The voltage characteristics of electrostatic capacitance

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Greetings, everyone.
This technical column describes the basic facts about capacitors.
This lesson describes the voltage characteristics of electrostatic capacitance.

Voltage characteristics

The phenomenon where the effective capacitance value of a capacitor changes according to the direct current (DC) or alternating current (AC) voltage is called the voltage characteristics. Capacitors are said to have good voltage characteristics when this variance width is small, or poor temperature characteristics when the variance width is large. When using capacitors in electronic equipment used for applications such as ripple rejection in power lines, the design must take into account the operating voltage conditions.

1. DC bias characteristic

DC bias characteristic refers to the phenomenon where the effective electrostatic capacitance changes (decreases) when DC voltage is applied to a capacitor. This phenomenon is peculiar to high dielectric constant-type monolithic ceramic capacitors that use barium titanate-based ferroelectrics, and does not occur much at all in conductive polymer aluminum electrolytic capacitors (Polymer Al), conductive polymer tantalum electrolytic capacitors (Polymer Ta), film capacitors (Film), and temperature-compensating-type monolithic ceramic capacitors that use titanium oxide or calcium zirconate-based paraelectrics (MLCC<C0G>) (see Figure 1).
I will use an example to explain what actually occurs. Imagine the case where DC voltage of 1.8 V is applied to a high dielectric constant-type monolithic ceramic capacitor with a rated voltage of 6.3 V and an electrostatic capacitance of 100 uF. In this case, the electrostatic capacitance of a product with X5R temperature characteristics decreases by approximately 10%, so the effective capacitance value becomes 90 uF. In addition, the electrostatic capacitance of a Y5V characteristics product decreases by approximately 40%, so the effective capacitance value becomes 60 uF.

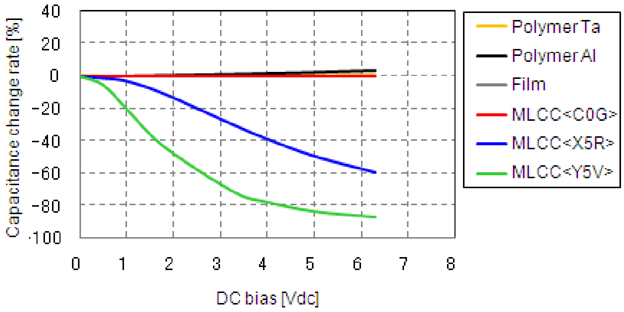

Figure 1. Capacitance change rate vs. DC bias characteristics of various capacitor types (Example)

When DC voltage is applied to a barium titanate-based ferroelectric, the electric flux density (D) and the electric field (E) are proportional when the electric field is small. However, as the electric field increases, the spontaneous polarization (Ps) that was oriented in various directions begins to rearrange in the direction of the electric field, the material exhibits an extremely large dielectric constant, and the effective capacitance value increases. When the electric field increases further to the point where spontaneous polarization rearrangement ends and the polarization becomes saturated, the dielectric constant becomes smaller and the effective capacitance value decreases (see Figure 2).
For this reason, when selecting monolithic ceramic capacitors, the electrostatic capacitance noted in the catalog should not be accepted without question. Instead, it is necessary to measure the electrostatic capacitance while applying the DC voltage component of the power supply (signal) line where the capacitor is to be used, and understand the effective capacitance value. However, this DC bias characteristic is such that the amount of decrease in the electrostatic capacitance becomes smaller as the applied DC voltage component decreases. Recently,

semiconductor chips such as FPGA and ASIC that operate with a supply voltage (DC voltage) of less than 1 V have been appearing, and issues related to DC bias characteristics are not so noticeable for monolithic ceramic capacitors used in the power supply lines of these semiconductor chips.

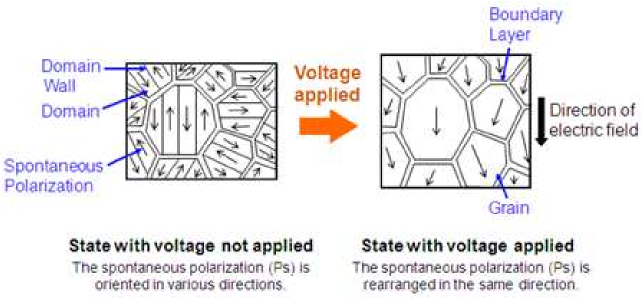

Figure 2. State when voltage is applied to a ferroelectric ceramic
(Click the image to see the enlarged image.)

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