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A LOW-COST REWORK METHOD SAFELY AND EFFECTIVELY REMOVES AND REPLACES MODERN "HIDDEN-LEAD" SURFACE-MOUNT PACKAGES.

Rework within your reach

THE INTRODUCTION OF SMALL, chip-scale packaging has been a great benefit to the electronics industry. These small packages save precious pc-board space and have made possible modern devices, such as cell phones and PDAs. Engineers have designed most modern semiconductor packages to minimize production costs for semiconductor manufacturers as well as pc-board-assembly houses. The ultimate limit for reduction in package size is the size of the silicon chip itself, and many devices, called chip-scale devices, have reached this limit.

Most manufacturers have retooled production lines to handle the modern devices that are now available. Unfortunately, many engineering labs find it difficult to remove and resolder these advanced packages in a laboratory setting. Rework machines for CSP, LLP, TSSOP, and other packages do exist in today's market, but they are often specialized, large, and difficult to use. They can be expensive, too, with some selling for $30,000 or more. More often than not, they are out of the reach of the average engineering lab. The good news is that you can now employ a low-cost alternative method for reworking—removing and replacing—these modern packages.

The packages you typically encounter on a modern pc board may not yield to traditional soldering-iron rework methods (**Figure 1**). Laminate CSP, LLP, and MicroSMD packages can be particularly troubling, because their solder connections are inaccessible, on the bottom of the part. Although TSSOP and SOIC packages do not have hidden leads, they also yield to the low-cost-rework method.

"Rework" has become a dirty word in the electronics world. Mention it to a production manager, and watch him cringe! In the production environment, the need to rework material generally represents a significant failure somewhere in the production process. In the engineering lab, the word "rework" can also cause your co-workers to cringe, especially now that modern simulators are supposed to mean that the first revision of your pc board will work flawlessly. The reality is, any serious development project will eventually require rework on parts such as those shown in **Figure 1**. You will want to leave rework of high-pin-count devices to the high-cost rework machines, but with practice, you can solder devices with many pins and fine lead spacings using the low-cost method.

So, what is the easiest way to remove and resolder parts? If you are fortunate enough to be in the same location as your manufacturing facility, high-priced rework gear will certainly be available to serve your needs. However, few modern labs are in the same location as production. In fact, many production lines are now in Asia or Mexico. Therefore, some engineering labs have resorted to purchasing production-grade rework stations that screen solder paste, control hot air temperatures, lift parts with vacuum chucks, and optically align parts for soldering. These machines are indispensable in a production environment, but are they necessary in an engineering lab? The following method will allow you to rework modern SMD (surface-mount-device) parts using only a few hundred dollars' worth of equipment.

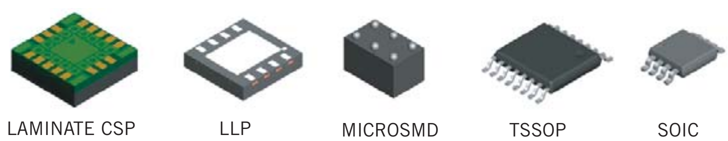

Figure 1 Typical packages on a modern pc board may not yield to the traditional soldering-iron-rework methods.

THE LOW-COST REWORK METHOD

Although manufacturers don't recommend this low-cost rework method for production, it can be satisfactory for the engineering lab. All you need is a heat gun; liquid RMA (rosin mildly activated) flux (in a bottle or syringe dispenser); solder (fine rosin-core solder wire on the order of 0.015-in. in diameter is appropriate); flux remover; tweezers for placing, adjusting, and jiggling the part; and some practice.

Careful selection of a good heat gun is important. Many of the heat guns on the market are de-

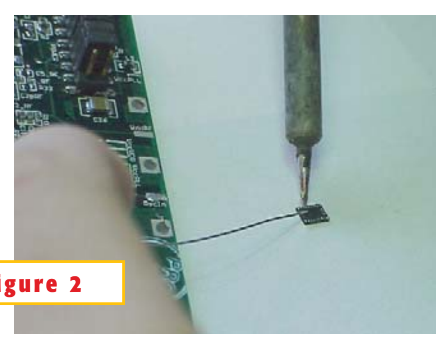

Figure 2 Prepare the pads on the pc board and on CSP and LLP packages by tinning them with a small amount of solder.

signed for heat shrinking or paint removal. These guns usually produce too much heat, too much airflow, or too wide an airflow. Although the Weller Princess heat gun primarily targets heat shrinking, it is well-suited for SMD rework, because it offers a thin stream of low-velocity air. A wide stream of air would heat too wide an area of the pc board, and a high velocity stream of air would blow parts off the board.

Optionally, you can use a stopwatch to time the hot-air application; a low-cost, noncontact IR temperature probe to check reflow temperatures; and a thermocouple to check board temperature. However, temperature measurements are not mandatory for good results, and precise control of the reflow profile is not necessary for lab rework. This article uses a $200 Protek 506 DVM (digital voltmeter) to measure temperature. This DVM comes with a type-K thermocouple, which performs well at −20 to +1200°C.

You may also want to employ chart-recording software. This article measures temperature-versus-time profiles using free RS-232 chart-recording software that also comes with the Protek 506. A Tektronix 177/D1 Curve Tracer tests for completed electrical connections.

EASY REMOVAL PROCEDURE

Many engineers still have a death grip on their beloved soldering irons. Soldering irons are valuable tools, but they are diminishing in importance. If you inquire, you will find that most SMD vendors, especially the ceramic-chip-capacitor guys, recommend that you use hot air for rework, because it simplifies the removal of high-pin-count parts. Follow these steps to remove parts:

1. Apply gentle heat with the heat gun about 2 to 3 in. from the board. Heat from directly above to avoid blowing parts off the board.
2. Wait about 40 to 60 seconds for the solder to liquefy. Don't bring the heat gun in close, or the board will heat unevenly.
3. Lift the part with tweezers. (Never pry; wait for the solder to completely liquefy.)
4. Clean the pads with solder wick only if there is bridging. When putting a part back down, use the old solder that is present on the pads in the appropriate amounts. If you use solder wick for cleanup, take care not to damage the fragile pc-board traces with excessive heat.

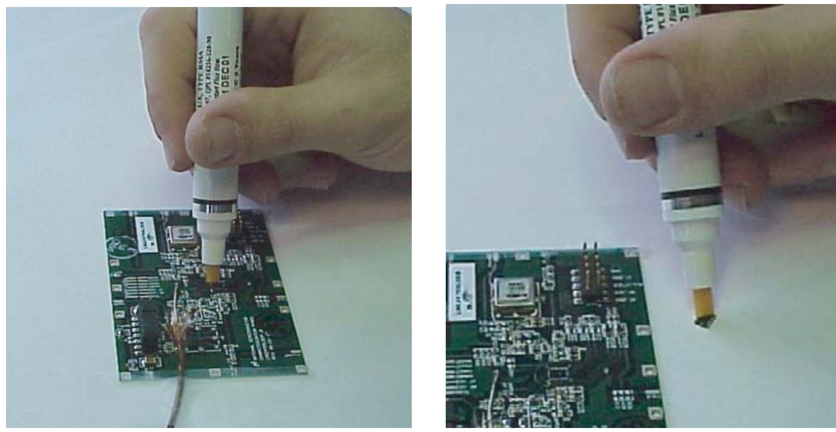

Figure 3 Apply flux to the pc-board pads (left) as well as to the underside of the part (right).

PLACEMENT IS MORE DIFFICULT

Removing parts with hot air is simple. Putting them back on the board can be easy, too, but it requires more skill and practice. The good thing about hot air is that, when you use it carefully, you can remove and replace parts several times with minimal board damage. As such, you'll be able to retry if your part has shorts or opens after you put it down.

To place surface-mount parts, such as the parts in **Figure 1**, you may want to tape the edges of your pc board to the table to prevent it from shifting during rework. Remember that the board is going to get hot, so find a Formica tabletop and avoid melting your expensive ESD mat. (An insulating pad might be helpful, too.) If you want, tape a thermocouple probe to the pc board near the rework site. Prepare the pads on the pc board by tinning them with a small amount of solder (**Figure 2**). If the board contains solder from a recently removed part, leave it. Remove any bridged solder with solder wick.

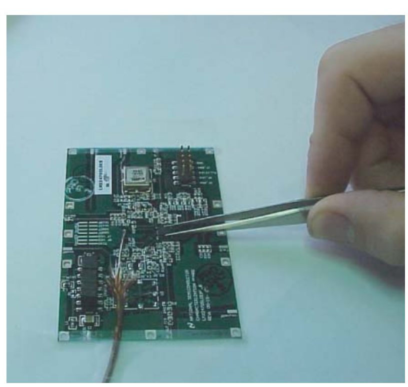

Figure 4 You can place the part on the pads using tweezers, visually aligning it by looking from directly above and gently jiggling it into place.

Your next step is to apply flux to the pc-board pads as well as to the underside of the part. A thin (but visible) coat of flux is all that is necessary (**Figure 3**). Place the part on the pads, visually aligning it by looking from directly above and gently jiggling it into place (**Figure 4**). Yes, most pad spacings are small, but visual alignment can be helpful. (Be sure Pin 1 is correctly positioned, too.)

Apply heat with the heat gun 2 to 3 in. away. Don't be impatient! Bringing the gun too close will blow your part away and heat things too quickly for even soldering. Directing the hot air onto the part from directly above helps prevent the part from blowing off of the board. After about 40 sec, the part will begin to sink into liquid solder. The surface tension of the liquid solder and the boiling flux will help to properly align the part. You may need to gently jiggle the part by tapping it with the tweezers or make other minor adjustments. Continue applying hot air for 20 to 30 sec longer. If the airflow blows your part away, you can fashion a small hold-down tool by bending a paper clip and taping it into place (**Figure 5**). Generally, you won't need the hold-down tool if you apply the hot air from a sufficient distance. You can also hold parts in place with tweezers, if necessary.

Finally, turn off the hot air and allow the board to cool slowly, clean the excess flux with flux remover, and test for shorts and opens, if necessary.

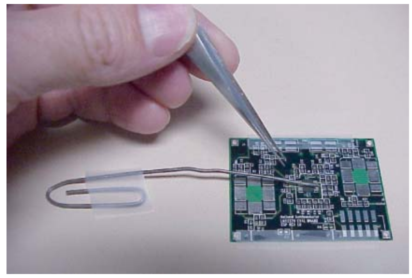

Figure 5 Fashioning a hold-down tool from a bent paper clip can prevent airflow from blowing your part off the board.

This method works well with a stopwatch and simple visual monitoring of the process. You can also measure a profile to confirm that you are soldering in a way that mirrors the process a production-reflow oven uses. A "profile" describes a temperature-versus-time graph for soldering. The profile shown in **Figure 6** uses free software and a thermocouple from the Protek DVM.

You can also perform this procedure using solder paste rather than directly tinning the pads. Carefully apply solder paste with a syringe or screen it into place with a paste mask. Old solder screens are a good source of partial-screen sections; just cut out the desired device screen with tin snips and mask unwanted holes with Kapton tape. Although the solder-paste method can be more difficult than simply using the solder, it may yield better results. (Because solder paste contains microscopic, easily ingested, lead particles, it is a hazardous material. If you use solder paste, take care and respect the manufacturer's warnings. These warnings strongly recommend the use of rubber gloves.)

Although some production lines now use no-clean fluxes, the procedure works best with RMA flux, and manufacturers recommend cleaning. Clean reworked boards with a vapor degreaser or another appropriate spray-type flux remover. Because the flux remover washes away flux by dissolving it, hold the board over a trashcan and spray flux remover, allowing the excess to rinse into the trash. Failure to remove excess RMA flux can cause your board to fail prematurely because of corrosion, dendrite growth, or both.

TESTING METHODS

The most common way to test for success is to power up your circuit and see whether it works. What if your board doesn't work? Some engineering-prototype boards may be so new that you may be uncertain whether to blame the rework job. Some simple tests can check pins to confirm that a connection has been made. It is also useful to check adjacent pins to ensure that they are not shorted together (solder bridging).

Most of these tests rely on the fact that semiconductor devices almost always have a pair of ESD-protection diodes on every pin (except ground). Sweeping the pins of a reworked device with a curve

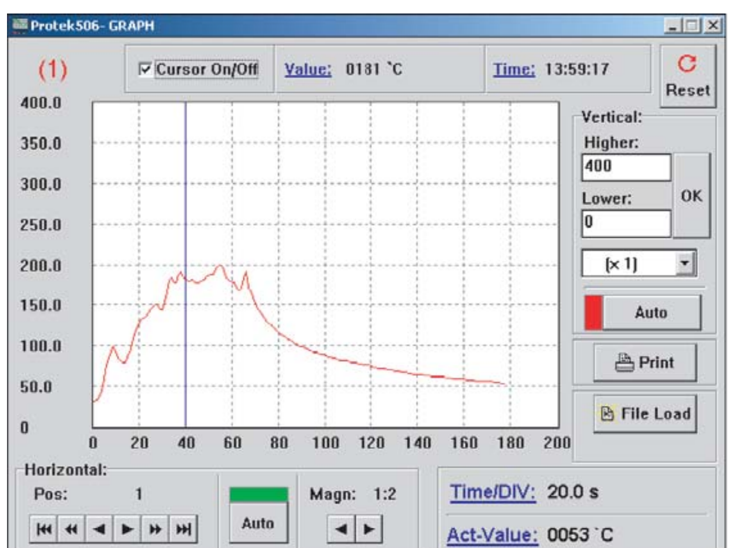

Figure 6 The results of a temperature profile measured with the Protek 506 DVM, showing that the solder began to visibly liquefy at the blue line (40 sec), are consistent with the published melting point of Sn63/Pb37—183°C.

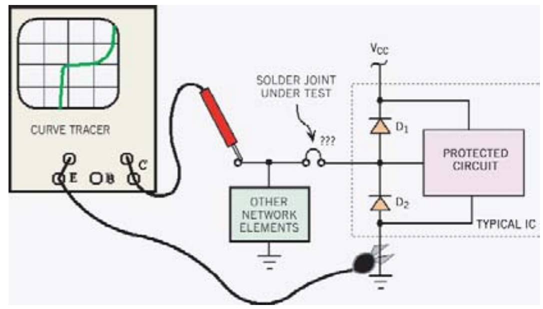

Figure 7 Sweeping the pins of a reworked device reveals whether a good solder joint is present.

tracer can help you to determine whether these diodes are present, implying a good solder connection (**Figure 7**). You can also complete this test with a DVM, but a curve tracer provides a better picture of what is going on, and it allows more control over the maximum test current. In general, you should keep the test currents lower than 10 mA to avoid permanent damage to the device under test. It is generally a good idea to turn off the curve tracer's collector supply and then slowly bring it up until you can see about 1 mA in the low-side diode, which is enough to show that a connection is present. Most "bed-of-nails" production-test machines confirm continuity by looking for the low-side diode (D_2 in **Figure 7**), so this approach is well-established as safe and effective.

You can use a DVM-with-diode test mode as a lower cost alternative to the curve tracer. However, the problem with the DVM is that it is sometimes unclear exactly how much test current is injected. Most diode-test modes do a 10-mA diode test. The curve tracer gives a better picture of what is going on. As you can see from the nonlinear IV curves, a DVM on "resistance mode" would be inappropriate (because the slope of the curves is a function of test current). Older curve tracers are inexpensive. Used Tektronix 177/D1 systems are available for less than $1000.

Because the reworked part is almost certainly embedded into a circuit network, it is certain that other network components will confuse the test method. If a "known-good" board is handy, an "A-versus-B" IV curve comparison for each node can be useful. Of course, if the "other network elements" shown in **Figure 7** include a direct connection to ground, then this pin will be untestable using this method. Because D_1 creates a low impedance when in its on state, you can detect its presence even when it is in parallel with the relatively low impedances that might be present.

If you apply power (V_{CC}) during this test, the high-side diode, D_1, is also visible and should turn on a few hundred millivolts above V_{CC}. If V_{CC} is not connected, then the knee of the high-side diode will break below V_{CC}, because power from the test input will try to power the device through D_1. Focus primarily on D_2, because its behavior in the unpowered state is more predictable.

Figure 8 shows examples of curves that a Tektronix 177/D1 curve tracer measured and makes apparent the difference when you apply power. By focusing primarily on the low-side diode, D_2, this approach eliminates the need to power the board for testing. The example shows testing using a common 74HC00 NAND gate. The approach is the same for almost all digital and analog semiconductors, because these devices rarely omit ESD protection (even in RF ICs).

With the exception of the powered-output case, when a connection is present, the low-side diode behavior is visible. For this reason, it is preferable and easier to test without application of V_{CC} power. You should keep a schematic close at hand to ensure that the other network elements don't include a direct connection to ground or a parallel diode that would mimic the behavior of D_2.

OTHER TESTING METHODS

In some instances, visual inspection is also possible, certainly for SOIC-type packages. For CSP, LLP, and other ball packages, a limited amount of visual inspection may be possible by looking in from the side with a microscope or jeweler's loupe. Engineers have employed other methods, such as microfocus-X-ray inspection, but they require expensive machines that are usually unavailable to a production operation, let alone an engineering lab.

In most cases, if you find rework errors, the only recourse is to remove the

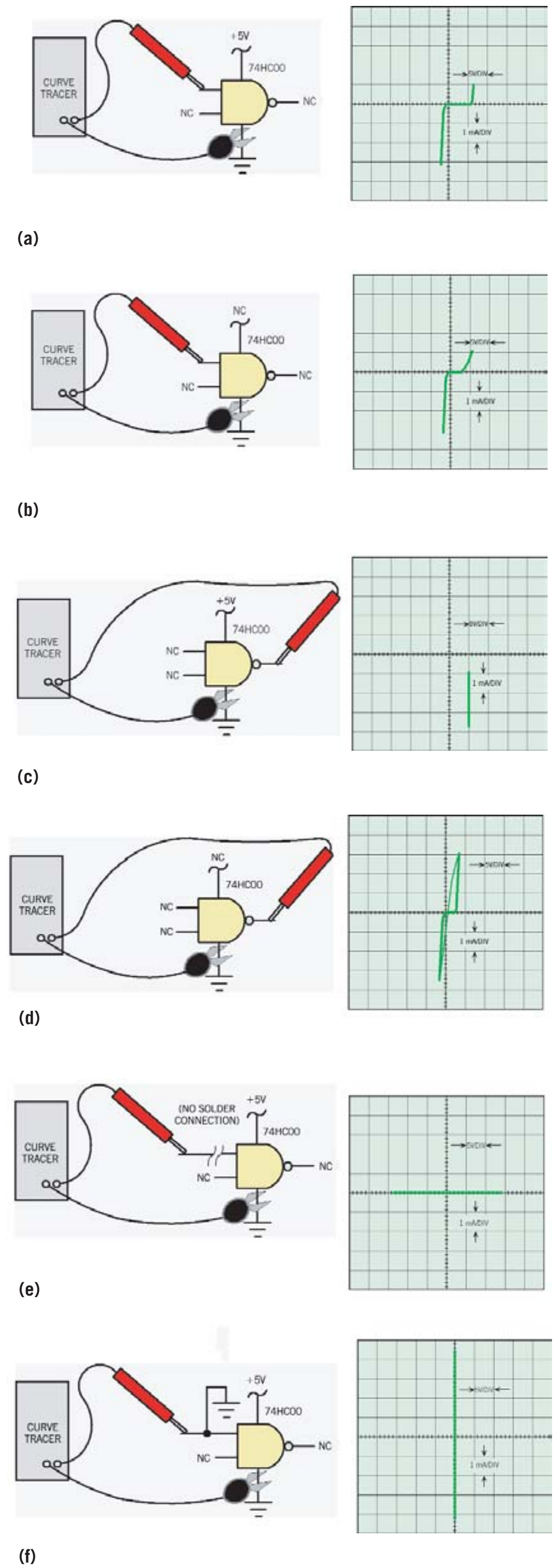

Figure 8 Examples of curves measured with a Tektronix 177/D1 curve tracer include an input-IV curve with power applied (a), an input-IV curve with no power applied (b), an output-IV curve with power applied (c), an output-IV curve with no power applied (d), an input or output open circuit with no solder (e), and a pin shorted to ground (f).

part using hot air and then replace it. Because this rework method is gentle on pc-board copper traces, several rework cycles are possible before damage (pulled-up lands) occurs.

It is sometimes possible to repair an incomplete connection, or "no solder," by heating the land associated with it, in the hope that the solder will reflow. However, this method risks damaging fragile pc-board copper. Reheating the part with hot air and gently jiggling it with tweezers is probably a better approach.

Although it is preferable to use production-grade rework tools, these tools are somtimes unavailable and may simply be outside the budget of your engineering lab. In these cases, the low-cost-rework method is a safe and effective way to both remove and replace modern "hidden-lead" SMD packages.□

Authors' biographies

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