# Device Success Contingent Upon Flexible Circuit Design

*Defining the requirements unique to the medical application is essential before starting the design.*

**Michael Barbella, Managing Editor 09.30.20**

Consider, for just one moment, the ability to monitor human brain activity at its source. Imagine the knowledge that could be gleaned by directly observing the non-stop electric symphony composed and conducted by a 120 billion-piece neuronal orchestra.

Fancy gaining a ringside seat to this cerebral concerto, without the need for big, bulky machines, strange-looking skull caps, or long, tangle-prone wires. A tiny, perhaps flexible, electrode would suffice as the entrance fee.

To truly witness the magical harmony of the brain's electric oscillations, that electrode would have to be extremely small—conceivably, 100 nanometers or so (roughly 1,000 times thinner than a human hair).

Creating an electrode of that size certainly is technologically possible. Medical electronics have steadily been shrinking over the last two decades as digital health and minimally invasive surgical procedures spawned a worldwide thirst for smaller, more complex computerized devices that improve diagnoses and tracking. The scramble for diagnostic tests, personal protective equipment, ventilators, and other medical supplies associated with the planet's battle against COVID-19 is expected to increase demand for medical electronics over the next seven years.

*Medical Product Outsourcing's* September feature, "**Mission Critical**," details the various trends and challenges currently shaping the custom medical electronics market. Carey Burkett, vice president at **Flexible Circuit Technologies**, a global supplier of flexible circuits, rigid flex, flexible heaters, sub-assemblies, and related value-added services, was among the various experts interviewed for the story. His full input is provided in the following commentary:

Flexible circuits are used in such a wide variety of medical applications; it is important to define the requirements unique to the application prior to starting the design. For example, if the flex will be used in a static, room temperature environment (like an interconnect in a piece of medical diagnostic equipment), the requirements will be much different than a dynamic flex used in a surgical probe, or a wearable activity tracker.

Considering the flex or rigid flex is the component on which all other components are mounted, it is imperative the flex is designed properly to ensure a successful and reliable finished product. A good starting point is to first determine if the application will require a static or dynamic flex, and if dynamic, how many cycles it will it be subjected to in service.

## Static or Flex-To-Install Applications (Less Than 10-15 Flexing Cycles)

A good rule of thumb (per IPC-2223D) is that for one- or two-layer flex circuits, the bend ratio (bend radius to circuit thickness) should at least 10:1. For three to eight layers, it is recommended the ratio be increased to 20:1. Keep in mind these are minimum suggestions and a larger bend radius will almost never be detrimental. It also important to note these suggested bend ratios assume a bend of 90 degrees or less. A bend of more than 90 degrees will require a more liberal bend radius to ensure the flex will perform reliably. One the flip side, a bend angle of less than 90 degrees can typically be bent reliably to a smaller bend ratio.

## Dynamic Flexing Applications

For dynamic flexing applications, the total number of layers should not exceed two, and should preferably be just a single layer. The rule of thumb (per IPC-2223D) is that the bend ratio should be a minimum of 100:1 for single layer circuits, and a minimum of 150:1 for two-layer circuits. Again, these recommendations should be considered bare minimums, and larger bend ratios will almost always improve long term performance.

In addition to making certain that minimum bend ratios are met or exceeded, the designer must also carefully review the circuit construction. For the best dynamic performance, circuit materials should be selected to generate the absolute minimum amount of internal stress on the conductors when the circuit is flexed. To do this, the designer must determine where in the neutral bend axis falls within the material stack up. The neutral bed axis is an imaginary planar region within the circuit, with zero thickness, that does not experience any stresses when the circuit is flexed. When bent or flexed, any material that is inside the neutral axis will experience compression forces, and any material that is on the outside of the neutral axis will experience compression forces. Either of these generated forces can wreak havoc on the copper traces during bending cycles and can ultimately result in conductor cracks. Also, as the overall thickness of a flex circuit is increased, these forces become greater, which makes it very important to keep the overall circuit thickness to a minimum. The closer the conductors are to the neutral bend axis, the better they will tolerate dynamic flexing. An optimum dynamic design would be a single layer of copper that is centered in the middle of a symmetrical material stack up. The best two-layer design would have one copper layer on each side of the neutral bend axis with minimal distance between the two copper layers.

Dynamic flexing applications also require the copper is specified as 1 oz or less in thickness (to keep overall thickness to a minimum), and should be RA (rolled and annealed) or HA (hyper annealed). Due to the annealing process, RA and HA copper are much softer and more tolerant to both tension and compression forces than ED (electrically deposited) copper. Rolled copper also has a distinct “grain direction” that runs parallel to the direction the copper web was fed through the compression rollers at the mill. It is recommended to keep any dynamic flex lines perpendicular to the grain direction of the copper.

Another very critical item to specify on any dynamic flex circuit application is that POP (pads only plating), also known as button plating, is performed. As mentioned earlier, plated copper will not perform nearly as well as annealed copper. By plating only the interconnect pads, plated copper will be kept off of the flexing traces. This will greatly improve the dynamic life expectancy of the flex.

Whether the flexible circuit application is static or dynamic, it is very important to follow established industry guidelines during the design process. These guidelines have been developed and proven over many decades. There are also design **guides** and **standards** that can be consulted to get a more in-depth understanding of flexible circuit design.

The circuit is at the heart of a medical application or device, and therefore it may very well be the most important component of all. The success of a device will be determined by the success of the circuit and its ability to perform as desired while also being the carrier of all other components.