The flexible inter connect

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Flexible circuits are more widely used today than many people realise. Yet how many of your colleagues and friends would be able to name some typical products containing flex circuits? Do they appreciate that in day to day life they most likely spend a good portion of their time within 2 metres of a flexible circuit?

ABSTRACT

Créés à l'origine pour la recherche spatiale, les circuits flexibles existent depuis plus de quarante ans et sont largement utilisés avec succès dans de nombreuses applications industrielles. De nos jours, surtout à cause de leurs dimensions et de leurs poids réduits, les circuits flexibles sont très recherchés comme alternative aux CS traditionnels et aux câbles rigides.

Ursprünglich für die Weltraumforschung entwickelt, gibt es die flexiblen Schaltungen seit über 40 Jahren und finden auch heute noch sehr erfolgreich umfassend Anwendung in der Industrie. Ihre reduzierte Grösse und Gewicht machen die flexiblen Schaltungen heute zu einer attraktiven Alternative zu herkömmlichen starren Platten und Kabelbäumen.

Originariamente creati per ricerche spaziali, i circuiti flessibili esistono da più di quarant'anni e oggi vengono ampiamente usati con grande successo in molte applicazioni industriali. Al giorno d'oggi in particolare, per la loro ridotta dimensione e peso, i circuiti flessibili sono molto richiesti come un alternativa ai tradizionali CS e cavi rigidi.

Even though many of us in the industry know that flexible circuits are used within products ranging from the simplest of consumer products to some of the most complex IT, telecom, aerospace & defence electronic hardware, it is still sometimes difficult to explain the benefits and the technology to those who are unaware of this method of interconnection.

Flexible circuits have been in existence for more than 40 years, having been developed for space exploration and are now used extensively in the following industries with great success:

- Consumer
- Telecom
- EDP
- Automotive
- Medical
- Aerospace
- Defence

A number of unique characteristics make flexible circuits suitable for such a wide range of applications. These include:

- Low profile
- Low mass
- Flexible - flex to fit or dynamic interconnection
- Multi-dimensional
- Increased system reliability
- Improved signal performance
- Better heat dissipation
- Compatible with component assembly processes
- Cost tailored to application

Given that reduced size and weight are important to circuit designers in almost every application, flex circuits are becoming increasingly attractive as an alternative to traditional rigid boards and cable harnesses. Their use can mean reductions in circuit mass of up to 75% and, thanks to the availability of thin films, overall circuit thickness can be reduced. Ultimately, this reduced thickness (with appropriate design consideration) can also lead to much more mechanical and dynamic flexibility. This allows the use of more of the substrate area than would otherwise be used to incorporate other forms of interconnect (connectors) and/or more components thus providing greater functionality. The combination of flex circuits' multi-dimensional nature, substrate stability and material repeatability allow the number of interconnections to be reduced thereby providing easier assembly, better electrical performance, enhanced reliability and lower cost.

Flat conductors, as used in flexible circuits, have a significantly larger surface area to volume than equivalent round cross-section wires. Heat build-up and dissipation is improved in many instan-

ces due to this and in fact localised heatsinks can be incorporated to help remove heat from particularly sensitive components. Such heatsinks can be manufactured from metals such as aluminium, stainless steel or copper and bonded directly to the circuit. Typical adhesives can be thin or filled to improve the thermal conductivity. Grounding can be facilitated in a number of ways to prevent issues with higher frequency applications if required.

Although they are essentially 2D objects, innovative design utilising folds, bends or forms results in a 3D flexible circuit interconnection and component mounting media. Certain types of flexible laminate material lend themselves to thermal forming more readily than others and, there are even special grades of polyimide that have properties tailored to achieve this.

Typical applications

Flexible circuits can take many forms dependent upon their use and the materials from which they are manufactured. Table 1 shows the main circuit types in production today and how they match some of the requirements of different applications.

The properties of laminate materials as shown in table 2 can be used initially to assess suitability for use in an application. Further work is always required to verify this in any application as material types and performance can vary significantly dependent upon the design, processing and application. For example, for a product that must operate within an elevated temperature environment for short periods of time, a PET laminate may not perform as well as a polyimide adhesive or adhesiveless laminate. However, for a circuit that operates continuously in a benign environment at room temperature, PET may be the ideal cost effective solution.

Dimensional stability, moisture absorption, dielectric constant, breakdown voltage, surface insulation resistance and dendrite resistance can also be equally important although they can be complex to understand and predict as they can be influenced by circuit design and processing, as well as by material type. An example of this can be observed during the processing of all flexible laminates where dimensional stability is concerned. During laminate production stresses can be "built" into the web or panel when the copper is laminated to the film and adhesive. This typically takes the form of stretch in the Machine Direction (MD) and shrink in the Transverse Direction (TD). When the circuit pattern is etched off, this residual stress is relieved due to the reduced stiffness of the film when less copper is present. This will result in relative positional changes of features, and in extreme cases, curl.

Circuit types and their benefits

Manufacturable with or without plated through holes on any of the substrates shown in table 2, flexible circuits provide cost effective methods for making interconnections of wide ranging geometries. They are also compatible with many surface finishes, thus allowing through hole, surface mount, wirebond and flipchip assembly techniques to be used. They can be produced in reel form - which is the most cost effective method for high volumes, or in panels.

Sculptured™ flexible circuits are produced by selectively etching or chemically milling the copper conductors so that specific features can be formed and copper thickness can be reduced locally to allow greater flexibility. Initial conductor thickness is typically in the range of 140 to 250 µm. Testing has shown that one common form of sculptured circuit, the surface mount interconnect or SMI jumper, can sur-

TABLE 1 - COMPARISON OF FLEXIBLE CIRCUIT TYPES AGAINST APPLICATION

CIRCUIT TYPE	APPLICATIONS							
	TELECOM	CELLULAR	COMPUTER	AUTOMOTIVE	MEDICAL	AEROSPACE	DEFENCE	INSTRUMENT ATION
SINGLE /DOUBLE SIDED NO PTH	✓	✓	✓	✓	✓	✓	✓	✓
DOUBLE SIDED PTH	✓	✓	✓	✓	✓	✓	✓	✓
SCULPTURED ™	✓	✓	✓	✓	✓	✓	✓	✓
FLEX-RIGID MULTILAYER	✓	✓	✓	✗	✓	✓	✓	✓
REGALFLEX ™	✓	✗	✓	✗	✓	✓	✓	✓
BRAZED PINS	✗	✗	✗	✗	✓	✓	✓	✓
CONDUCTIVE POLYMER	✓	✓	✓	✓	✓	✓	✓	✓
REEL TO REEL	✓	✓	✓	✓	✗	✗	✗	✗
SURFACE MOUNT & THROUGH HOLE ASSEMBL Y	✓	✓	✓	✓	✓	✓	✓	✓

TABLE 2 - TYPICAL FLEXIBLE LAMINATE PROPERTIES COMPARING MATERIAL TYPES

MATERIAL	RELATIVE COST	TYPICAL OPERATIONAL TEMPERATURE RANGE /°C		TYPICAL CTE/K $^{-1}$	TYPICAL PEEL STRENGTH /NMM^{-1}	
		MINIMUM	MAXIMUM		MINIMUM	MAXIMUM
POLYESTER PET (ADHESIVE)	1	-55	+85	$21x10^{-6}$	0.7	1.4
POLYETHYLENE NAPHTHALATE PEN (ADHESIVE)	2.5	-50	+150	$13x10^{-6}$ (30 TO 50 °C)	0.7	1.4
POLYIMIDE (ADHESIVE)	3.5	-60	+125	$20x1^{0-6}$ TO $400x10^{-6}$	0.5	1.4
POLYIMIDE (ADHESIVELESS)	5	-60	+180	$12x10^{-6}$	1.07	1.79

NOTE VALUESARE FORREFERENCEONLY AS THEYARE TYPICALOF A RANGE OFSUPPLIERS' PRODUCTS AND MATERIALTYPES

Fig. 1 - Sculptured™ flexible circuits use selective etching or chemical milling to form copper conductors and features

vive repeated flexural cycles during assembly and in service and is highly mechanically robust.

The SMI jumper provides a very cost effective, reliable and neat solution for connecting rigid PCBs in many applications. Novel lead geometries can also be accommodated by sculptured circuits such as raised contact points and finishes such as gold and nickel can be plated selectively to provide excellent contact mating surfaces. Due to the short distances & reduced number of interconnects this method is highly suitable for high frequency applications. Hybrids can also be formed using silver conductive polymer screening layers.

Flex Rigid Multilayers (FRMLs) facilitate circuit design by allowing several rigid areas to be interconnected by flexible sections to ensure best use of space and optimise mass, cost & reliability.

Regalflex™ (Rigid Epoxy Glass Acrylic Laminate) flexible circuits provide a higher integrity and reliability version of FRMLs at increased layer counts.

Both FRML and Regalflex™ can be combined with sculptured circuit technology to yield highly effective and reliable interconnection solutions. Inherently, there are fewer interconnections and less reliance on mechanical connectors thus providing greater resistance to environmental factors such as humidity and vibration.

All of the above circuit types are compatible with through hole and surface mount component assembly technology. Furthermore, many of the above circuit materials are compatible with over-moulding or back potting, which ease assembly, reduce costs and increase reliability in demanding environments such as automotive, aerospace & defence.

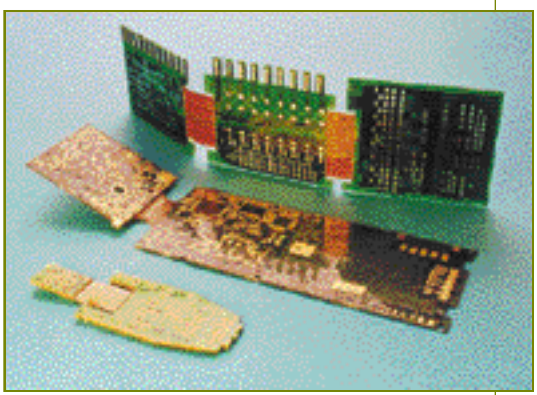

Fig. 2 - Flex Rigid Multilayers facilitate circuit design ensuring space, mass, cost & reliability are optimised

Fig. 3 - Regalflex™ circuits provide high integrity and reliability at increased layer counts

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Future directions

Flexible circuits can be configured to reduce size, mass and cost while increasing reliability in virtually all applications, so notwithstanding fluctuations in the electronics market, the future for flexible circuits of all types is exciting. Growing use of lower cost materials such as PET and PEN has driven development of compatible assembly techniques, while sculptured circuits are being developed with finer track and space geometries and more complex combinations of surface finish. Layer counts in FRML and Regalflex™ circuits continue to increase, driving the move to finer geometries, and hybrid circuits have been developed which combine these circuit types with sculptured circuits. This cost effective technology has been incorporated into a number of major programmes to date.

As well as circuit technologies and base materials, surface finishes are also seeing major developments. The use of organic solderable preservatives and electroless nickel/immersion gold is expected to grow, while environmental pressures will mean that the use of finishes containing tin/lead will diminish. ✓

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