

How to Avoid Creep Problems on Board Assemblies

Introduction

Microwave circuit board materials based on polytetrafluoroethylene (PTFE), whether reinforced with woven or non-woven glass fiber such as RT/duroid® 5870 and 5880 materials exhibit Z-axis thermal expansion somewhat greater than pure PTFE. The difference is caused by the constraint on expansion imposed by the reinforcing fiber oriented largely in the X-, Y- plane of the laminate. For stripline circuit devices the Z-axis expansion is considerably greater than the metal hardware used to clamp boards together or to attach surface launchers.

Bonded assemblies avoid the problems of thermal mismatch between clamping hardware and the board. However, thermal mismatch can still hurt performance, for example, when a circle of screws attaches a surface coax-to-stripline launcher.

Torque values for the screws may be specific to maintain clamp force through the worst expected thermal excursion but not exceeding the elastic limit or plastic yield point of the hardware or board material. This may be adequate when the service temperature varies little. For more severe thermal excursions the creep characteristics of PTFE-based materials must be considered.

Thermoplastic materials exhibit time-related relaxation under stress known as creep. Elastic recovery after an applied force is removed is also time dependent. Both creep rate and elastic recovery generally increase with temperature.

Effect on Attachment

How does creep affect attaching hardware such as a surface launcher to a stripline board?

The screws are torqued to a given value which represents a screw stress level. At constant temperature, creep will decrease the initial stress at a decreasing rate such that it never becomes zero and the assembly never loosens.

However, if there are temperature excursions loosening can occur as follows: At a temperature maximum creep rate is maximized, due to both the increased stress caused by the thermal mismatch of expansion coefficients, and the increased temperature. At lower temperatures the initial stress will decrease to zero and the assembly will loosen. The actual amount of compressive deformation of the board for loosening is very small and may take several temperature cycles, but loosening will eventually happen.

Suggested Solutions

To alleviate the problem of creep, lower the hardware stiffness and increase the range of elastic response. This will maintain tightness in spite of creep, and minimize stress increase at high temperatures. A simple way to implement this method is to provide longer screws fitted with springs, such as a stack of Belleville washers.

Example

Consider the following case:

Board:

Stripline board assembly of RT/duroid 5880 microwave laminates with 0.125 in. ground plane spacing.

Assembly:

A standard brass surface launcher with a 0.562 in. diameter flange and opposing backup plate held in place with eight #2-56 brass screws.

Assumption:

Service with thermal cycling from 23°C to 150°C.

Interpolation of the RT/duroid 5880 microwave laminate data sheet thermal expansion values shows 5.0 mm/mm at 23°C and 28.3 mm/m at 150°C; a total change of 32.5 mm/m. This amounts to an unimpeded change of 0.0041 in. for the total board thickness of 0.125 in. Since the fixture hardware is all brass with a coefficient of thermal expansion (CTE) of 20 ppm/K, the differential expansion will be 0.003845 in.

The assembly could include four offset washers and eight series stacks of two stainless steel Belleville springs per screw, as shown in Figure 1. The Belleville springs have a standard outside diameter of 0.187 in. and a hole size of 0.093 in. with the height of each spring specified to change from 0.0130 in. to 0.0100 in. between unloaded and loaded at 6.75 lbs. force. If the screws are tightened to deflect 0.002 in. for each spring stack at 23°C, then the initial force of 18.0 lbs. will increase to 52.6 lbs, at 150°C.

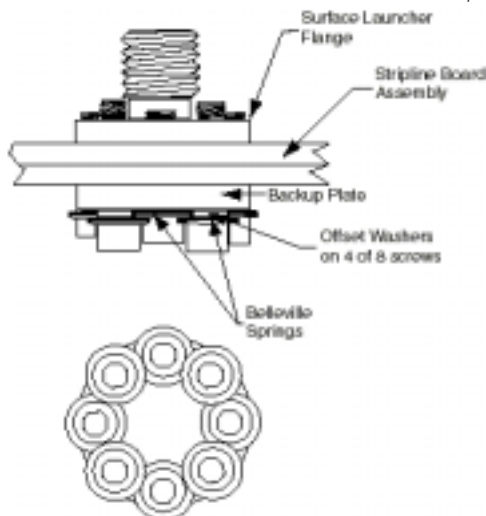


Figure 1. Surface launcher flange mounted with backup plate and Belleville springs.

Stress in the dielectric in the 0.248 inch² flange area will vary from 73 to 212 psi. At these stress levels creep is negligible.

The situation is quite different when the Belleville springs are not included. The differential expansion of 0.00385 in. is distributed between the screws and the dielectric so that the compressive force on the dielectric equals the tensile force on the screws. If linear elastic force is assumed for first approximation, the force equals (modulus) X (area stressed) X (deflection) / (effective length).

Terms	Dielectric	Brass Screws
Modulus, kpsi	97	13000
Area stressed, in ²	0.248	8X0.0045 = 0.036
Length, inch	0.1275	0.21
Deflection, inch	X	0.00385 - X

Balancing the force on the dielectric against that on the brass screws, and assuming ideal linear response of the dielectric, yields an X value of 0.00355 in. and a stress of 2700 psi. This is much greater than the 212 psi with Belleville springs, and well above the point where permanent deformation will occur. The system can be expected to loosen at room temperature after exposure to 150°C for less than one day. The expected loosening is based upon experimental observations of creep deformation. The effect of using stainless steel hardware would be even greater, since it has a CTE about 90% of brass and a modulus over twice that of brass.

A high aspect ratio test specimen, 0.5 in X 0.5 in. X 1.0 high, of a molded PTFE/glass composite with fiber type, amount and orientation similar to that of RT/duroid 5880 microwave laminate has been observed to permanently deform about 1% after 24 hours at 2000 psi and 150°C, with most of the deformation occurring in the first hour.

Conclusion

Loosening of hardware attached to RT/duroid microwave circuit boards due to creep can be avoided through consideration of the factors involved and by designing to minimize creep deformation. The use of Belleville spring washers illustrated in the example above is one effective way in which the problem can be eliminated.

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