KEMET Electronics Corp

PIEZOELECTRIC EFFECTS CERAMIC CHIP CAPACITORS (Singing Capacitors)

Most dielectrics of ceramic capacitors exhibit a characteristic identified as piezoelectric effects than can cause unexpected signals in certain circuits. In some cases, the piezoelectric effect may result in the appearance of electrical noise, while in other cases; an acoustic sound may be heard, emanating from the capacitor itself.

The basic element in most MLCCs is barium-titanate, or some close derivative of this. Piezoelectric properties are common to the barium-titanate structure. If you are old enough to recall before CDs, acoustic recordings were mostly sold on vinyl records and the signals were picked up using a needle that was contained in a spiraling groove cut in the record's surface. Within these grooves, the needle would ride on roughened surfaces that created mechanical vibrations of the needle. The needle was connected to a crystal structure (in less expensive turntables), and this crystal would generate an electrical signal that correlated with the vibration's frequency and magnitude, which was then amplified to generate the speaker signals. What was the crystal structure of these ceramic cartridges? They were based on barium-titanate!

Piezoelectric effects can result in noise for ferroelectric ceramic chips, such as those of the middle to high dielectric constants like X5R, X7R, X8R, Y5V, Y5U, Z5U, etc. Piezoelectricity occurs in all ferroelectric dielectrics, regardless of manufacturer, and the means to reduce these effects usually requires the dielectric constant be lowered (the capacitance capability is also lowered with the lower dielectric constant) while moving to higher dielectrics (Y5V, Z5V are usually cheaper) creates a higher susceptibility to this effect. Note that there are no measurable piezoelectric effects in Class 1 capacitors, such as C0G or NP0 - neither of which is considered ferroelectric.

Historically, the piezoelectric noise has been only an occasional issue, since it was at such a low level. It can occur as a mechanically induced electrical noise or it can occur as an electrically induced mechanical noise (this is what a speaker or buzzer does). If a capacitor is surface-mounted on a PCB, there is a direct mechanical connection between the board and the capacitor. Vibrations created on the board can create electrical signals within the capacitor. Electrical signals in the capacitor can create mechanical vibrations of the board. Multiple chips located in a specific area can flex the board, creating a larger speaker area.

These created signals can be problematic enough, but the translation from electrical to mechanical, then mechanical back to electrical both involve delays and can create a slight echo or distortion effect in the circuit. The peak response of these capacitors is within and slightly above the audio frequency range. Many attempts to use these SMT devices in final stages of audio amplifiers have left many designers scrambling for alternatives, yet they can be used in the front-end stages because the signal levels are lower.

More recently, power integrity circuits involved with microprocessor decoupling have been experiencing this effect in ceramic capacitors. The microprocessor 'sleep' mode involves removing the voltage from the power rails on an intermittent basis, and periodically checking for any request for activity. The typical frequency for this sleep mode is at 1 kHz, and designers are experiencing a 1 kHz tone emanating from the processor region of the computer when the processor goes into its sleep mode.

This problem is becoming more noticeable because the MLC capacitors are evolving and their applications are expanding. This effect is related to the signal strength, which is related to the electrical stress within the capacitor. As the dielectrics are shrinking to enable higher capacitance with these packages, the critical stress levels are being reached at lower voltage levels.

Solutions to these noise problems may involve alternative types of capacitors (e.g., tantalum, aluminum, ta-polymer, al-polymer, film, as this effect is unique to ceramic), leaded or standoff capacitors (using leadframes to eliminate the mechanical tie to the PCB eliminates a unified or cumulative response of multiple ceramic capacitors), using higher voltage ratings (lowers the stress), and others. It should be pointed out that this effect is lost at frequencies well above 30 kHz because the body cannot respond fast enough to the changing stress levels. The peak response region and the noise attributes dictates that these capacitors should be used very carefully in audio circuits, as well as high-gain circuits; and, be careful that an audio application may not easily appear to be an audio circuit (sleep mode conditions of microprocessors).

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