped with the latest processor generations alongside with the necessary peripheral device build up on classical printed circuit boards in extreme large dimensions. After the production process and during their operational life time, these assemblies may also be subject to rework. What are the aspects of big board rework when dimensions of 24 x 24 inches and larger are reached? What strategies and machines are required to successfully repair these extremely large, heavy and expensive electronic assemblies?

Introduction

Big board rework is successfully executed already. But along with the new technologies even higher demands are reaching the factories, the production equipment and also the rework sector. The following application related factors need to be observed when rework on extremely large boards should be carried out with a high success rate:

- size of the PCB (24 x 24 “ and bigger)
- thickness of the PCB (up to 10 mm)
- internal build up (thermal mass, copper layers)
- population of the PCB (type of PTH and SMD components)
- as a result of the above: total weight of the assembly
- rework task (large and small target components, solder alloy, heat demand)

These board related parameters are defining the hardware demands for a rework system and also the strategy of how to rework a big board assembly:

- size of the bottom heater
- PCB holder and board fixture (board warpage)
- homogeneous preheating with matrix bottom heater
- top to bottom heater balance
- smooth heating technology (protect sensitive components)
- extended preheating for very large assemblies (up to 24 x 48 inch)
- external preheating (if required for heavy boards)
- closed loop temperature control – multiple sensors
- component handling (automatic removal, preparation, placement)

During typical system evaluations of rework equipment parameters like heat distribution and PCB warpage are measured and evaluated. The system design needs to focus on such evaluations in order to find the best settings for the product demands.

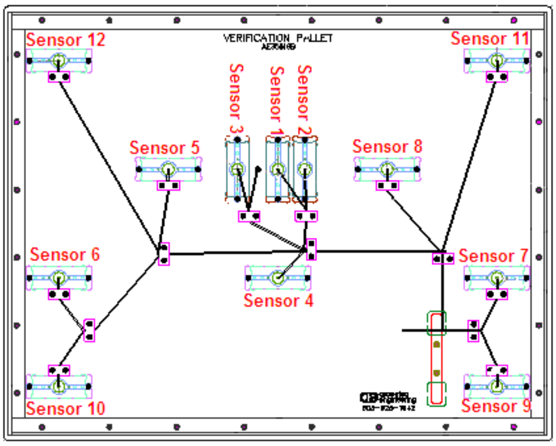


Figure 1.1 test pallet for rework system evaluation (12 sensors)

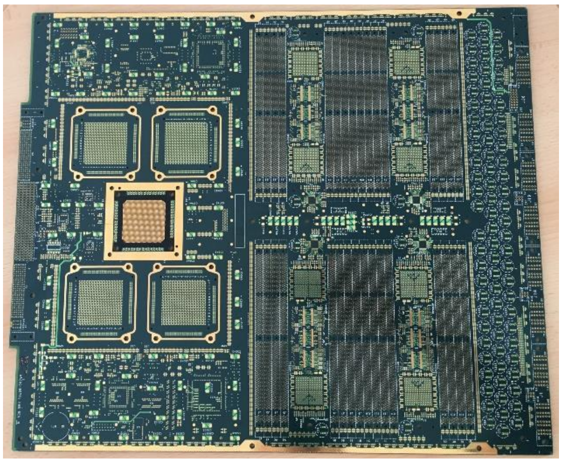


Figure 1.2 bare board to test heat distribution

Sensor shuttles or test vehicles with several embedded thermocouples are used to measure and optimize the temperature deviation across the board (see figures 1.1. and 1.2). Performing repeatability tests provides information about the system's ability to perform identical heat up cycles many times.

Moreover different measures are taken to identify board warpage. i.e. dial gauges to quantify rising or falling of PCB edges. In the centre area of the PCB precision guides identify bumps and pockets on the board's surface. Even more advanced are non-contacting laser sensors: They can precisely identify and record the warping and bending of an assembly during the entire heating cycle.

Observing the development over the past 5 to 10 years one can summarize that the currently existing rework systems are capable to handle large board applications. But improvement is possible and limitations in terms of heat distribution and soldering performance are clearly visible.

Intelligent PCB preheating with matrix bottom heater

The reason for problems in large board rework is in many cases an imbalanced heating of the assembly. Other than in a reflow oven an important criteria is that mostly all todays' rework systems have an open environment. The assembly is not thermally treated within a closed heating chamber.

This has mainly three reasons:

1. the operator wants / needs to have visible and operational (manual) access to the rework area
2. the neighbouring component solder joints should not go to liquidus (stay below T_L)
3. sensitive components (displays, connectors, capacitors…) cannot be exposed to high temperatures

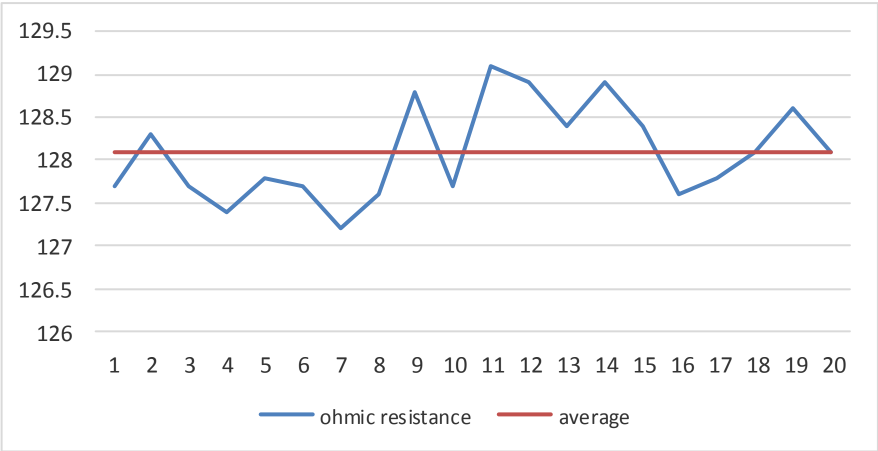
Taking this as given, the open environment rework system needs to balance out large temperature differences between the coldest spot (surrounding temperature e.g. 25°C) and hottest spot (soldering temperature at target component e.g. 230°C). The most important element on a rework system for big assemblies to achieve this is the bottom heater.

Referring to the bottom side preheater the parameter to watch and optimize is the temperature deviation across the PCB. Measures on test vehicles and circuit board assemblies (like in figure 1.1 and 1.2) have shown that on large boards (> 20 inch) temperature deviations of more than 20 °C (@180°C) can easily be reached. Here the design and setting of the bottom side preheater has essential influence.

The selection of individual heaters in a large filed bottom heater should stay within a minimum tolerance (Table 1):

Table 1 deviation of bottom heater ohmic resistance (taken from a production rework machine [20 radiators 125 x 125 mm])

Bottom Heater No.	Resistance In Ohms	Ohm Delta To Average
1	127,7	0,39
2	128,3	-0,21
3	127,7	0,39
4	127,4	0,69
5	127,8	0,29
6	127,7	0,39
7	127,2	0,89
8	127,6	0,49
9	128,8	-0,71
10	127,7	0,39
11	129,1	-1,01
12	128,9	-0,81
13	128,4	-0,31
14	128,9	-0,81
15	128,4	-0,31
16	127,6	0,49
17	127,8	0,29
18	128,1	-0,01
19	128,6	-0,51
20	128,1	-0,01
Average	**128,09**	



With as little as possible variations in their ohmic resistance, also the electrical current for each heater will be the same and thus the transmitted energy of each heater will be constant over the large bottom heater area.

In many rework systems the bottom heaters are relatively inflexible: Either they operate on one complete heating zone with variable energy or they are split up to e.g. five fixed heating zones with variable intensity. Existing heaters might be segmented into fixed zones (e.g. 5 zones on a production rework machine) but these zones are not flexible enough in their size or settings for optimal board preheating.

A matrix organized heater with selectable columns and rows, individual power pre-sets and a hot spot functionality shows the way to future designs. The new approach is a matrix bottom heater:

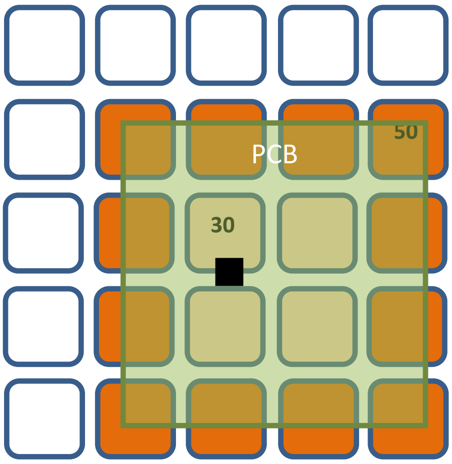


Figure 2.1 5 x 5 bottom heater matrix

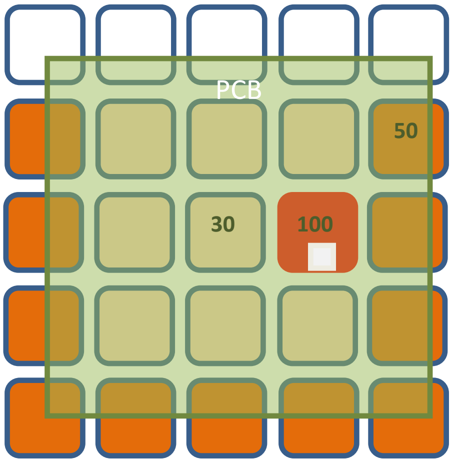


Figure 2.2 hot spot zone (under target component)

A matrix heater configuration allows to set the actual bottom side preheating area in accordance to the size and thermal demands of the PCB. Referencing to Table 1, all single heaters must perform in the same way; their ohmic resistance must stay within a small tolerance window (+/-1 Ohm).

As shown in figure 2.1 the not required heater rows and columns are simply switched off. The heating zones at the PCB edges can be set to a predefined power level (e.g. 50%), the centre area of the PCB is preheated with for e.g. 30 % only. In this region the target component (i.e. BGA) is located and the top heater will heat this area intensively from the top.

In another application e.g. an extremely high mass ceramic CGA component on a very large PCB, the hot spot zone in the area under the component is set to 100% in order to provide intensive bottom side preheating within this zone. See figure 2.2.
Further intelligent usage of this flexible preheating system is obvious: In different sections of the large heating area, separate heating processes can be applied: One zone is running a desoldering process while in a second zone another assembly is already preheated.

If assemblies exceed the bottom heater dimensions in many cases the problem of board warpage is unpreventable. Some equipment product have reached sizes up to 24 x 48" based on product requirements which is possible by adding another very large bottom heater as an extension.

Choose the right rework heating technology
Besides the heater configuration a very important factor is the heater technology. The technology needs to supply a homogenous emissivity of radiation and at the same time the material of the PCB needs to absorb the energy from the heaters. During the soldering processes the board is static over the heating elements. All areas need to absorb the energy without creating a thermal overload on the substrate surface. Especially large boards have high sensitivity to large temperature deviations on their surface.

The intensity of board warpage is affected by the internal copper layers of the assembly. The more homogeneous the copper layers are spread, the better the absorbed thermal energy can distribute and thus bring all areas of the PCB onto the same temperature level.

Note: bare boards always behave differently than populated boards i.e. with large connectors or sockets installed.

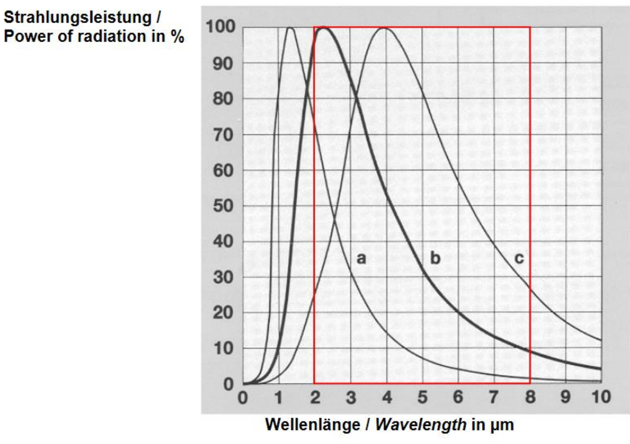


Figure 3 emissivity of different heater types a: halogen light heater (bulb) b: ceramic radiator (top heater) c: ceramic radiator (bottom heater)

With dark IR heaters the best effect has been reached. Other than quartz lamps the peak emissivity of ceramic bottom heater ranges around 4 µm wave length. This wave length is known to be well absorbed by FR4 and other standard materials of electronic assemblies. At the same time with 600 W heaters a comparatively quick heat up rate of 0.5 K/s can be achieved at a working distance (bottom heater to PCB) of up to 80 mm!

Top to bottom heater balance and closed loop processes

When taking a closer look at the thermal process it will be noticed that the heating procedure is not a static process. Dynamic heat control during the entire phase of soldering or desoldering components is required.
The proven and best technology to achieve this is a sensor based closed loop process. The sensor (a thermocouple located to the component position or a calibrated non-contacting pyrometer targeted to the component surface) is detecting the actual temperature and the rework system follows the pre-set temperature profile.

During the initial process phase the bottom side heater needs to bring up the assembly to temperature. Once the board is well preheated the top heater starts to heat the target component. From this point on the follow on heating process needs to be balanced. Depending on the PCB requirements and the tendency of board warpage the profile needs to be operated more bottom- or more top heater based. It is necessary to define this balance for every section of the thermal process. I.e. it is typical that the bottom heater intensity is reduced within the last phase of the process (peak zone). This reduces overshooting effects and the thermal load to the entire assembly.

Top side and bottom side heat are affecting the soldering process. Finding the correct balance might be challenging but in many cases predefined template profile settings can be taken as a good starting point.

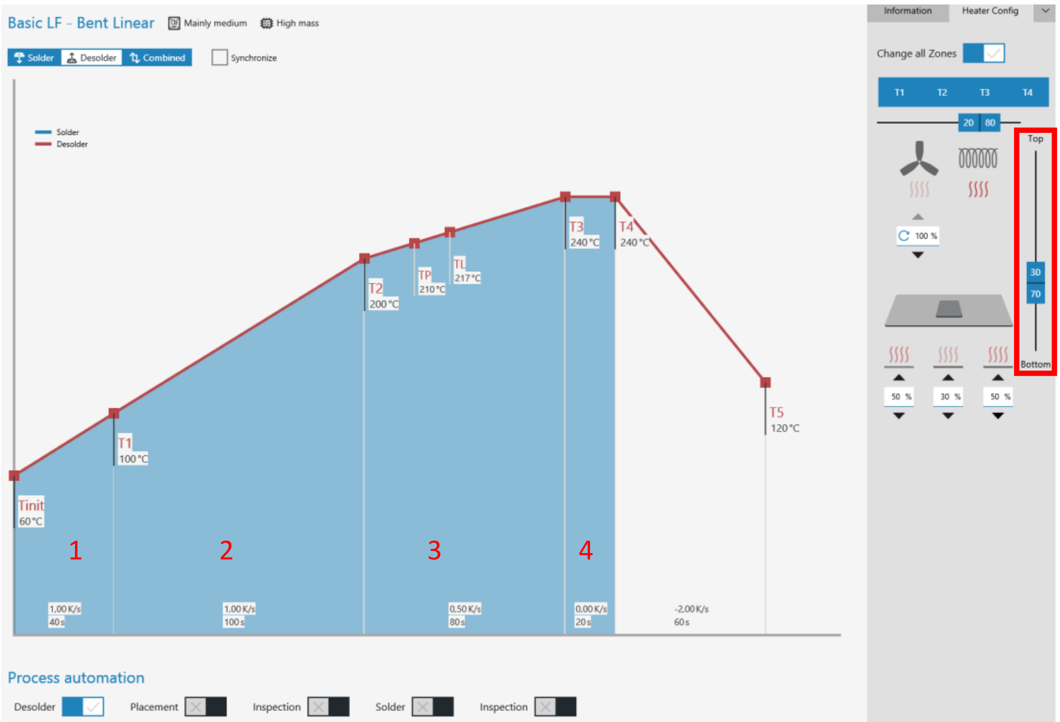


Figure 4 setting of top to bottom heater balance in four separate process sections for a desoldering profile

PCB holder and board support

The best support is no support! But in big board rework the simple size and weight of the assemblies require a good PCB fixture and support.

A 24 x 24" fully populated multi-layer board can easily weigh several kilograms. With the T_G temperature starting at about 130°C every FR4 based assembly will start softening during the preheating phase. All assemblies larger than 200 mm should be supported in order to avoid non reversible board deformation. On very large boards it is of utmost importance to have the assembly fixed in a holder and at the same time have access to the bottom side of the assembly to fix the supportive elements. Pallets may be preferred for the individual assemblies and support. In those cases the heated area needs to be large enough to let the bottom heater transfer adequate preheating energy.

In the standard case the assembly is usually fitted to some PCB holder rails and additional support rails with individually adjustable pins are located on the PCB bottom side. Ideally the PCB holder needs to be removable or tiltable to have access to the PCB bottom side.

The use of freely adjustable and spring loaded pins can provide additional board support. The larger the assembly the more pins are needed to get an even support. Needless to mention that the support rails and pins should shade out a minimum of the bottom side heating and the pins should never be placed on to bottom side components.

In an ideal case the support rails carry the weight of the assembly and compensate the softening of the PCB above the T_G. But the supports should not be misused to force the PCB into a flat position. Long years of experience has shown that this approach is not even reachable as the high bending forces on an unevenly preheated board are not controllable. In an overall tendency, thicker boards with more layers tend to have less warpage than thinner boards, always assuming that the preheating and profile are well adopted. On the other hand, side weight is increasing with thickness, so the number of support elements needs to increase as well.

Figure 5 shows a large rework system with a removable 24 x 24" PCB holder and support elements.

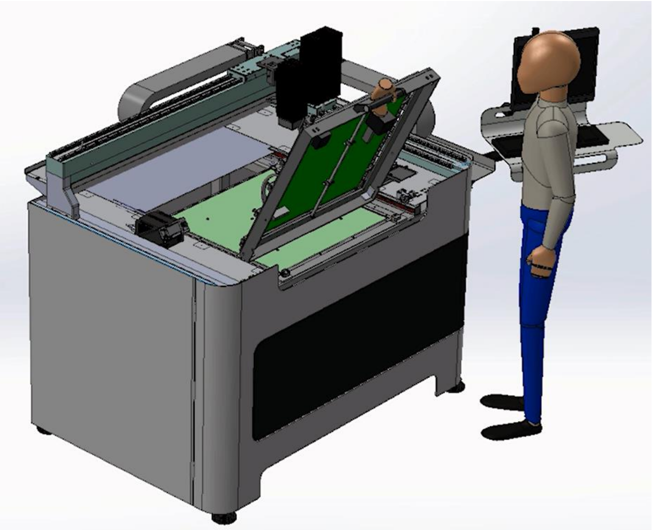


Figure 5 rework system with Production Rework Equipment PCB holder and bottom support

And the component?

Like in all cases of rework, flexibility is one of the most mentioned demands. Also large and very large assemblies contain all types of target rework SMT components from small chips to large BGA or LGA components, sockets or SMD connectors. The high variation of components leads to questions in component treatment and thermal management. As the goal on large assemblies is to keep the temperature deviation across the assembly minimized, also the top side heating process is very important. Certain components have quite small process windows, and some react critically to temperature deviation across their body.

Closed loop control primarily guarantees that the maximum temperature on the board is limited to the required soldering temperature of the target component. i.e. 235 °C so rework happens at the lowest possible temperature. At the same time, it is well known and accepted that component and the attachment area on the PCB level create one thermal system. So not only the component itself, but also the PCB it is placed on, are absorbing the required soldering energy. Of course, the temperature profile (heat up gradient) is also affecting this (figure 6). The more thermal mass is involved in a rework scenario, the slower the temperature gradients should be – within the IPC/JEDEC- or component manufacturer given profile limitations.

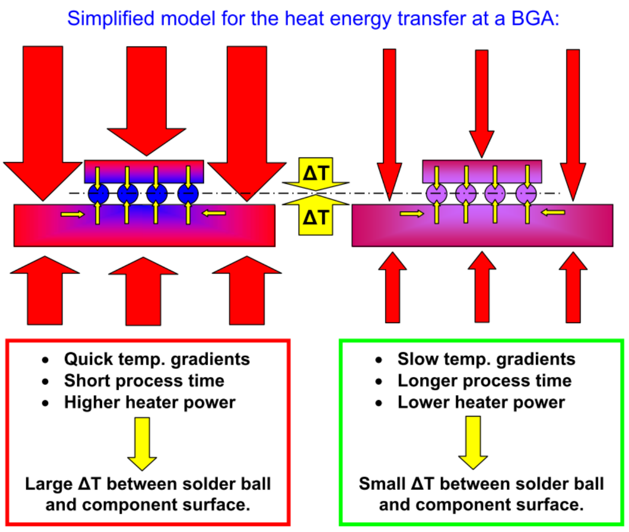


Figure 6 energy transfer on a BGA connected to the PCB

Nevertheless, smaller components need smaller heating areas and larger components (e.g. SMD DIMM socket, length 132 mm) need larger top side heating. Exchangeable heating heads with different maximum heating areas and shutter systems on the heating heads provide solutions for this demand.

Infrared and hybrid heating head technologies moreover offer a very homogeneous top side heating. This again positively affects the heat balance. This technology shows - especially on big board assemblies – benefits against hot gas based systems as hot spots or high delta T across short distances is mostly never a topic to worry about.

Summary and Outlook

Electronic assemblies are reaching higher integration and a generally increasing complexity. In some segments, this is leading to very large PCB assemblies. The rework of those boards is challenging but solvable. At the same time, the degree of automation will rise in the segment of rework equipment. Making big board rework systems look more like a machine than like your standard table top rework unit. But at the same time, it may be necessary to perform for applications that may seem unsolvable today.