Capacitors Piezoelectric Effect

How to address vibrations or low audible hums

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Our experience has shown that it is not a well-known fact that some multilayer ceramic capacitors can exhibit piezoelectric characteristics. This effect occurs in ferroelectric capacitors (class II and III) which possess medium to high dielectric constants such as X5R, X7R, X8R, Y5V, Y5U, and Z5U. The piezoelectric effect can cause the capacitor to vibrate and, if this occurs within audible frequencies (20 Hz to 20 kHz), may cause the capacitor to "sing" and be audible.

Having a capacitor susceptible to piezoelectric effect is not enough to cause the ringing noise since the amplitude caused by it is so small. Multiple condition must be met for it to be loud enough to be heard. Apart from the signal frequency and the capacitor design and construction, the effect is influenced mainly by the DC bias and the ripple amplitude of the signal applied on the capacitor. The PCB itself and the layout also play an important role, in addition to having the possibility that temperature may play a role as well.

This piezoelectric effect can also be reversed. An external mechanical pressure may cause the capacitor to produce a signal in microvolts, therefore, under certain conditions, making the capacitor potentially act as a microphone and capture acoustical noises in its surroundings and insert these in the system.

Application

Depending on the application, this effect may or not be an issue. The piezoelectric effect has no effect on the reliability of the components. However, in certain devices such as amplifier circuits and handheld devices, the noise caused or inserted in the system may become an issue.

We have encountered such an issue in a microphone amplifier circuit. The microphone was powered by a phantom DC and the audio signal was coupled to the amplifier using a 1uF ceramic surface mount capacitor. This was an echo canceller card installed in a PC. The circuit was working perfectly, except that a hard disk noise could be heard even with the microphone isolated. The initial plan involved an inspection of the coupling through the power supply rails, but upon doing this, the board was accidentally bumped and produced a 'tick' noise, which alerted us to a mechanical coupling problem. After replacing the 1uF ceramic surface mount capacitor, the issue disappeared.

Solutions

One manner to reduce the piezoelectric effect is to use through hole capacitors or ones with metal terminations which greatly reduce the vibration by decoupling the movement from the PCB. Capacitors which tend to not produce this effect include tantalum, aluminium electrolytic, C0G and NP0 capacitors.

Another way would be to improve the signal; as the ripple amplitude is directly proportional with the piezoelectric effect, reducing it will diminish the noise. Having a duty cycle closer to 10% or 90%, instead of 50%, will also improve this. A signal frequency outside the audible range would also prevent a user from hearing any ringing.

Finally, the use of a thicker PCB, which resist deformation better than thinner boards, will contribute to the reduction of the effect. Positioning the capacitor on the edge rather than the center of the board should also provide a lesser surface upon which to cause vibrations, therefore reducing the noise. Lastly, laying out the capacitors symmetrically on the top and bottom layers, one on top of the other, should make the deformation of each pair of capacitors cancel each other out.

Conclusion

When using ceramic capacitors in sensitive circuits, precautions should be taken to mitigate the piezoelectric effect, especially when working with high dielectric constant ceramic capacitors such as X7R and ZU5.

References

1. https://web.archive.org/web/20190402155252/https://product.tdk.com/en/contact/faq/31_singing_capacitors_piezoelectric_effect.pdf

2. https://sh.kemet.com/Lists/TechnicalArticles/Attachments/88/2006%2007%20ArrowAsiaTimes%20-%20MLC%20Noise.pdf

3. https://www.edn.com/reducing-mlccs-piezoelectric-effects-and-audible-noise/

4. https://e2e.ti.com/blogs_/b/powerhouse/posts/how-to-reduce-acoustic-noise-of-mlccs-in-power-applications

5. R. Nelson and L. Davidson, Electrical noise generated from the microphonic effect in capacitors, 2002 IEEE International Symposium on Electromagnetic Compatibility, Minneapolis, MN, USA, 2002, pp. 855-860 vol.2, doi: 10.1109/ISEMC.2002.1032708.