The Art of Sculptured Flexible Circuits (Circuitree)

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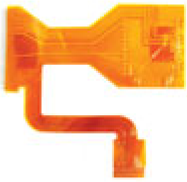


There is an interconnection technology with a level of electrical and mechanical versatility that is quite unsurpassed by any other type of printed circuit. The technology is that of Sculptured Flexible Circuits, or SFCs, and this article provides a basic introduction to the special features, construction options, materials, and application of SFCs.

Before explaining the detail of this technology, it is of value to first summarize what we mean by a flexible circuit.

Flexible circuits

Conventional flexible circuits are broadly comparable to standard rigid printed circuits in that they can be single or double sided or multilayer that they can be single- or double-sided or multilayer. The key difference is, of course, that they are much thinner, being typically 100-150 micron or less for a single- or double-sided circuit as compared with a normal rigid PCB, which may have a minimum thickness of 0.8mm (800µm). A typical single-sided flexible circuit is produced by taking a copper clad dielectric film, generally of polyimide or polyester, then drilling, imaging, etching, bonding a coverlay, and finally profiling in order to create the finished circuit. The coverlay, which is usually of the same dielectric material as the base stock, will have been pierced or drilled as necessary, in order to facilitate component attachment, before being bonded to the etched circuit. The exposed copper features of flexible circuits are usually protected by one of the conventional surface finishes (e.g. Tin, Nickel Gold, etc). They usually have printed notation and frequently have local stiffeners or rigidizers.

Sculptured flexible circuits

The manufacturing process for a simple single-sided flexible circuit comprises two basic elements: the copper clad base material and an insulating coverlay.

A Sculptured Circuit, however, of similar electrical and mechanical complexity, is built from three separate materials. Firstly, there is typically a sheet of 250 micron copper foil, one side of which is imaged and partially etched before being laminated to one of two pre-pierced or drilled coverlays. A second imaging and etching process enables the final conductive pattern to be completed before the third material element, the second coverlay, is bonded on top of the copper conductors. The resultant circuit comprises a conductive pattern that, apart from pre-pierced or drilled apertures in the coverlays for component attachment, is fully encapsulated and protected both environmentally and mechanically.

Features

These are the key features that give Sculptured Circuits significant technological advantages over other interconnection technologies:

- Variable Conductor Thicknesses
- Robust Terminations
- Pressure Contact Connector Systems
- Connections to Odd-Form Electrical and Electronic Devices
- Double-Sided Access to a Single Conductive Layer
- Power and Ground Planes
- Effective EMC Screening
- Impedance Control
- Thermal Management

Variable conductor thicknesses

Sculptured Circuits are produced from a thick copper foil, typically 254 microns, which is usually selectively reduced in thickness to approximately 100 microns, by imaging and etching, in areas where flexibility or a thinner cross-section is required. The circuit is protected on both sides by pre-pierced or drilled insulator films giving access to the interface pads, holes, or unsupported fingers. The full thickness and reduced thickness conductors can actually be located anywhere within the copper pattern, although, in most designs, the terminations – the pads and fingers – are left at full thickness while all other areas are etched down to the reduced thickness in order to increase flexibility.

Robust terminations

The starting copper thickness employed in Sculptured Circuits is 0.010” (254microns). Sculptured Circuits utilize this material to its maximum benefit, providing robust, unsupported terminations. Any unsupported fingers, formed or otherwise, are far more durable than could be achieved using conventional flexible circuit techniques, which utilize much thinner copper, typically 0.0027" (0.07mm), or even thinner, throughout the circuit.

Pressure contact connector systems

A Sculptured Jumper

While most Sculptured Circuit terminations are used for soldered interconnection (e.g. pads, holes, and fingers), a non soldered disconnectable interface is sometimes required. This can be achieved by using the "sculpturing" process to create Raised Contact Points (RCPs). RCPs are essentially solid, full thickness (254 micron - 0.010") pads that are created by chemically reducing the thickness of the surrounding copper, resulting in pillars that stand proud of the top surface of the insulating film. This enables a pressure contact to be made by a connector or, indeed, a custom clamping system.

Connections to odd-form electrical and electronic devices

Fully exposed termination areas and apertures in Sculptured Circuits are not limited to round holes for pin insertion or exposed unsupported fingers. Almost any shape that can be conceived can be etched into the copper of an SFC. Hook's and latches are typical examples of mechanical features that have been designed into SFCs. This versatility enables circuits to be designed that can interconnect to electronic components not originally designed for any kind of PCB-mounting.

Double-sided access to a single conductor layer

Because of the way SFCs are fabricated, it is relatively easy to include copper features such as termination pads that are exposed on both sides of the circuit either in different areas or co-located, as in the case of unsupported termination fingers. Therefore, some of the features of a double-sided circuit become available in a single-sided structure that provides mechanical and electrical, as well as cost, advantages to the user.

Also, because Sculptured Circuits can be designed with solder access available on both sides in different areas, circuits can be manufactured and folded to create a second conducting layer. The two 'halves' of such circuits can have different outline profiles. For example, this configuration can be used to remotely connect popular two-row micro 'D' connectors to a rigid printed circuit board.

Power and ground planes

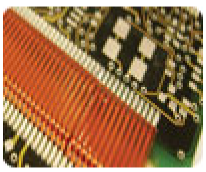
By adding other copper foil layers to a Sculptured Circuit, separate power and zero-voltage layers or shielding for electromagnetic compatibility (EMC) can be provided. If required, electrical interconnection to conductors on the main signal layer is possible using standard plated-through-hole techniques.

Effective EMC screening

For EMC screening and low-voltage planes, a thinner, and therefore more flexible, solution can be achieved by printing layers of conductive silver loaded polymer, especially formulated for use in flexible circuit applications. Silver printed screens can also be connected, as required, to the signal layer by appropriate positioning of bleed holes in the insulators surrounding the copper traces. Solid copper layers offer a shielding effectiveness of around 90dB at 1GHz, while printed silver polymer provides around 70dB at the same frequency.

Impedance control

Ever faster data transmission rates mean that signal integrity becomes increasingly important over shorter and shorter distances within electronic assemblies. This requirement also impacts on Sculptured Circuits, which may be used to transfer high speed signals between PCBs or between a PCB and panel-mounted connectors, etc.


A Surface Mount Interconnect or SMI

Fortunately, this requirement is readily accomplished with Sculptured Circuits. Standard embedded microstrip and stripline transmission line configurations are easily implemented thanks, in part, to the perfect insulation symmetry of the basic Sculptured Circuit signal layer and the ease with which reference planes can be electrically connected to ground lines on that layer. In the interest of mechanical flexibility, especially in small circuits, printed silver polymer layers are the preferred approach for the reference plane(s).

Thermal management

Many modern and technologically sophisticated electronic devices and micro-processors operate at elevated temperatures. It is necessary in certain applications to dissipate this heat either by forced cooling, heat sinking, or a combination of both.

Sculptured Circuits can, because of their ability to have copper conductors of variable thickness, be configured in such a way as to provide not only power and signal lines but also heat ladders. The flexible, conformable nature of the product allows heat ladders to be routed to the cool source, be it a forced air stream or metal heat sink. Such heat ladders may be bonded to the surface of the PCB on which the heat generating devices are mounted or could, in themselves, be the medium upon which the components are assembled.

Types of Sculptured Circuits

Sculptured Circuits range from simple forms to as complex as the designer's imagination allows. The following are just some of the wide range of possibilities:

- Simple Flat Jumpers
- Vertical Jumpers
- Jumpers with Formed Terminations
- Surface Mount Interconnects (SMI)
- Complex Shapes
- Stiffened and Rigidized Circuits
- Transitional Circuits
- Plated-Through-Hole and Multilayer

Simple flat jumpers

Sculptured Jumpers are the simplest form of Sculptured Circuit. They are somewhat analogous to ribbon cable as they are often rectangular in shape and have pin-type termination interfaces at both ends and a central insulated zone. They are typically produced without design or tooling costs in 0.1" (0.254 mm) and 0.050" (0.127 mm) pitches in insulator lengths ranging from 0.5" (12.7 mm) to 4" (101.6 mm). Investment in modest design and tooling enables almost any variation in length or pitch to be accommodated.

Vertical jumpers

Most point-to-point jumpers lie flat or are slightly looped but are assembled; in general, broadly parallel with the printed circuit boards or other items that they are connecting. Sometimes, however, space in the x-y axis is so limited that there is simply no space to accommodate a flat jumper. In such cases the solution is often to rotate the jumper into the z-axis making it vertical relative to the rest of the components in the assembly with input and output terminations emerging at right angles to the main direction of the conductors.

Jumpers with formed terminations

Staggered and formed termination fingers allow Sculptured Jumpers to provide an in-line address to two, row ‘D’ style and similar connector footprints on pitches down to 1.27 mm (0.050”). Cranking the fingers through 90 degree is common, although there are many other forms in which the fingers can be bent, including joggled and staggered rows.

Surface-mount interconnects (SMI)

A development of Sculptured Jumpers is the Surface Mount Interconnect, or SMI. These are low-cost, pre-formed, machine-placeable jumpers that can be treated exactly like any other surface mount component. SMIs, unlike ribbon cable and wiring harnesses used for “board-to-board” electrical interconnection, require minimal labor input as they are machine placeable. SMIs are usually employed to interconnect two or more rigid printed circuit boards providing a robust interconnection that, if required, allows for de-soldering and replacement of a faulty PCB without scrapping the whole multi-board assembly. SMIs therefore provide a low-cost, low-risk modular solution when compared with alternative methods including single piece flex-rigid multilayers. Currently, 0.93 mm and 0.5 mm pitch SMIs are available.

Stiffened and rigidized circuits

As with ordinary flexible circuits, designers often need to provide extra mechanical support in areas of a Sculptured Circuit, perhaps to aid component mounting or provide mechanical rigidity for later assembly. Most commonly, this will involve the selective bonding of plain FR4 PCB material, generally with a pressure-sensitive adhesive.

Where less reinforcement is required, additional layers of flexible insulator material may be added. It is worth noting at this point that, with Sculptured Circuits, there is no need to provide a separate stiffener to address a standard Zero Insertion Force (ZIF) connector. Simply leaving the copper at its original (254 micron) thickness in the ZIF area provides ample rigidity and thickness to adequately engage with most ZIFs.

Plated-through-hole and multilayer circuits

Although many applications where the technology of Sculptured Circuits has been adopted use a single layer approach, there are instances where the complexity of the interconnection requirement necessitates the use of more than one conducting layer. Crossovers or copper ground planes are examples where more than one layer may be required. The solution in such cases is to hybridize a Sculptured Circuit with standard flexible printed circuit technology to create a double-sided, or multilayer, plated-through-hole circuit. This enables the designer to utilize all of the advantages of both technologies in a single product.

Markets

The technology of Sculptured Circuits has broad market applications being used extensively in industries that include: aviation, defense, automotive, domestic appliances, office equipment, process control equipment, medical instrumentation, and space systems. These wide ranging market applications are a function of the versatility, reliability, and cost effectiveness of the technology.

Designing Sculptured Circuits

The unusual material structure and process sequence of Sculptured Circuits means that their design requirements are somewhat different to those of conventional PCBs and flexible circuits. For this reason, collaboration with the manufacturer at an early stage is an essential part of achieving a successful outcome.

In order to optimize the design for “least cost manufacture” and maximum “in-service” performance, it is preferable that the Sculptured Circuit manufacturer understand the assembly, operational, and environmental requirements of the circuit and the application. It is also important that there is a clearly defined acceptability standard, either industry or customer specific, against which the circuits can be verified and released.

Although a simple Sculptured Circuit may, in many instances, only have a single copper layer, two Gerber files are required to define both the full thickness and reduced thickness areas. Holes in the copper, for connector or component attachment/soldering, are usually etched while the conductor pattern is being etched. These features, therefore, need to be defined in the track Gerber data rather than in a separate drill file. Holes that appear only in the dielectric material are produced using conventional drilling methods and do, therefore, require a drill file. Other Gerber files are required to define the access apertures in the insulator materials and, of course, the circuit profile.

Summary

This article has described an interconnection technology that exhibits extraordinary versatility, adaptability, and robustness. It is stressed, however, that maximum benefit will only be achieved by communicating with the circuit manufacturer at an early stage in the design process.

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