Board-Level Multi-Cavity Shielding

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Photo-chemical machining offers significant advantages over traditional methods of manufacture.

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The ever-increasing demands on RF and microwave circuitry design and development teams to achieve EMC, eliminate crosstalk, save PCB real estate, decrease overall product size, provide access for rework and, last but not least, reduce production costs, has led to the development of labyrinth and lid shielding assemblies.

Alternatives to the labyrinth and lid approach are either a multitude of individual shielding cans or a labyrinth milled from a solid material, generally aluminium.

The disadvantages of multiple cans, even if they can be machine-placed from tape and reel, are a considerable increase in the PCB real estate because of double tracks for the individual cans and the space required between the cans for adjacent spring finger or other lid fixings.

If the labyrinth is machined from solid material, then, inevitably, the walls will be thicker than the photo-chemical machined labyrinth, and the connection to the PCB may not be as effective as a seam-soldered joint.

A labyrinth is hand-placed onto the PCB as a one-piece assembly between the electronic component pick-and-place operation and the re-flow soldering; hence, a seam-soldered joint can be achieved around any cavity that requires shielding.

The lid can be fitted following additional production processes, such as visual inspection, in-circuit testing, and in any subsequent rework of the PCB.

Component Production

One method of producing screening enclosures is photo-chemical machining (PCM), a method that offers many advantages to both the development engineer and those involved in volume manufacturing.
The PCM process uses relatively inexpensive photo-tooling created from either manual drawings or CAD information provided by the customer. The process allows changes to be made rapidly and without the considerable expense and lead times required with hard tooling.

The design process includes the basic outline and fold lines for forming (both of which can be complex shapes) and location tags, all of which can be manufactured without the need for special tools. The mechanical designer can be as creative as he wishes regarding track clearance apertures and connector or other lead-through component holes since these complexities are contained within the photo-tooling and do not directly affect the individual component cost.

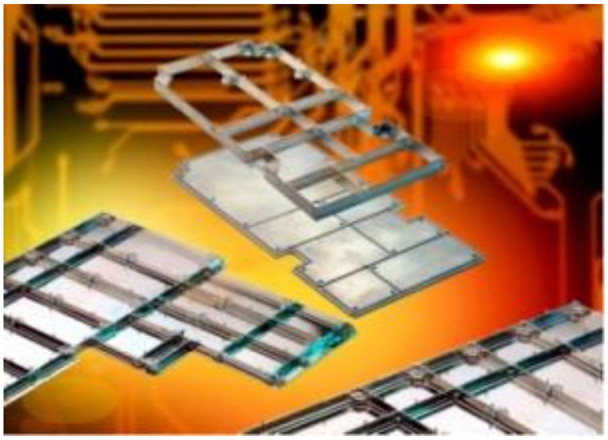

Figure 1. Examples of PCM labyrinth shielding.

Photo-Chemical Machining (PCM)

PCM uses chemical etchants in place of hard cutting tools. This technique was developed over a number of years. The end result was a process that produces complex profiles accurately using a variety of sheet metals, including copper, brass, steel, aluminium, nickel-silver, and mu-metal. Another advantage of PCM is its use of part-etching to produce fold lines which facilitates accurate formation of the shielding enclosure from flat material.

The shielding enclosures can be assembled using spot welded and/or soldered joints, complete with the internal walls, forming complex labyrinths and separate lids with either tag, spring fingers, or screw fixings.

The part-etching process can also be used to provide logos, part numbers, or channels for other inserted sealing material, providing both hermetic and RFI sealing between the lid and the fence, at no extra production cost.

The advantages of PCM are as follows:

- Low tooling cost.
- Fast turnaround of initial design and changes.
- High quality finish.
- Half-etched bend lines.
- Capacity for tooling a variety of metals.
- Low modification cost.
- Elimination of burrs and stress.
- No effect on magnetic and other material properties.
- Ease of tooling complex designs.
- Fast supply of prototypes.
- Different options available via the same photo-tooling process for development trials.
- Manufacturing quantities that range from one to a million or more.

- Convenient etching of company logos, part numbers, and indents of all kind.

Base Material and Plating Finish

The choice of base material is determined by the type and frequency of the radiated signal that the labyrinth is intended to shield. For high frequencies and electromagnetic interference, the use of non-ferrous material is recommended; however, for low frequencies and primarily magnetic interference, ferrous materials are used.
Examples of high frequency equipment applications are microcontrollers, AD/DA converters, RF and microwave amplifiers/oscillators/phase locked loops, fast logic and switching devices, microprocessors, and peripheral devices. Materials best suited to provide effective screening are non-ferrous materials such as brass, copper, beryllium-copper, and phosphor-bronze.

Low frequency equipment applications include conventional wire wound transformers, toroidal transformers, electromagnetic coils, circuit breakers, relays, and audio and sonic frequency components. Ferrous materials such as steel, mu-metal*, radio-metal,* and molybdenum* should be used in these applications. The materials marked with an asterisk have an inherent, yet fragile, magnetic field which is key to absorbing emissions. Most forms of mechanical profiling, such as press stamping, CNC punching, and similar methods destroy this magnetic field during processing. Expensive environmentally controlled heat treatment is then required to restore the magnetic field; however, it is never restored to its previous state. In contrast, photo-chemical machining does not affect the inherent magnetic field in any way.

Plating finishes are necessary to prevent oxidation and to aid solderability, as well as to increase surface conductivity and to assist radiation reflection. Obviously, if the enclosures are to be soldered in-place, by re-flow, or other processes, the chosen finish must have a melting point above that of the solder. The following finishes are recommended for shielding enclosures:

Finish	Melting Point, deg C	Solderability
Bright Tin	232	Very good
Nickel (electrolytic)	1452	Good
Nickel (electroless)*	825-925	Good
Tin/Lead (60/40)	183	Very good
Bright Silver	961	Very good

*Note: The melting point varies according to the co-deposited phosphorous content.

For most high frequency applications, a material thickness of 0.5 mm is more than adequate. Because the high frequency screening enclosure operates on reflection principles, thickness need not be a major concern. More important are other selection criteria such as a suitable, non-ferrous base material, maximization of the connection to the PCB, and the quality of the assembly with regard to soldering to ground. An adequate thickness of material should be selected to ensure that the flat blank or can will be self-rigid in manufacture and in assembly to the PCB. Sufficiently thick material minimizes problems associated with handling a product that is too flimsy and avoids any possible microphony at higher frequencies of operation.

PCM offers significant advantages over traditional methods of manufacture. These traditional methods include laser cutting, in which problems of rigidity and edge burning cause difficulty in profiling material less than 0.70 mm (0.028”) thick. However, the designer of modern electronic equipment does not wish to introduce additional material cost and excess weight to the PCB by using unnecessarily heavy metal cans.

To achieve cost-effective results over a wide application area, while maintaining optimum production and performance characteristics, the following three materials/thicknesses are base material types typically supplied.

Brass only	0.25 mm (0.010”)
Brass or Copper	0.40 mm (0.016”)
Brass or Copper	0.50 mm (0.020”)

Assembly

A number of issues may arise in the assembly of labyrinths to their PCBs during the reflow soldering process. One of the most critical issues is component flatness. Flatness can be achieved by jig assembling the labyrinths prior to soldering or spot welding the individual wall junctions.

The use of multi-level solder paste stencils ensures an adequate amount of solder at the joint of the labyrinth and the PCB. This multi-level facility can also be employed for power and larger microwave components. However, this larger amount of solder can be problematic. Because the metal labyrinth heats up before the rest of the PCB, the solder can wick up the side walls of the labyrinth, causing dry joints and blow holes. A process, dubbed the Plimsoll line, prevents this undesirable wicking by forming a natural break in the solder approximately 1 mm from the edge of the PCB.

A continuous solder joint around all four walls ensures the best isolation between individual cavities. A separate stencil for the component inside the cavity is a necessity if there is continuous tracking around all four walls. The use of a lattice stencil overcomes this problem. Traditionally, stencil manufacturers placed periodic breaks in the solder paste thus allowing the inner portion of the stencil to be held in place at regular intervals. Replacing these metal breaks with a mesh allows sufficient paste to be deposited on the PCB to ensure that a continuous solder joint (via the capillary action of the molten solder) is created as the board goes through the reflow oven.

Finally, using higher melting point solder joints or spot welded joints ensures that the structure does not re-flow itself during the soldering of the labyrinth to the PCB. Also, special processes can be used when customers need to move to non-lead solder with its higher melting point.

Additional factors that need to be considered for enclosures used at very high frequencies are microphony and the waveguide effect of cavities. Microphony can be overcome by the use of thicker material and the careful design of any cavities that house susceptible circuitry. The waveguide effect can be overcome by careful selection of cavity size and circuitry allocation in the individual cavities. On-going research is being carried out on this effect.

CONCLUSION

EMC screening can be achieved via a number of methods. However, if the need for EMC shielding is considered at the outset of a design, a successful end result can be easily achieved, easily manufactured, and, if required, can be treated as just another component in the assembly process—rather than a cumbersome add-on or afterthought. Thus, it becomes an integral part of the printed circuit board.

With electronic equipment getting smaller, operational frequencies becoming higher, and digital clock speeds increasing, the demand for effective shielding solutions increases exponentially.

One of these solutions is PCB labyrinth and lid shielding.

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