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Resistance Welding – Parallel Gap Welding Basics
By David Steinmeier

Introduction

Parallel gap resistance welding is the process of bonding two parts together by placing both electrodes against the same surface on just one part. Weld current flows from one electrode through the top part and partially into the bottom part before returning to the power supply via the second electrode. See Figure-1. Parallel gap welding may be the only viable bonding method when electrode access is limited to one part or the part materials preclude the use of pulsed YAG laser welding.

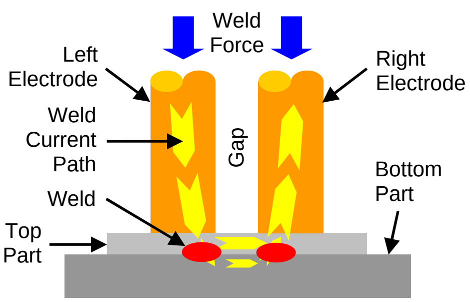

Figure-1, Parallel Gap Resistance Weld

Typical Applications

Typical parallel gap resistance welding applications include:

- *Battery Packs* – Join individual cells by welding a "connecting strap" or "tab" between cells.
- *Medical or Automotive Sensor Wire-to-PCB* – Weld round or flattened wires to gold, solder, or tin-plated copper pads on FR4, Polyimide, or ceramic substrates.
- Solar Cell – Join individual solar cells by welding silver, tin-lead solder, or tin-plated connector straps between solar cells.

Bond Types

The bond type formed during the welding process depends upon the part materials, weld energy, weld time, and weld force. The following bond types are possible, with the diffusion, solid-state and reflow-solder or brazing types being the most prevalent.

- Fusion
- Diffusion
- Solid-State
- Reflow-Solder or Braze

Figure-2 shows a parallel gap created diffusion bond between the top silver-plated connecting strap and the bottom silver-plated substrate for a solar cell application. For more details on Bond Types, please download our microTip on Metal Bond Types.

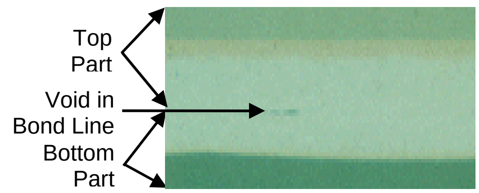

Figure-2, Parallel Gap Diffusion Bond

Parallel Gap Weld Physics

Successful parallel gap welding is strongly dependent on the part materials and part geometry. Electrically resistive parts such as nickel and steel alloys can be easily bonded to these same alloys, provided that top part thickness does not exceed 0.15-mm without employing special geometry designs. Beyond 0.15-mm, very little weld current flows through the bottom part, resulting in weak and inconsistent welds. Top part geometry is discussed later on in this microTip.

Parallel gap welding electrically conductive materials such as aluminum, brass alloy or copper is much more problematic for two reasons:

1. Most of the weld current flows through the top part so the bottom part doesn't heat up.
2. The high thermal conductivity of these materials dissipates the weld heat in both the top and bottom parts very quickly.

To overcome these problems, create a reflow braze joint by applying a brazing material between both parts or cover both parts with tin plating. The lower melting temperature of the brazing material or tin plating creates a strong bond between the parts.

Top Part Geometry - General

The primary welding goal of the top part geometry design is to control the weld current path. Ideally, the weld current should flow in a single path through both parts. The uncontrolled division of weld current between top and bottom parts is called "shunting". See Figure-1.

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There are two primary techniques for controlling the weld current path in the top part:

1. Add air gap barriers called "slots" to block the flow of current into unwanted current paths.
2. Add projections or raised surfaces to direct the weld current flow through the desired path.

Top Part Geometry – Slot

Slots are commonly used in flat nickel or steel alloy connecting straps greater than 0.15-mm in thickness to force the weld current to flow through both parts in a single path. Adding a slot blocks weld current flow in the top part between both electrodes. In resistive parts, the slot length should extend at least 3-mm past the electrode tip. For conductive parts, the slot may need to extend 6-mm past the electrode tip. If the slot in the top part is too short, then some weld current will flow around the slot end between both electrodes. Figure-3 shows how the slot controls the weld current flow between both electrodes.

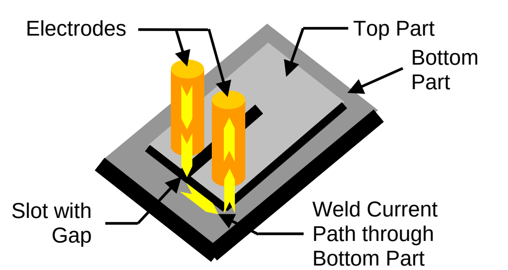

Figure-3, Weld Current Control with Slots

Top Part Geometry – Projections

The addition of the slot in Figure-3 prevents the weld current from shunting in the top part between the electrodes. However, the slot is not effective at directing or "focusing" the weld current directly under the electrode tips. Due to non-coplanarity between the top and bottom parts and the electrode tip-to-top part, the weld current may begin near the side wall of the slot, overheating the top part. To better control where the initial weld current starts, add a projection. A projection is a raised "bump" that is stamped into the top part. The projection ensures that the weld current goes into the bottom part directly at the interface of the projection and the bottom part. See Figure-4. For a more detailed discussion on projections, please download our microTip on Weld Projection Design.

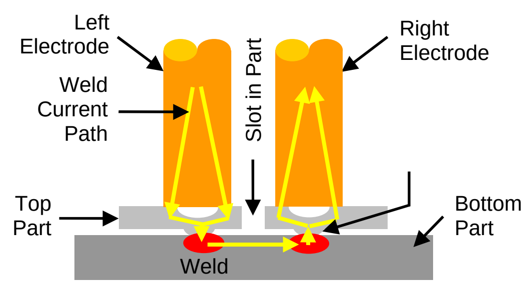

Figure-4, Projection and Slot Welding

Trying to weld solid or stranded round wire to a flat metal substrate will result in a blow-out due to the high interface resistance between the round wire and flat substrate. Compact stranded wire and flatten solid round wire to about one-half of the wire's original diameter to prevent the blow-out problem.

Bottom Part – Material and Geometry Issues

For electrically resistive parts, the bottom part thickness should be no less than 50% of the top part thickness. This ratio increases to 75% for electrically conductive parts. Verify these ratios by testing.

In cases where the bottom part is a 50-um thick copper foil on a FR4, Polyimide, or ceramic substrate, flattening the wire will not be sufficient to prevent copper foil blow-out. Solder a 0.25-mm thick nickel block to the foil to thermally isolate the weld area from the copper foil. Figure-5 shows parallel gap welding a 0.5-mm diameter nickel wire, flattened to 0.25-mm, to a 0.25-mm thick nickel block. The nickel block is soldered to a 50-um thick copper foil on a FR4 substrate.

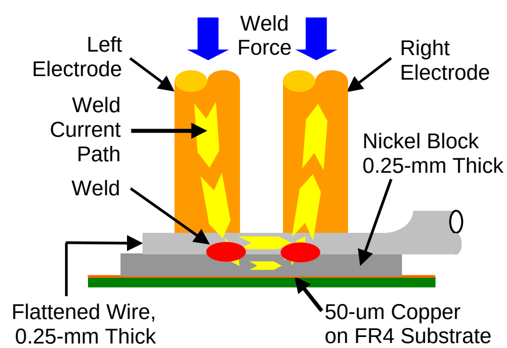

Figure-5, Nickel Wire-to-Nickel Block Weld on Copper Foil attached to FR4 PCB