Stressed out over capacitor failure

Shilpa Jadhav - January 30, 2013

While working at a company that makes automotive embedded control systems, my colleagues and I set out to create a new PCB layout for one of our products. The product worked fine, but we needed to simplify the PCB assembly and increase production speed.

We totally changed the PCB layout and performed validation tests on the new PCB. All the results were satisfactory and encouraging, so we sent the PCB into volume production.

A few days after the unit had begun being installed in vehicles, we received a complaint from the production line that none of the functions of one unit were working. We studied the unit in our laboratory and found that one multilayer ceramic (MLC) capacitor in the circuit was burned. We soon started receiving more complaints about the same failure. It was easy to imagine a resistor burning in this fashion, but it was surprising to find such a failure in a capacitor.

We first suspected a problem with the manufacturing quality of the capacitor. We consulted with the capacitor manufacturer, who had been checking only a sample of his products, and he agreed to check each and every capacitor at the time of its manufacture. But even after he took this precaution, the rate of capacitor failures remained the same.

We further analyzed the issue by studying the new layout. The MLC capacitor was being used for ESD protection at one of the digital inputs, which was how it had been used in the original layout. We checked whether the capacitor had the proper voltage rating, and it did. We also observed that several capacitors with the same specifications were used on different inputs of the same board for the same purpose (ESD protection). But only the capacitor at this particular location was getting damaged. Finally, we switched to using the previous PCB and not a single failure occurred.

Further study of the situation revealed that when we redesigned the PCB layout, we had shifted the placement of the capacitor. It was now placed near one of the surface-mount holes of the PCB, and all the failures were found after the PCB was mounted in the housing.

We read several application notes about MLC capacitors and learned that because of their brittle nature, multilayer ceramic capacitors are more susceptible to excesses of mechanical stress than other components used in surface mounting. In our case, when we tighten the mounting screws, the PCB bends slightly. Excessive bending of the board can create mechanical cracks within the ceramic capacitor. Over time, moisture penetrates the crack and can cause a reduction in insulation resistance that is accelerated by humidity and temperature, and this generates a conductive path. As
a result, it gets shorted and because of high current flow through the capacitor, the capacitor gets burned. Although these mechanical cracks may not lead to capacitor failure during the final assembly test, failures may occur once the product is in the field, when they are expensive and time consuming to correct.

For confirmation of our theory, we removed one capacitor from a board that was working satisfactorily but that we suspected had undergone stress during the mounting process. We sent the capacitor for cross-sectional analysis and discovered it had a crack that could lead to damage in the field. Now, we have modified the PCB layout again to shift the placement of that capacitor away from the mounting hole. After this modification, all the critical tests related to the mechanical stress were successfully carried out and no such failure was found in the product.

Hardware designers for automotive embedded control systems pay a great deal of attention to electrical overstress, but they also need to take into account mechanical overstress on small components like resistors and capacitors. Although many international standards provide guidelines for protecting components against overstress, similar standards for mechanical overstress are conspicuous by their absence.

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