Cracks in through hole multilayer ceramic capacitors CKR06 MIL-PRF-39014/02 (≤1µF 50V) leading to short-circuit failures

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CNES INFORMATION

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MANUFACTURER / PART

CERAMIC CAPACITORS CKR06 MIL-PRF 39014/02 (≤1µF 50V)	**FAMILY :** CAPACITOR **SUB-FAMILY :** MLCC **PART NUMBER :** CKR06 M39014/02-1415 (EFR R) AND M39014/02-1419 (EFR S) ≤1µF 50V MANUFACTURED ACCORDING TO MIL-PRF-39014/02 **LOT DATE CODE :** ALL

OCCURRENCE AND FAILURE DESCRIPTION

Seven 1µF, 50V through-hole multilayer ceramic capacitors manufactured according to MIL-PRF-39014/02 presented electrical anomalies during acceptance tests at equipment level. Four failures concerned MIL-PRF-39014/02-1415 (EFR R) parts and three concerned 39014/02-1419 (EFR S) parts, from different date codes.
Investigations revealed that all capacitors failed in short-circuit mode:

- the electrical measurement of the capacitors indicated a decrease of the insulation resistance,
- IR showed the presence of hot spots in the active area of the capacitors,
- Microsections showed melted electrodes and cracks in the active area.

These capacitors were glued and soldered in two different configurations (perpendicular and parallel to the PCB) by two different assembly houses. The cracks occurred on both configurations of each assembly house.

The failure is caused by cracks in the active area of the capacitors. These cracks, mainly originating from lead sides and propagating to the active area, create a path through which the inner electrodes' metal (silver) starts to electromigrate. Eventually, opposite electrodes inside the active area of the capacitor end up electrically connected. This has a direct impact on the insulation resistance, drastically diminishing it with time - even after several years – and finally leading to an internal short-circuit.
The electromigration of the silver creates an electrical path among opposite electrodes and leads to an internal short circuit of the capacitor. This is a known and well documented phenomenon.
The root cause has been identified and related to the combination of several factors:

- the internal design and manufacturing process of the capacitor.
- improper assembly processes.
- mishandling during the final integration of the assembly board.
- low voltage application.

The main suspected root cause is the CKR06 component's internal design (a large number of electrodes with very thin dielectric layers) and manufacturing processes (i.e. sintering, pressing, internal soldering, etc.) which makes the capacitor particularly susceptible and sensitive to cracks under thermal, mechanical and voltage stresses.
It is known that for low voltage (<10 V) failure mechanisms, multilayer ceramic capacitors with thin dielectrics and/or large voids, delamination, inclusions, microcracks, and other defects may develop low and unstable insulation resistances. These defects propagate to cracks, due to several stress factors (i.e., thermal, mechanical, or voltage).

OCCURRENCE AND FAILURE DESCRIPTION

These defects have been observed in different areas of the failed capacitors.
It should be noted that an inappropriate assembly process (i.e., excessive thermal stress) whether it is internal to the manufacturer or during the assembly of the capacitors, is considered as an extra stress factor that weakens the capacitors.

RECOMMENDATIONS

Recommendations for new procurement and stock parts:

This specific capacitor CKR06 M39014/02 (1µF 50V), with all available EFR levels (M, P, R and S), **shall not be used** for flight applications. As a preferred option, it is recommended to procure the space grade alternative capacitor MIL-PRF-123/2 CKS06 1µF, 50 V (part number M123A02BXB105KC).

Capacitors CRK06 with lower values (<1µF) shall be procured with additional lot acceptance test depending on the components' class:

- For class 1 and 2 components of ECSS-Q-ST-60C on a minimum of 20 parts if possible or according to AQL:
  - Thermal Shock as per MIL-PRF-123 with 100 cycles per lot,
  - Humidity Steady State Test Low Voltage Test as per ESCC 3009 (1000h 85/85 1.5V) per lot
  - DPA (3 samples)

- For class 3 components of ECSS-Q-ST-60C on a minimum of 20 parts if possible or according to AQL:
  - Humidity Steady State Test Low Voltage Test as per ESCC 3009 (1000h 85/85 1.5V) per lot

Recommendations for already mounted parts:

CKR06 M39014/02 (1µF 50V) parts can be used as is for class 2 and 3 projects. For class 1 project, parts shall be replaced by space grade CKS06 in case of a **critical application at low voltage (<10V)**. If replacement is made impossible (risky boards, lead times etc.), additional risk analysis shall be performed:

- Necessary electrical tests at the equipment level, and capacitor DC conditioning screening yield to assess the risk of a capacitor short circuit according to the application's condition (low or high voltage >10V, temperature, etc.), understand the system impact and propose appropriate mitigation actions
- How are the parts stored? How do you intend to mount them? Are they pre-tinned?
- Any other relevant information shall also be provided.

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