
Beam Lead Device Bonding to Soft Substrates

Application Note 993

Introduction

The hard gold surface on standard PC boards combined with soft substrate materials makes it almost impossible to successfully bond beam lead devices onto the boards with normally recommended thermocompression bonding. An alternate method of bonding by modified parallel gap or series resistance welding uses a single electrode to weld the beam while the conductor is contacted separately. This method allows light pressure to be applied to the weld probe, resulting in an effective bond without damaging the beam lead device.

Description

There are three methods that can be used for attaching beam lead devices to soft substrates. The method selected will depend on the substrate material, the plating applied to the conductors, equipment available, constraints on the use of conductive epoxys, and volume.

1. Epoxy

Epoxy should be considered if there is to be volume production and the use of this material is allowed. Equipment is available to dispense the epoxy and place the beam lead onto the epoxy fully automatically. (See Application Note AN-992 for more information.)

2. Reflow

If conditions allow, the conductor can be plated with bright tin (100 to 300 μ inches) and the beam lead attached by reflowing the tin using a wire bonder with a solid tool used as a soldering tip. (See Application Note AN-992 for more information.)

3. Resistance Welding

The most versatile and probably the easiest to control is the resistance weld method. Attachment with this method is achieved with very little lead deformation and provides very good mechanical results. Almost any substrate material such as Duroid, Kapton, Epsilam, and G10/G11 epoxy can be used. Resistance welding is easily performed on all of the commonly used conductor finishes, such as tin, gold, or nickel on copper lines. (Palladium/silver finish is not recommended because of its excessively high resistance.)

Resistance Welding

Resistance welding is a very effective beam lead bonding method which can be used with nearly any substrate material and most conductors. There are a number of ways of using pulsed power to create bonds between the beam and conductor. All of these methods are useful, but when working with parts as small as beam lead devices, one should be careful about the method used. Examples of these methods and the difficulties encountered are described below:

A. Parallel Gap - A parallel gap welding system is shown in Figure 1. In this case, the electrodes are bonded together with an insulator between the electrodes. The current is then passed from one electrode to the other through the part to be welded, in this case the beam lead. The energy required to fuse the bottom conductor must be generated at this interface. The spacing between the electrodes should be kept to a minimum (below 0.3 millimeter) to minimize the substrate conductor heat-up and thus prevent the conductor from lifting off the substrate. This is especially important with very thin lines (8 micron copper). The lines should be covered by a gold finish of more than 0.5 micron if possible. One alternative is to use a nickel layer between the copper and the gold.

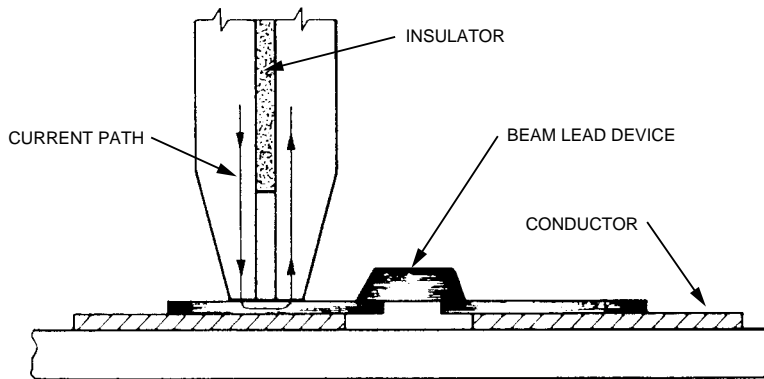


Figure 1. Parallel Gap Welding System

B. Series Welding - This method uses a single electrode to make contact to the beam. The power supply return makes contact to the conductor by means of a welding frame (positioned on the substrate around the part to be welded as shown in Figure 2), or probe (placed on the conductor adjacent to the lead as shown in Figure 3). The supply return electrode is fixtured to provide a low resistance path close to the point of the weld. The weld current is passed through the beam to the conductor to the power supply return electrode. Although the set-up in Figure 3 is a form of series welding, it is basically a modified parallel gap welding system. The electrode spacing restrictions and conductor considerations for the parallel gap system should also be adhered to in the modified parallel gap system. Because of the beam size and the problem of aligning the electrodes to the beam, neither the parallel gap nor modified parallel system is recommended if many parts are to be bonded. The series welding system with the welding frame as power supply return is preferred.

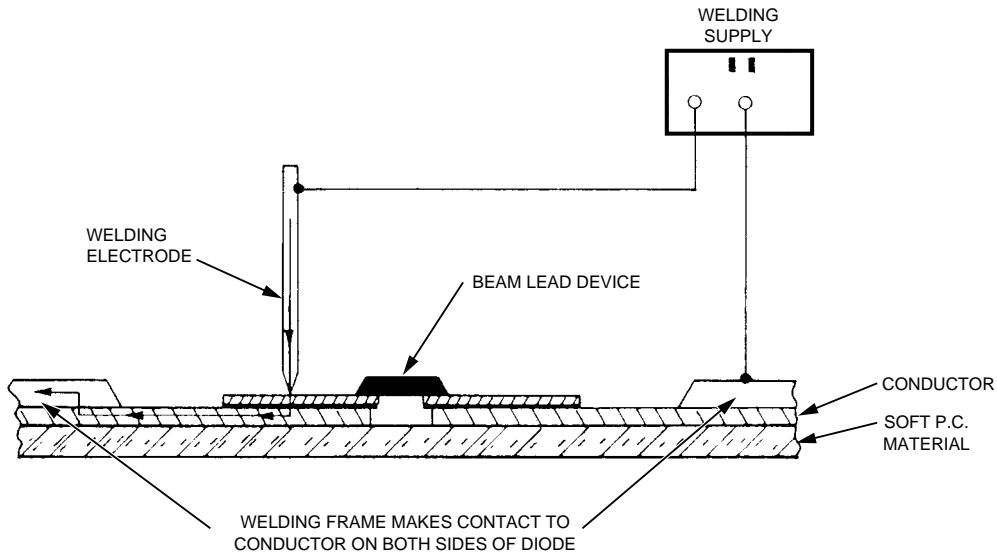


Figure 2. A Single Electrode Series Welding System

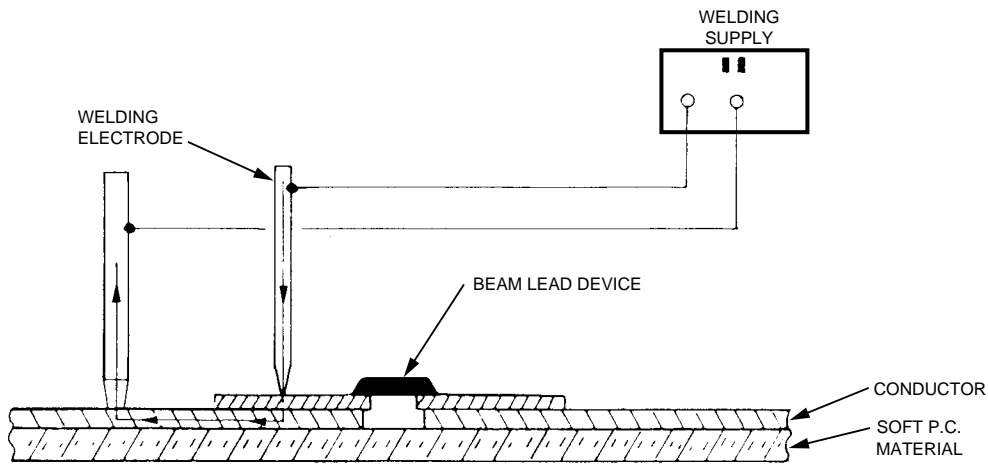


Figure 3. Modified Parallel Gap Welding System

In the series welding process, the concentration of current at the interface between the beam and the conductor causes the materials to fuse. The use of a single electrode is a major advantage since it is not necessary to align the device to the electrode. Fixturing with a material such as copper with a nickel strike and then gold plating in the area of contact to the circuit is important in order to concentrate the weld energy at the desired point. The required energy should be from 0.1 to 0.15 wattseconds to bond Hewlett-Packard beam leads to materials such as gold, tin nickel, and alloy 42. If the level required to weld exceeds this, the fixturing should be considered suspect.

The shape of the electrode tip is very important. The recommended electrode is shown in Figure 4. The preferred electrode tip is 7 mils in diameter. If the tip diameter is too large, or the tip angle is more than 30 degrees, more current and voltage is needed to heat it up. Furthermore, if the voltage is too high, the diode is susceptible to damage.

The electrode force should be confined to approximately 10 grams. If excessive force is applied, the electrode will be pressed into the substrate and a pull on the diode leads can occur. Weld heads are available which can apply the very light pressure needed with good repeatability.

The electrical power during the welding process should be adjusted so that the electrode will not melt the substrate line totally and thus will not be pressed into the substrate. Additionally, the welding voltage across the electrodes should be limited to below 0.35 volts to ensure that the diode will not be damaged. Welding power supplies with constant voltage or voltage control should preferably be used, although capacitor discharge supplies can work well if the resistances in the current path are kept at a minimum and uniform.

Total current path resistance should be limited to below 10 to 20 milliohms. If that is accomplished, the pulse will be low in voltage (0.2 volt) and long in duration (500 - 1000 milliseconds).

The welding power required for a good bond depends not only on the weld electrode tip form, but also on the material used. Highly conductive materials are welded with electrodes of lower conductivity. Soft materials are welded with hard electrodes. Gold to gold is welded using copper tungsten, molybdenum or pure tungsten electrodes. In general, beam lead bonding to soft substrates using the resistance welding method requires electrodes with high conductivity, high hardness, low contact resistance, minimum adhesion to gold, and the appropriate electrode tip shape. The characteristics of various electrode materials are summarized in Table I.

Table I. Characteristics of Electrode Materials

Electrode Material	Hardness	Wearout	Adhesion to Gold	Electrical Conductivity	Low Ohmic Contacts	Machineability
Copper	Poor	High	Very High	Good	Good	Good
Steel	Medium	Medium	High	Medium	Medium	Good
Tungsten/ Carbide	Good	Medium-High	High	Medium	Medium	Difficult
Copper/ Tungsten	Good	Low	Low	Good	Good	Good
Copper/ Beryllium	Good	Low	Low	Good	Good	Good
Molybdenum	Good	Low	Low	Good-Medium	Good	Good
Tungsten (100%)	Very Good	Low	Low	Good	Good	Difficult (Grinding Only)

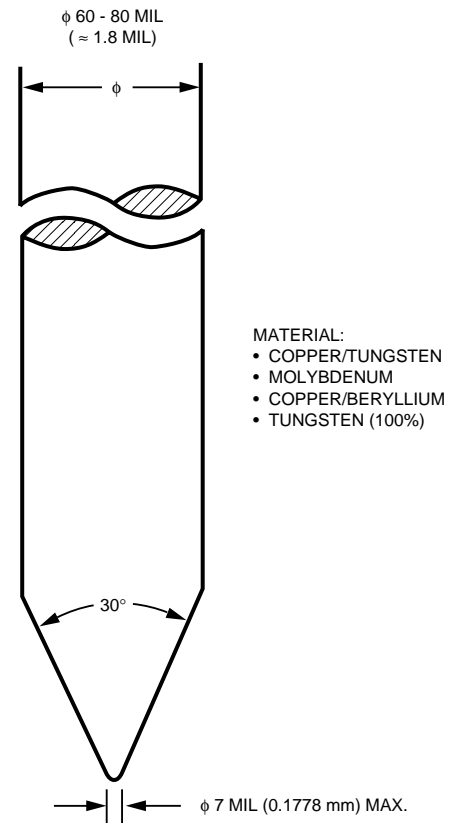


Figure 4. The Shape of the Electrode Tip

Equipment

Several commercially available bonders are specifically designed for resistance welding. Two examples, including their capabilities, are tabulated below:

Welding Current Waveform	Hughes Model MCW/JL with MCW 550	Unitek Unibond
Weld Energy (Watt-Sec)	0.13	0.13 – 0.14
Pulse Width (ms)	15 – 20	20 – 2000
*Voltage (Volts)	0.2 V Typical (0.3 V Max.)	0.2 V Typical (0.35 V Max.)

* This voltage, applied across the two electrodes during the welding process, should not be exceeded in the welding of boom lead devices. Otherwise, device damage may occur.

The Hughes system is shown in Figure 4. The parts list for this system is contained in the Appendix of this Note. The Unitek system is available as a complete unit.

The equipment setups suggested here are those which have been readily available and have been tested in Hewlett-Packard's Application Laboratories. The examples should not, however, be considered all inclusive. Furthermore, the mention of the equipment in this Application Note does not constitute an endorsement of that equipment by HP nor does HP assume any guarantees for the performance of that equipment.

Summary

Resistance welding is a very effective beam lead bonding method which can be used on soft substrates with most conductors. Constant voltage power supplies are available which reduce the possibility of damage to the beam lead device by overvoltage. Weld heads are available which can apply the very light pressure needed for an effective bond without undue strain on the device. Tests have been successfully performed to attach beam lead diodes to soft substrates like Kapton, RT-Duroid, or Epsilam, where copper lines were covered with layers of nickel and gold or pure gold.

Appendix

Hughes Resistance Welder Parts List

Hughes Aircraft Co. Industrial Products Division
Carlsbad, CA

Req. Qty.	Part #	Description
1 ea	MCW-550	Constant voltage power supply
1 ea	VTA90	Ultra light weld head (less compliant tip accessory for setup with welding frame)
1 ea	MAXY90	XY Positioner
1 ea	MCW552	Optical Aid Assembly
1 ea	MA09-11	System Mounting Base Plate
1 ea	MA-02-25	Bus Bar Set
1 ea	WE-2231	Horn Assembly, upper and lower (for setup with welding frame)

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