un proceso continuo controlado, la interposición de una protección Kapton es altamente recomendable en el caso que el termodo está en contacto directo con la pasta de soldadura y el flux. La cinta Kapton previene de la contaminación del termodo y garantiza un proceso de calidad.

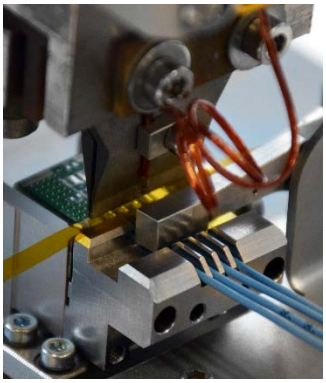


Figure 3: Showing optional Kapton feeder (manual or automated) to help protect the hot bar from solder and flux residues when the hot bar makes direct contact to the solder joints.

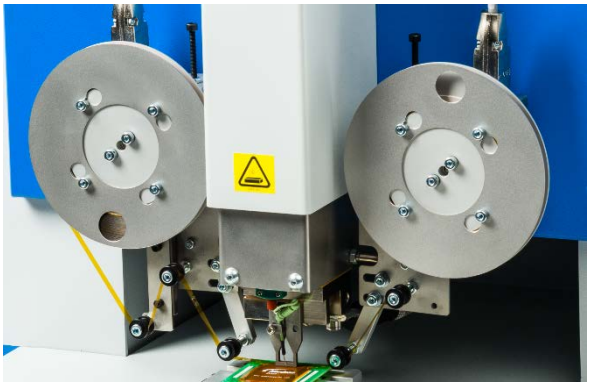


Figure 4: Kapton tape on interposer module

Hot Bar Reflow Soldering Process defined

Once the appropriate system parameters are determined, the basic procedure for hot bar soldering is a five-step process:

1) Place the PCB in the jig and apply flux to the joint (can also be done before placing the PCB).
2) Place the flex circuit on the PCB
3) Move the solder head down to align the hot bar to the leads and check for co-planarity
4) Press the start button(s) for the solder head to come down. When the head is down, it automatically starts the heating process by the firing switch sensor.
5) After a programmed period of time the heating stops and cooling starts
6) The head will automatically come up when the (first) programmed cooling is done.
7) After solder solidus, remove the parts.

Advantages of the Process

Hot bar reflow soldering of flex circuits has several advantages over conventional reflow processes.

- **Localized Heating.**
  Since heat is transferred by direct-contact conduction, sensitive areas or components immediately adjacent to the solder joint are unaffected. This makes the process suitable for assembly as well as rework.
- **Co-planarity of Leads.**
  By pressing the flex down during the entire process, hot bar soldering ensures that the leads have intimate contact with their correctly aligned pads, thus eliminating the risk of lead/pad separation.

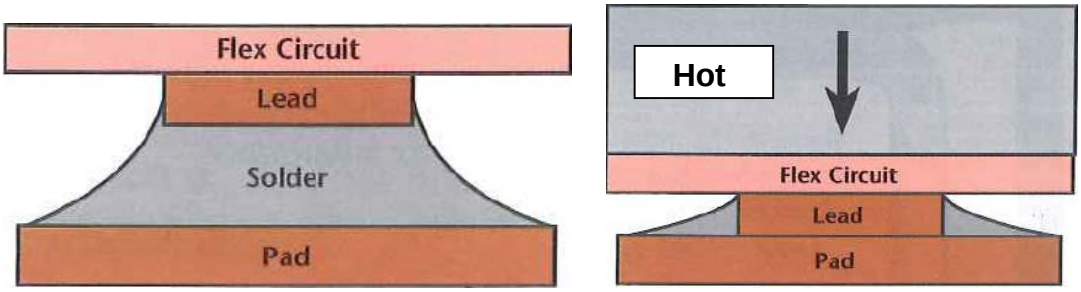


Figure 5: The process ensures co-planarity of leads via equalization of bar pressure during solder reflow and solidus

- **Flexibility.**
  Systems can often be reconfigured to accommodate various applications. Just as flex-circuit dimensions vary, so does hot bar size, the varieties of which are generally kept on the shelf ready for quick change out and minimum downtime.
- **Training and Maintenance.**
  An operator can be fully proficient on a hot bar system within a few hours; the only maintenance required is to keep the hot bar itself clean, In many instances, the hot bar machine replaces a hand soldering operation at which the assembler's experience or best judgment determines how much solder, heat, time and pressure are applied. In contrast, the entire hot bar process is controllable and repeatable regardless of operator experience.
- **Rework/Repair.**
  The benefit of localizes heat means that the system can also be used for reworking boards containing sensitive components that cannot withstand oven reflow temperatures. Defective flex circuits may be removed via the hot bar or hot air pencil and new assemblies attached with minimal risk of heat damage to surrounding parts.

Basic System Components

Hot Bar

The most significant component in any hot bar system is the hot bar itself. Hot bars come in many sizes and shapes, but two configurations are basic, each of which is designed and sized to accommodate individual application requirements.

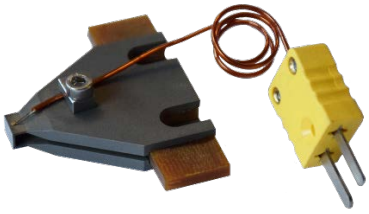


Figure 6: Fold up or 3D hot bar (thermode) with thermocouple feedback wire

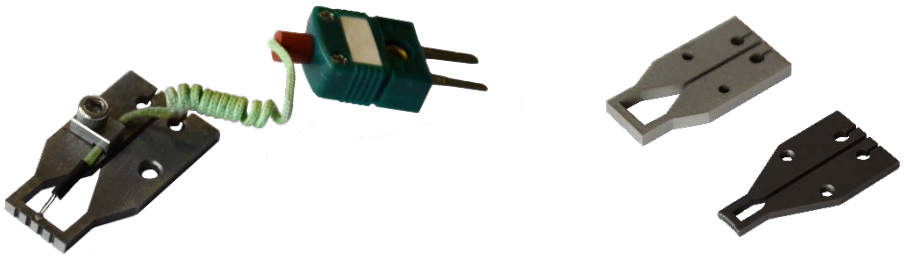


Figure 7: Straight or 2D hot bars (thermodes) with and without thermocouple feedback wire

The Fold-up Bar type or 3D is made from a solid piece of metal and is wire EDM machined, then mounted to a specially designed connect block (mounting block). It has a folded shape so that current flows evenly from front (-) to back (+) along the contact area. Electrically, one end of the bar has the same voltage potential as the other so that there is no difference of potential from lead to lead, eliminating the possibility of inducing current flow through the components. The folded design lends the hot bar more structural rigidity than does the 2D type, permitting the style to accommodate flex circuits of up to 5.12" (130mm) in length. The 3D with its open design has less mass in the heated area and cools down faster than the 2D thermode. Air cooling is used to speed up the process time for cooling down, resulting into the highest output.

The Straight Bar Type or 2D is also made from a solid piece of metal and is also typically wire EDM machined. Maximum length is around 1.0" (25mm). These are a less expensive type of hot bar and can also be machined with small notches or slots to hold wires in place while reflow soldering to a PCB or connector. On this style of hot bar the current flow left to right (or right to left) which increases the voltage potential along the length of the hot bar.

Connect block

Connect blocks are used to mount the hot bar to the soldering head. By using a mounting block co-planarity can be optimized and a quick exchange of thermode without further adjustment is possible. The block enables current transfer to the thermode, which leads to fast heat-up and cool-down. A nozzle for cooling air is built-in and the clamping design secures repeatable position of the thermode.

Figure 8: Connect block for hot bar mounting.

Jig (Fixture)

To ensure a guaranteed alignment of the parts that need to be soldered, it is highly recommended to use a product specific jig. In this jig the parts can be positioned repeatedly which saves times in alignment efforts.

Hot Bar Maintenance

Proper maintenance of hot bars is critical to extension of useful life. Flux must be removed periodically from the surface, in case its build-up acts as an insulator. A solvent with a cotton swab or soft brush is recommended for cleaning, the type depending on the flux, such as water-soluble, RMA, etc. If abrasive cleaning is indicated, it must be done with care and very evenly along the entire length of the bar or its temperature profile will become uneven. This can be done with 600+ grit sand paper on a flat stainless steel block. Never hold the sand paper in your hands as you will create uneven surfaces. Since it is the bar's material resistance that generates heat, if removed, the resistance of the bar and its heating profiles will be altered. Even better is to protect the thermode by a Kapton interposer tape. It keeps the thermode clean and no maintenance is required. It also offers a higher level of process control.

Thermocouples and Power Supply

Thermocouples sense temperature at the bar and feed the information back to the power supply. Thus, it is important that the condition of the thermocouples be monitored for wear. Most thermocouples are welded directly to the bar, which provides a very accurate representation of bar temperatures (Figure 6 and 7). If the weld breaks, however, the controller cannot sense the temperature and process control is lost. Properly designed controllers will have a built-in thermocouple-fault-detection circuit to disable the output if detachment occurs. Reattachment of the thermocouple is feasible as long as the bar is in good shape. There should also be a strain relief for the thermocouple added to the hot bar to help prevent any breaks within the weld connection.

The power supply controls the process parameters of time and temperature. It senses the real-time temperature of the hot bar via the thermocouple and adjusts its output proportionally according to the operator-set schedule. The power supply delivers a controlled current, which actually heats the bar, and provides high flexibility in tailoring the reflow soldering sequence. Its logic circuits and pneumatic valves control functions such as driving and latching the reflow head down, and returning and cooling the head and the solder joint.

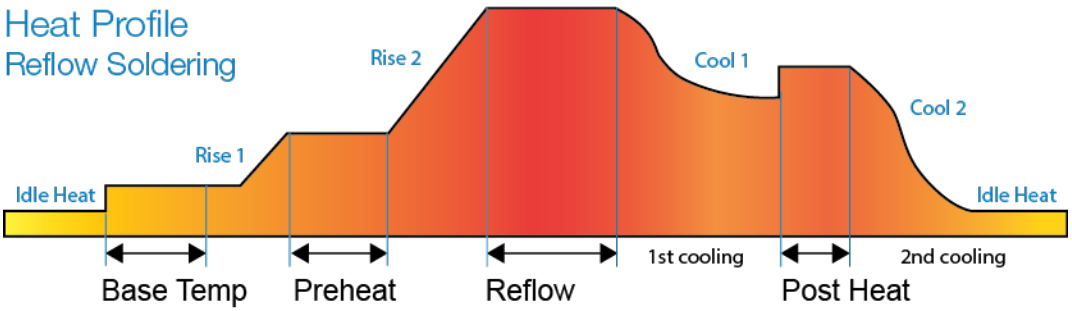


Figure 9 Heat Profile - Reflow Soldering

Some typical controller parameter (Figure 9) include:

Idle – Maintains a constant temperature of the bar while at rest and minimizes thermal shock to the bar while heating to reflow temperatures. Features a timer to limit oxidation on the hot bar surface.

Preheat – To overcome heat sinking problems with substrates. Preheat is used to activate flux, to minimize the time at reflow and to heat up the thermode in a controlled and repeatable way.

Ramp – Defined as a controlled time between preheat sequence and reflow. Also useful in reducing the risk of thermal shock to certain substrates.

Reflow – The actual time and temperature specified for solder liquids. Typical controller temperature settings range from 250˚ to 450˚C, depending on the type of flex, PCB and hot bar. Reflow time is usually from 1 to 6 sec. Using a Kapton interposer requires a higher temperature setting as it is a barrier for heat transfer, however needed for certain processes.

Cool – Its set point signals the end of the process. The reflow head holds the bar down through preheat, ramp and reflow and is not released until the cool set point is reached.

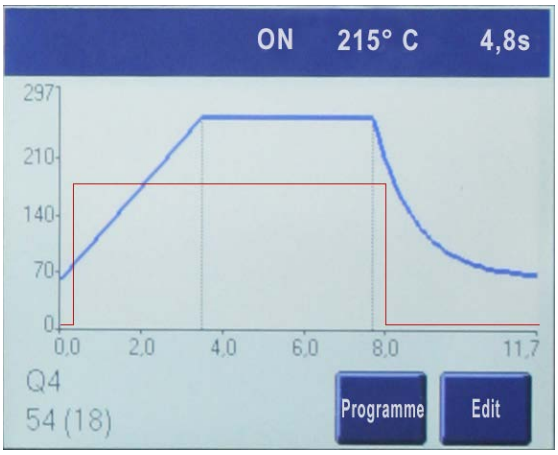


Figure 10 Hot bar power supply screen graphic.
This unit's circuits also control reflow-head movement while tailoring the soldering space.
Shown with optional programmable force control (red line).

The Reflow Head

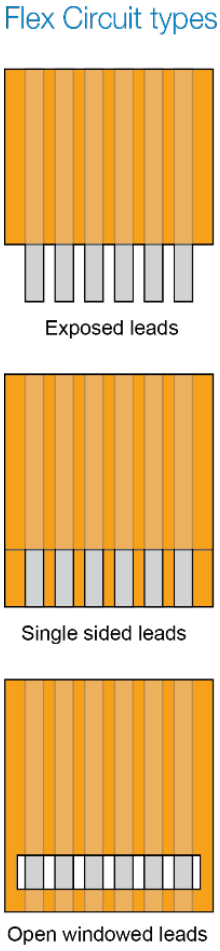
The purpose of the reflow head is three-fold: to mechanically clamp or hold the hot bar in the proper orientation; to provide the Z-motion to move the hot bar to the parts; and to apply a repeatable, consistent pressure on the hot bar. The amount of heat transferred to the leads depends on and is directly proportional to the pressure applied. It must be sufficient so that each flex lead is in intimate contact with its mating pad on the PCB yet impose no damage to circuit or board.

Planarity of the heater bar is also critical. Whether the hot bar is only 25mm (1.0") in length or 100mm (4.0") in length, having a pivoting mechanism for adjusting the thermode will ensure proper planarity of the hot bar to the flex/substrate. Some styles have the co-planarity adjustments in the hot bar mount and others on the whole bond head assembly.

A solder joint cool-down function is available on some reflow heads. Cooling air is blown directly on the flex circuit (2D hot bar) or between the hot bar walls (3D hot bar) at the end of reflow and stops when the desires temperature is reached, in effect speeding cooling downtime and increasing system throughput.

Figure 11 Soldering Head

Flex Circuit Types



Exposed and loose Lead Flex (Figure 11) – is the simplest of the flex designs. The leads are free hanging, protruding from between the two layers of polyimide. When met by hot bar in direct contact with the copper leads, heat is efficiently transferred. Normally, a small amount of excess solder volume can be tolerated since the solder can fillet along the sides of the lead. This type of flex does require using Kapton interposer to protect the soldering process.

Single-sided Flex – Here only the bottom layer of polyimide is removed, leaving the copper leads exposed on just the contact surface. While the hot bar contacting the top polyimide layer effectively heats through it, it is important that the layer be no more than 0.002" thick lest the insulation burn before solder flows on the leads. It is recommended to use Kapton interposer for this type of flex.

Open windowed Flex – features a cutout from both the top and bottom polyimide layers. The copper leads are exposed from above so that the hot bar directly contacts the leads and provides a highly efficient heat transfer. Also, the outer portion of the window protects the delicate leads during handling. Caution: The hot bar must fit entirely within the window, if not the insulation will hinder it from fully contacting the leads. This type of flex requires using Kapton interposer to protect the soldering process.

Figure 12 Flex circuit types include exposed or loose lead, single-sided lead and open windowed leads. For single-sided: Although heat is transferred efficiently through the insulation, it is important that its thickness does not exceed 0.002".

Lead-to-lead Relationships

For the best results with hot bar, it is important that the flex circuit be designed properly relative to its mating pads. The PCB pads generally should be slightly wider than the flex leads, a "mismatch" that provides two immediate benefits: an automatic space for a side fillet to absorb a small amount of excess solder without risking bridges or shorts (sometimes caused by leads of the same width), and so that slight errors in alignment can be compensated for automatically without loss of net spacing. By contrast, when flex-lead width is equal to pad width, slightly misaligned leads effectively reduce net spacing, which in turn increases the possibility of bridging (Figure 13). The most accurate, consistent and easiest way to align the products is using reference holes, enabling the positioning of the parts over pins in the product jig.

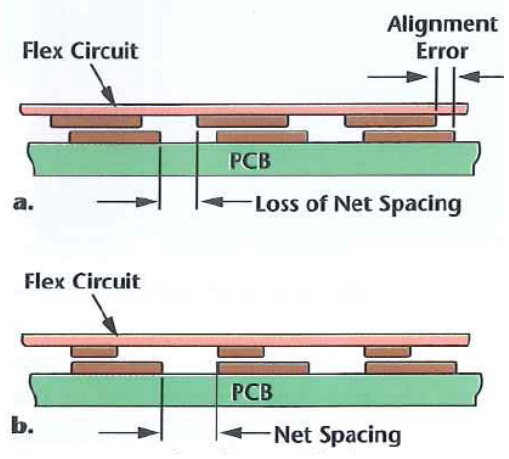


Figure 13 Equal pad sizing (a) does not accommodate alignment errors without loss of spacing, possibly promoting bridging in solder is excessive. Mismatched pad spacing (b) accepts alignment errors without net loss of spacing.

Process Considerations

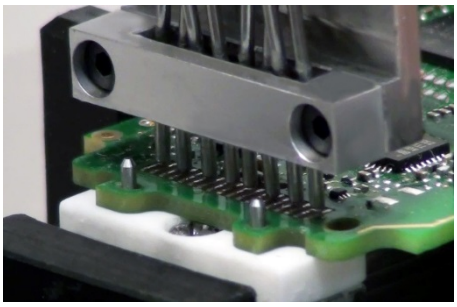


Figure 14 Automated flux dispensing module

Flux

Flux is always recommended to remove oxide barriers that inhibit thermal transfer. Flux can be applied manually or automatically.

Solder

Solder must be pre-applied to the parts to be joined. While it is generally recommended that both parts be solder plated, if there is enough solder already on the PCB pads, gold-plated, or even tin-plated, flex leads will work quite well. The volume of solder depends on lead pitch and the type of flex circuit to be reflowed. Generally, the finer the pitch, the less solder required. With single-sided window flex, any excess solder is trapped between the board and the flex's insulation. Here, solder volume must be very small and tightly controlled. With open window or loose lead flex, volume is less critical. If designed properly, excess solder will wick around the sides and tops of the leads.

Tooling

In regard to tooling for hot bar soldering, proper support it critical. The tooling must withstand the pressure of the hot bar without flexing; any board sag will prevent equal contact with each lead uniform heat transfer. Evidence of this problem is usually found around the center section of leads. Also, the tooling should not be too thermally conductive, in which case it sink too much heat away from the solder joint. A nonmetallic material that can withstand reflow temperatures is recommended, however, may not last long in high volume production. If metal tooling must be used, it may be necessary to preheat it in order to minimize thermal loading of the hot bar.

Visual Inspection

There should be an obvious impression made by the hot bar on the surface of each of the flex leads. With single-sided flex, the imprint should display no evidence of burning. (Some bake-on flux may be evident, but it can be removed by cleaning.) With loose-lead and open-window joints, the imprinted area will be on the copper leads themselves. The surface should appear grainy and joints will not be shiny as those oven reflowed, though the imprint is a good indicator of how well each lead has been contacted by the hot bar (Figure 14).

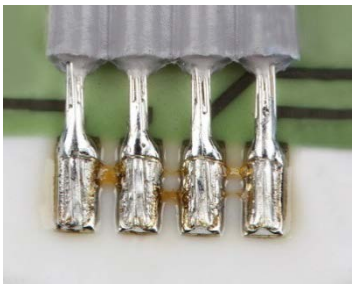


Figure 15 The hot bar imprint on the surface of the wires is a good indicator of how well a joint has been formed

With all types of flex, there should be no burning of the polyimide or the PCB material. (Note: With single-sided window flex, some darkening of the top layer of insulation is normal.) There should be no measling or delamination of the epoxy boards and flex, and PCB leads should not be stretched or appear stressed.

Conclusion

Hot bar soldering is a proven and reliable method for attaching flex circuits to PCBs. The advantages are many, including safe localized soldering and ensured lead co-planarity. It is a low cost, easy-to-use, reliable and adaptable technology that will not be quickly obsolete by new packaging trends. As more and more flex circuits are utilized within assemblies, the demand for various flex circuit interconnect technologies continues to grow. As this demand increases, the benefits of hot bar soldering will be realized as will the need for hot bar equipment.

TABLE 1

Flex Circuit Comparison

Flex Type	Lead Contact	Heat Transfer	Solder Volume	Bar Sizing
Loose Lead	Yes	Excellent	Forgiving	Forgiving
Single-sided	No	Good	Critical	Forgiving
Open Window	Yes	Excellent	Forgiving	Critical

Figure 16 Flex Circuit Comparison

Other types of hot bar soldering are ACF (anisotropic conductive film) laminating, heat seal bonding, and heat staking, all using the same hot bar system as for reflow soldering. Only the hot bar, and sometimes the bonding head (due to higher bond forces) are changed out, along with a new bond profile or recipe.