Protecting against Mechanical Failure

Enhancing robustness

Having selected the right components, placed them on a correctly designed board, and protected them against the electrical and moisture environment, the final strategy for minimising failure is to protect against mechanical failure. In general, we are trying to enhance the robustness of the assembly without compromising weight or cost, and this task has both design and material choice implications. We are considering structural issues, because the printed circuit assembly is only part of a total product solution, and failure in the enclosure may well cause the assembly inside also to fail.

Issues of fatigue

An electronic product is more than just a board – frequently there will be an enclosure which needs to be fit for its intended purpose of protecting the electronics within, as well as meeting customer expectation for appearance. Whilst most enclosures are more than adequately strong, fatigue failure may be an issue with elements such as fastenings, hinges, and other elements which create an integrated structure from a set of components. The question is, how much effort and cost it is worth putting into resolving potential problems? As with the strength:stress relationship discussed under derating, we can choose to design elements to withstand potential fatigue by ensuring that the stress never exceeds the critical stress, or else we can design for a limited 'safe' life.

Given wide variation in the sensitivity of structures to stress and environment it is not easy to ensure that failure will never occur. However, we can improve the quality of our product by taking time to consider as wide a range as possible of the events that are likely to happen, and the consequent fault modes. Depending on the application, we may also want to consider the likely abuse of the product – ask any maker of vending machines!

At a finer level of detail, we also need to consider stress concentrations in the enclosure, paying careful attention to the design of holes, fixings, corners and fillets, in order to control the stress distribution.

The distribution of stress, and the avoidance of stress concentrations, are equally important when mounting boards. The danger time is during initial assembly and disassembly for servicing. A realistic assessment must be made of how these tasks are going to be carried out and where the resulting stresses will occur. There are also tolerance issues to consider – will the board fit easily into its intended position, or be removed from it, without applying excessive force? Particularly with plastic parts, we need to be aware that some materials will shrink and distort with time, so that there is more than CTE difference to consider.

Vibration and resonance

Amongst other things, component assemblies can be subjected to vibration and shock during use, transport and maintenance. This can cause fracture due to fatigue or mechanical overstress, wear on components such as connectors, and the loosening of fastenings.

Vibration can be generated by reciprocating or rotating machinery, by wheel vibration on vehicles, and by acoustic noise. Vibration may happen at a fixed frequency, at different frequencies over time, or simultaneously over a range of frequencies, and can occur in or about different linear or rotating axes. The important measures of vibration are frequency, displacement (generally defined as peak-to-peak values), velocity and acceleration.

Shock is a particular type of vibration input, with relatively high intensity and frequency, but for short intervals, and the amplitude of any induced vibration is usually attenuated by inherent or applied damping.

Every structure has one or more resonant frequencies, and printed circuit boards are no exception. If the vibration input occurs at these frequencies, or at their harmonics, the displacements due to vibration will be maximised. The locations on the board at which zero vibration displacement occurs are called nodes, and the maximum displacement amplitudes occur at the antinodes . In order to avoid premature failure, we need to remove or at least damp any resonances.

The resonant frequency of the structure is proportional to its stiffness and inversely proportional to the inertia. In order to ensure than resonant frequencies are well above any input vibrations that may be applied, the structures need to be sufficiently stiff, especially when they contain relatively heavy parts, such as large components on circuit boards. This has an implication for the mechanical strength and rigidity of the board itself, as well as for the way in which the board is mounted. With a trend to thinner boards, it may be necessary to provide additional stiffening.

Look after the surface

Failure often starts with surface defects, and protective techniques used for structural materials include surface treatment to relieve stresses (shot peening, heat treatment) and increasing surface toughness (nitriding of steels; heat treatment). Given the normally much smaller scale of electronic structures, this generally translates into choosing suitable stress-free materials and providing an effective protective coating.

With the pressure to cut costs, however, there are increasing moves to using ‘self-finished’ materials such as plastics and precoated metal, rather than passivating, plating or coating the finished part.

Care has to be taken in manufacture and maintenance to ensure that surfaces are not damaged by scratches, nicks or impact. Although surface damage will reduce the fatigue strength in a stressed component, the major issue with electronic products is the cosmetic impact of such damage. As a result designers have to think about how to protect surfaces and prevent damage. Typical solutions involve specifying final packaging in detail, and, on critical areas such as displays, using temporary films that are only removed by the end user.

Solder joint design

Although eventual mechanical failure is inevitable, we need to protect solder joints against excessive loading in order to achieve the desired service life. Avoiding board flexure is a major contributor. Other ways in which joints can be supported include:

- Adopting stress relief measures where bigger components/heavier loads are involved, for example, by providing a separate mechanical means of fixing

- Underfilling packages such as µBGAs with adhesive, so that stresses are spread across the whole area, and not just concentrated at the joint sites.

Protecting components from stress

Up to the functional test stage, small boards are usually processed in panels, each of which contains several circuit boards. This reduces process time, and makes the assembly easier to handle. However, separating individual circuits from a mother board introduces additional stress near corners and edges, and 'de-panelling' is probably the stage at which most fractures occur. The extent of the problem depends on the method used, and whether or not the components have compliant leads: the problem is worst with chip capacitors.

Depending on design/production volume, the panel may just have been scored by the PCB manufacturer, or pressed or routed, so that the circuits are held together by narrow laminate webs or 'tabs'. Pre-routing panels before assembly can minimise board deflection, but component defects will still be concentrated near the shear lines, even when care has been taken to support the assembly.

The key is to avoid stressing the board, so de-panelling should preferably not be undertaken by hand, as the operation is difficult to control, even when a suitable fixture is used. Suitable available methods include:

- by press, using a custom tool which supports the board
- routing to remove link areas, using a side-cutting drill bit which approaches the board from underneath.

The second of these methods has the practical difficulty that it produces dust, which has to be extracted for safety reasons, is cosmetically undesirable and, if not removed, will inhibit the adhesion of any conformal coatings used.

Other options which are being explored include routing with high pressure water jet and laser cutting (for thin laminates).

Stress countermeasures

There are no industry standards which cover how much bending or deflection is allowed before component damage occurs. Some chip manufacturers suggest a 1500mm bend radius, which allows little or no bending in short segments, but relatively large deflections for longer boards. This is more realistic than a linear mm/m specification, which becomes unusable with assemblies of even moderate size, although Rawal of AVX suggests 0.1mm/cm or 3mm for 10cm.

Assemblers should audit the process so that they are aware of the ways in which unintended flexure might occur. Manufacturing countermeasures include:

- Providing support to limit board deflection
- Monitoring placement nozzle condition
- Limiting the placement force applied.

Design methods available to reduce vulnerability to fracture include:

- Cutting slots in the board, to reduce stresses during planned board bending

- Maintaining an isolation gap between chips and areas that experience too much deflection to achieve high reliability (5mm is recommended) (Figure 1)
- Keeping parts away from sources of deflection such as connectors, variable components, mounting holes and board cut-outs(Figure 2)
- Placing components at right angles to expected stress gradients
- Avoiding large flexible boards.

Pad design may also play a part: Murata found that capacitors are more at risk if they are not sitting squarely on their solder pads, so that these should be designed to be only marginally wider than the component, and the stencil arranged to avoid excess solder paste.

Figure 1: Guidelines for positioning MLCs on multi-assembly panels

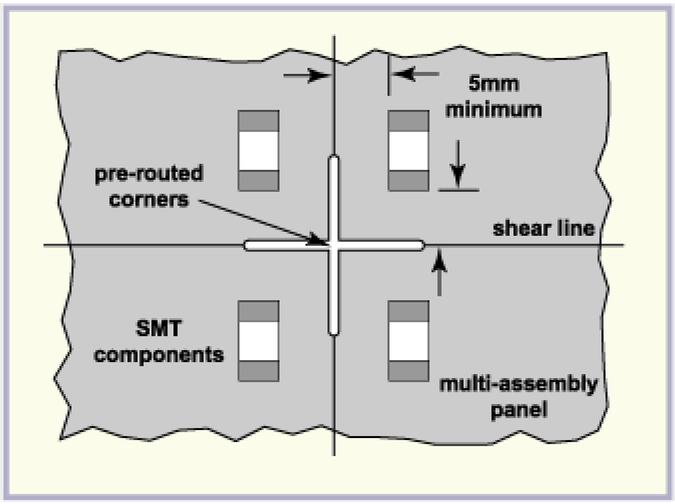
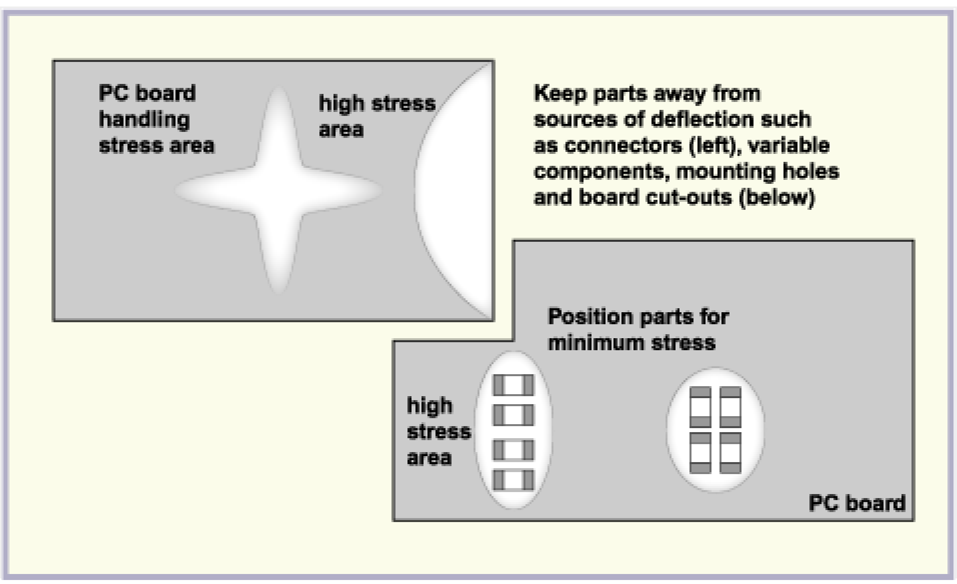


Figure 2: Guidelines for positioning MLCs for minimum stress



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