KEMET® TECH TOPICS

... THE LEADING EDGE

VOL. 3, NO. 7 • PUBLISHED BY KEMET ELECTRONICS CORP. • P. O. BOX 5928 • GREENVILLE, SC 29606 • (864) 963-6300 • SEPTEMBER 1993

As multilayer manufacturers and users have successfully reduced other failure modes, damage to capacitors from stresses induced by bending circuit boards has gained relative prominence.

This month's Tech Topics reports on a flex strength characterization test which KEMET is using to guide its continuous improvement activities in this area. John Prymak of KEMET's Technology Department developed the test for KEMET.

Dr. John Piper
Vice President — Technology

Flex or Bend Testing

by John Prymak

Flex Crack Failures

The glass epoxy printed circuit boards (PCB's) used with most surface mount devices will bend under a moderate force. Board loading, solder heat, depanellization, and end-user handling contribute to stress on a rigidly mounted device. In other words, the board bends but the capacitor, which is less flexible than the board, resists the deflection. As a result, secondary forces are concentrated at the bottom of the chip where the termination band ends.

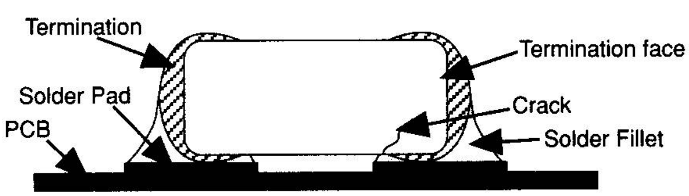

Figure 1

When the board bends, force is conveyed through the solder fillets and termination to the ceramic chip. Ceramic, which is hard and brittle, has the tendency to crack rather than bend. Whether or not the chip will crack depends on the physical strength of the ceramic, the termination material and amount, and the size of the solder fillet.

The typical example of this crack begins near the end of the termination margin on the bottom face (nearest the PCB) and extends into the chip towards the termination face. Once de-scribed as the "45 degree crack," this fissure can extend through the dielectric to opposing electrodes, creating a potential path for failure. Though electrical failure can occur at anytime, even under the most benign environmental conditions, such a crack may go undetected for years.

Flex Test

The flex test is designed to measure the capacitors reaction to a range of forces both similar to and more severe than those encountered during its post-monitoring life. The chip is mounted so that the longitudinal axis of a 120mm x 40mm x 1.6mm board (EIA-J RS 3402) equally divides both pads. An infrared reflow soldering process is controlled to ensure consistent attachment. The board is then mounted to a fixture designed to hold it across its width at 90mm separation. A ram bar (radius ~ 5mm) is set at the center of the board directly under the device and is pressed into the board to cause a deflection of the board and chip to a specified distance. The 5mm is much smaller than the recommended EIA-J specification for the radius of the ram. This smaller radius causes the board to take on a parabolic shape at high deflections. The capacitor, then, is subjected to forces equivalent to higher deflections (smaller radius of arc beneath the chip) than it would encounter under testing using a larger radius ram. The ram is driven into the board at a constant speed (0.37mm/sec.) to attain a given deflection. Electrical traces extending from the mounting pads of the capacitor to the edge of the board allowed electrical testing of the component before and after deflection.

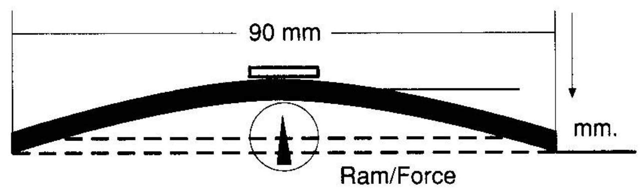

Figure 2

Though the JIS C 6429 document requires that the part be subjected to a deflection of 1mm for 5 seconds, several variations on the test process and acceptance criteria were considered. In addition to the standard measure of capacitance before the application of force (with preconditioning for class 2 ceramics) and at the point of maximum deflection, readings were also taken after flexing the device for multiple cycles to set displacements and dwells. In each case, allowable change is dependent upon the type of dielectric. After the electronic testing, a visual inspection of the solder joints was made.

Set displacement, or 'go/no go" testing is a form of attributes testing. Lots are evaluated with respect to a pre-established standard. As a result, two lots with potentially different reactions to the flex test may simply be categorized as both having zero failures or all failures. A variable approach to the flex test requires that the pieces be flexed to failure and that the flexures be statistically evaluated to determine a meaningful rating.

Capacitance Monitoring

The unit under test is read about six times per second. The test is terminated when a crack is detected. Crack detection is based on reading a significant loss in capacitance. During early tests, a drop of 20% from the initial capacitance, where the change could not be considered piezoelectric, defined significance. Later, a change of 10% between consecutive readings, regardless of piezoelectric effect, became the working value. At last, a capacitance change of ±2% in consecutive readings, regardless of body type, has become the accepted figure for significant loss.

A good example of the capacitor change with deflection provided by variable testing is displayed in Figure 3. This figure shows a unit where the capacitance suddenly drops at 2.87mm. (Note the point of inflection where the capacitance suddenly rises before the drop. This +2.2% change due to piezoelectric noise is enough to stop the test.) This particular test continued to flex to 6mm. On the return to 0mm, the capacitance returned to within 2% of initial readings while the DF was within 0.1% of the original 2.32%. The constant monitoring has indicated a capacitance drop that characterizes a "detected crack," but pre- and post-test capacitance checks may not have shown a significant capacitance change.

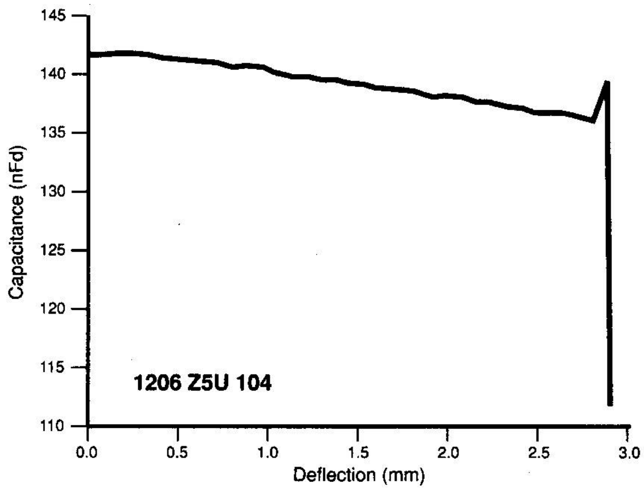

Figure 3

Parts were subsequently tested on load humidity so that "hidden" cracks would conduct and reveal themselves as low insulation resistance (IR) units. Of the units defined as "cracked" by a sudden capacitance change in a test to 3 and 4mm fixed flexures, load humidity exposure revealed only about 80% as actual IR rejects. However, DPA analysis of the "cracked" units not detected as having an IR problem revealed prevalent internal cracking.

The capacitance change test does have a drawback. Cracks beginning in the corner of the device may not completely sever the electrical connection. In components with fewer electrodes, there is less likelihood that a crack will extend high enough to sever an electrode. Still, if the device does not fail during capacitance testing, there is a good chance it will not fail during regular usage.

Data Analysis

The important figures calculated from the data are mean, correlation coefficient[2] (R^2), slope, and 100-PPM failure rate flexure. "Acceptable" R^2 is defined at >95%. Figure 4 represents the relationships between the raw data and projected linear relations. The plot compares the flexure in mm to the cumulative percentage of failures expressed as standard deviations. This particular lot exhibits a dual pattern of data distribution, and linear regressions were calculated for the bimodal distributions. The steeper relationship, established with the lower data points, is used to quantify the lot.

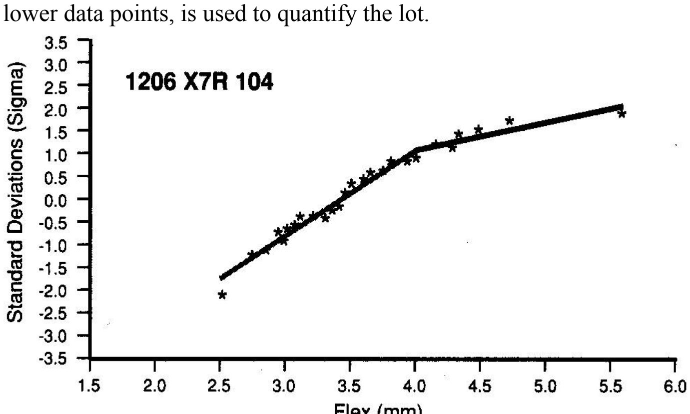

Figure 4

Figure 4 is difficult to interpret because there is no easy way to visualize the relationship between standard deviation and the percentage of failures. Though the relationship is no longer linear, Figure 5 depicts the data in a manner which is easier to under-stand. This graph shows the failure rates of the best and the worst of eight sample groups from five different competitors (three manufacturers had two lots represented) and the best and worst from 10 different production batches from KEMET.

When two lots were taken from each of three different manufacturers, the results showed wide disparities which were subsequently attributed to multiple production facilities. These early disparities inspired a second look at variation between KEMET's lots as well as at the repeatability of the test.

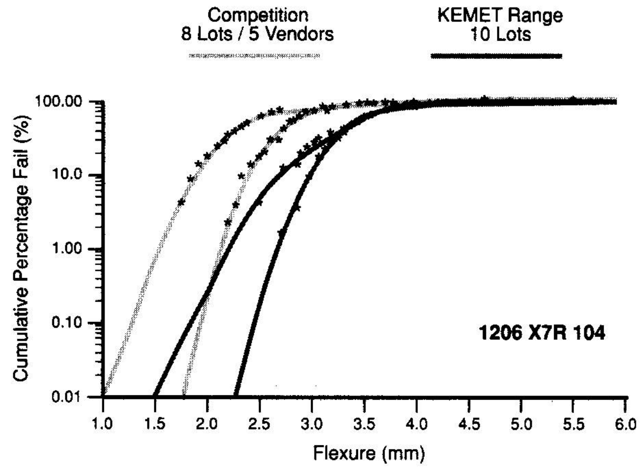

Figure 5

The graph highlights the differences in the extrapolated low percentage failure rates that are important to end users. Although this test of 50 pieces defines a resolution of 2%, it does not belittle the significance of the 100 PPM levels, as this linear portion of the relationship is well established.

Sample preparation throughout the mounting and test process proved extremely consistent. One lot was split into 6 fifty-piece sample groups which were mounted and tested at different times. Without exception, responses were identical.

Testing has also proven that pieces with electrode planes parallel to the PCB plane exhibit a greater susceptibility to failure detection. Data collected from several lots of 0805's in which the thickness nearly coincided with the width revealed definite bimodal distributions. DPA on all the pieces revealed that those demonstrating unusually high flexure without significant loss in capacitance had electrode planes perpendicular to the PCB.

Bimodal distributions in several lots (most notably 1206's) could not be explained with electrode orientation. The variations are representative of variations in process, materials, or structural anomalies.

Conclusion

Flex testing is easily duplicated using a capacitance system coupled with a computer to capture values for capacitance, time, and deflection. Conversions and fittings are easily manipulated through spreadsheet software.

The resulting characterization becomes a depiction of the flecture withstanding performance of a group of parts and an empirical tool for extrapolating behavior at low stress levels. Both are invaluable measures in the continuing product improvement cycle.