

ENGINEERING PRACTICE STUDY

TITLE: PARAMETERS TO BE MEASURED DURING BOARD FLEX TESTING FOR
MULTILAYER CERAMIC CAPACITORS (MLCCs)

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FINAL REPORT

Study Conducted by DLA Land and Maritime

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I. OBJECTIVE: An engineering practices study has been conducted to solicit feedback from ceramic capacitor manufacturers and users regarding the electrical parameters to be measured during board flex testing of MLCCs in accordance with [MIL-STD-202-218](#).

II. BACKGROUND: Board flex testing in accordance with [MIL-STD-202-218](#) is required for MLCCs in [MIL-PRF-123](#), [MIL-PRF-32535](#), and [MIL-PRF-55681](#). The board flex requirement in [MIL-PRF-32535](#) is as follows:

3.13 Board flex. When tested in accordance with 4.6.9, capacitors shall meet the following:

a. **Capacitance:**

(1) During examination: Shall change not more than $\pm 5\%$ or $\pm .5$ pF, whichever is greater, for class I dielectrics or $\pm 10\%$ for class II dielectrics.

(2) After examination: Shall be within the tolerance specified (see 3.1).

b. Dissipation factor: Shall not exceed the initial limit (see table VII).

c. Visual examination: There shall be no mechanical damage to the capacitor body, terminals, and body/terminal junction.

4.6.9 Board flex (see 3.13). Capacitors shall be tested in accordance with [MIL-STD-202-218](#). The following details and exceptions shall apply:

a. Mounting: At the option of the manufacturer, the length and width of the PCB may be increased to allow for electrical test connections and multiple samples to be mounted and subjected to the board flex test. Testing and all other dimensions shall remain as specified.

b. **Measurement during test: Capacitance** in accordance with 4.6.6, except the test frequency may be 1 KHz for capacitance values greater 10 μ F.

c. Examinations and measurements after test: Capacitors shall be visually inspected for mechanical damage to the capacitor body, terminals, and body/terminal junction (see 4.3.6). Capacitance and dissipation factor shall then be measured in accordance with 4.6.6 and 4.6.7.

During the coordination for revision B of [MIL-PRF-32535](#), DLA Land and Maritime received a comment from the Missile Defense Agency (MDA) suggesting an improvement to the required board flex test. *"In addition to monitoring capacitance during the test, MDA recommends monitoring insulation resistance. During board flex testing, cracks in the active region may occur, but do not always manifest in a loss of capacitance. However, cracks in the active region will result in an increase in leakage current and eventual failure. In MDA's experience, one of the best methods to detect this failure mode is to also monitor insulation resistance during the board flex test. NOTE: These cracks are typically not visually detected as they occur in the termination area of the device".*

Because DLA Land and Maritime considers the addition of a second measurement parameter to the board flex test to be a significant change affecting multiple specifications, we decided to hold MDA's comment from [MIL-PRF-32535B](#) in order to gather more information via this study.

III. RESULTS: Recipients of this study were asked to provide concurrence, objection, or comments regarding the proposal to add insulation resistance as a second measurement parameter during board flex testing for MLCCs in [MIL-PRF-123](#), [MIL-PRF-32535](#), and [MIL-PRF-55681](#). The following comments were received:

1. OEM Comment:

I'm not sure if manufacturers can actually monitor IR and Capacitance at the same time during testing. They can chime in on that. I looked at the [AEC-Q200-005](#) board flex test method and it specifies the measurement requirement below. The example is a megohmmeter which would be similar to monitoring IR. I'm not sure that the resistance will always decrease though. If the termination cracks or even a major ceramic crack, the bending force will pull the two halves apart potentially decreasing the resistance. I'm fine in general adding IR as a monitored electrical during test, but we would likely need a plus and minus percentage of allowed change. The manufacturers may need to do some testing to establish that limit.

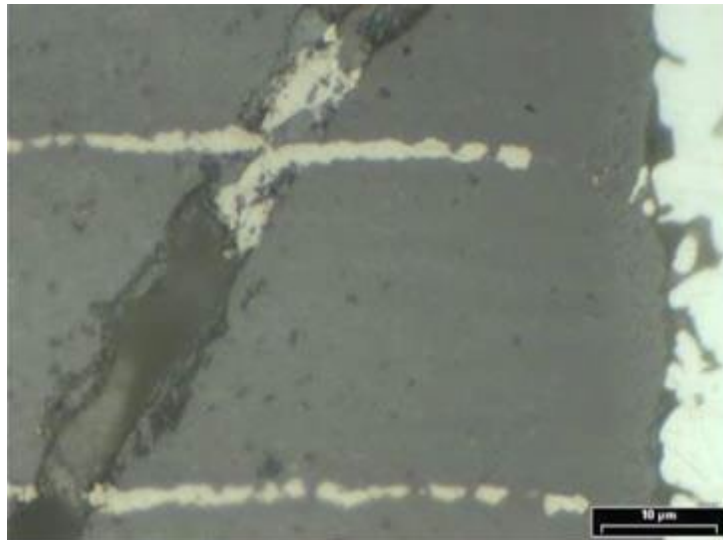
[AEC-Q200-005](#) para 3.3: Prior to beam load testing, complete the external Visual test in Q200. A test monitor shall be used to detect when a part cracks or a termination failure occurs. (example: Megohmmeter attached with leads during the time the force is being applied to a ceramic capacitor. A crack would cause a deflection of the needle towards zero.)

2. OEM Comment:

I recommend adding Insulation Resistance (at +125°C) as an additional parameter to be measured **after** board flex testing. IR must be measured at +125°C and not +25°C. NOTE: The current requirement for measurements after test includes capacitance and dissipation factor.

3. Qualified Manufacturer Comment:

We believe that a crack will reduce the measured capacitance of the MLCC because of the disconnection of inner electrode(s) from the external terminations. If the crack forms, it will occur during the flex, even though the connection may re-made when the flex is removed. See image below of crack after the flex is removed. Of course, this means that after the flex is removed, the capacitance of the device will possibly recover, so the measurement of capacitance during the board flexing should be the variable analyzed.



We believe that a crack induced by the flex may not necessarily evidence itself in a reduced insulation resistance (IR) during the board flex test. Just because there is a crack does not assure a less resistive path between two opposing electrodes. However, over time electromigration may occur to cause a lower IR. Since there is time and applied voltage required for this to occur, we believe any IR degradation will not be evidenced during the board flex testing.

Also, including measurement of IR during flex could result in a decrease in observed capacitance due to VCC (voltage coefficient of capacitance). This could be interpreted as a capacitance loss due to flexure, though in actuality no crack occurred.

At the present, equipment to perform this IR measurement during flex does not exist. we estimate that such equipment could cost six figures.

We believe that the current procedure of measuring capacitance loss during board flex is an effective test for cracking and adding the measurement of IR will not provide additional information regarding the quality of the product.

We are not in agreement to add an Insulation Resistance test to MIL-PRF-123 and MIL-PRF-55681 MLCC specifications.

4. Qualified Manufacturer Comment:

a. If the IR measurement is needed and it is to be "monitored", then the only practical way to run the test would be in series with the cap "monitoring". Trying to measure IR at rated voltage for parts rated above 40 volts, while also monitoring cap would be prohibitively expensive.

b. Designing the test to be run in series would still cost somewhere between \$20,000.00 and \$100,000.00 depending on how the IR is to be monitored.

c. Board flex is not a lot specific test. It is a periodic test that is only run for qual or retention of qual. Therefore, we question whether the additional testing would add much value.

d. The test is designed to show that our parts are capable of withstanding board flex on one type and thickness of board. Therefore, the customer still needs to qualify their attachment process.

e. Monitoring IR is only helpful if a crack extends between two electrodes of the opposite polarity. Given the "fail open" design of our parts >99% of any potential cracks would initially radius back into the termination through the non overlapping area of the electrodes. This type of failure is best seen by monitoring cap.

f. We don't see failures running this test and more importantly we don't have customers complaining about parts failing due to board flex cracks.

Conclusion: Our recommendation is not to add IR monitoring to the board flex test. If DLA does add the requirement, then the tests should be in series and not run in parallel. And, if at all possible, the monitoring should be analog not digital i.e. an operator should monitor the IR.

5. Qualified Manufacturer Comment:

a. We question the value in trying to add IR measurements to the Board Flex test protocol. Our experience is that the failure mode during Board Flex testing is a crack in the margin region. Therefore, capacitance is the most valuable parameter to measure to catch those defects since IR may not show an issue. We would like to see what actual data exists showing the benefits of adding IR to this protocol before consideration is made on making major investments to add IR monitoring to current equipment.

b. Current equipment is not capable of continuous monitoring of IR. Therefore, significant expenditures would be necessary to add this capability. In addition, because of the complexities of reading IR, it is our opinion that it would not be possible to continuously monitor both IR and Capacitance during the test.

c. IR measurement requires charge times (normally 2 minutes or longer). Therefore, it may not be feasible to try and do this during Board flex testing which only lasts for 60 seconds. In addition, the IR readings are not stable and will continue to increase during the charging period.

d. The addition of IR testing would significantly complicate the testing protocol. Because reading IR requires the application of voltage, this will impact the capacitance readings. Therefore, the entire test protocol will need to be evaluated to take into account the effects of applying rated voltage to the parts in order to measure IR.

IV. CONCLUSIONS: Qualified MLCC manufacturers strongly disagree with the proposal to monitor IR in addition to capacitance during the board flex test. They feel that capacitance is the best parameter to measure to detect cracking. The addition of an IR measurement would be very expensive and may adversely impact the required capacitance measurement.

OEMs appear to be unsure if the addition of IR monitoring during the board flex test would be an improvement to the current requirement.

V. RECOMMENDATIONS: Based on the feedback received as a result of this study, DLA Land and Maritime does not believe that the addition of insulation resistance as a second measurement parameter during board flex testing for MLCCs in [MIL-PRF-123](#), [MIL-PRF-32535](#), and [MIL-PRF-55681](#) is necessary at this time. We believe that this additional requirement would cause a significant cost burden to the manufacturer with little value added.

The results of this study will be discussed during the upcoming CE11 Component Parts Committee meeting.