Whereas the application of AC voltage (within a small signal range) tends to increase lower the capacitance, the application of DC voltage, AC voltage, the effect over time is called aging and tends to applied DC voltage, AC voltage. Class I dielectric materials also change their capacitance value over time and with.
The table below lists codes used for Class II materials, more commonly seen.

Standard EIA-198-D specifies a 2-digit code to name classes and class materials. Typically, less than 3000ppm (0.3%) so it will be ignored in this discussion. EIA Type stands for +/- 30ppm. This type is also called NPO (negative positive zero, zero, zero). Type is 00G (C stands for 0), 0 when confused as letter O is multiplier of 0 and G Type is 00G. Certain manufacturers name particular materials.

The variation in the Class II materials is specified in ppm (parts per million). It is measured zero change for either positive or negative change in temperature. EIA type is also called NPO (negative positive zero, zero, zero).

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At 28% of rated voltage, the capacitance is down almost 25%.

Figure 2. DC-bias effects for the X7R and X5R. Output a dramatically different.
A multilayer ceramic capacitor loses capacitance as the dc bias voltage increases, while a multilayer polymer capacitor maintains a constant value.

Fig. 7. A multilayer ceramic capacitor loses capacitance as the dc bias voltage increases, while a multilayer polymer capacitor maintains a constant value.
Typical Cap. Change vs. D.C. Volts

X7R
Figure 6. The choice of dielectric material influences the loss of capacitance over time in ceramic.
### Table: Aging rates of various dielectric types.

*MIL-HDBK-1547A is considered overly pessimistic.*

<table>
<thead>
<tr>
<th>Dielectric/capacitor type</th>
<th>Typical aging rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1.5 to 2.5</td>
</tr>
<tr>
<td>Ceramic NPO</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Ceramic X7R</td>
<td>4 to 5</td>
</tr>
<tr>
<td>Ceramic BX</td>
<td>6 to 7</td>
</tr>
<tr>
<td>Ceramic Z5U</td>
<td>1.25 to 2.1</td>
</tr>
<tr>
<td>Ceramic Y5V</td>
<td>1.25 to 2.1</td>
</tr>
<tr>
<td>Ceramic (BP) capacitors</td>
<td>±10</td>
</tr>
<tr>
<td>Tantalum (CSR) capacitors</td>
<td></td>
</tr>
</tbody>
</table>

*Note: ±21° (-2.5 to -4 per decade hour)*
<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
<th>Temperature Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>First Character</td>
<td>55°C</td>
</tr>
<tr>
<td>Y</td>
<td>Second Character</td>
<td>-30°C</td>
</tr>
<tr>
<td>Z</td>
<td>Third Character</td>
<td>10°C</td>
</tr>
<tr>
<td>S</td>
<td>Change in percentage</td>
<td>+22.82%</td>
</tr>
<tr>
<td>T</td>
<td>Change in percentage</td>
<td>+22.56%</td>
</tr>
<tr>
<td>U</td>
<td>Change in percentage</td>
<td>+12.10%</td>
</tr>
<tr>
<td>F</td>
<td>Change in percentage</td>
<td>+7.5%</td>
</tr>
<tr>
<td>E</td>
<td>Change in percentage</td>
<td>±4.7%</td>
</tr>
</tbody>
</table>
Low ESR Chip Capacitors

The S-Series line of low ESR, high Q, high frequency multilayer ceramic capacitors is made with a proprietary combination of low loss dielectric and a highly conductive electrode system. This process lowers their equivalent series resistance. They are offered in 0201, 0402, 0603, and 0805 sizes, and in capacitance values from 0.2 pF to 220 pF.

Johanson Technology Inc.,
Camarillo, Calif.
Circle 315

Tantalum Chip Capacitor

The organic polymer KOCAP (T520B) offers high capacitance in a smaller footprint. Used as a drop-in replacement for a 1210 high-capacitance ceramic, it can save board space as a replacement for C- and D-sized tantalum chips. With reduced ESR (70mΩ), there is enhanced capacitance retention in higher frequencies as compared to a standard MnO₂. It is offered in the “B” case size in 47μF rated at 6.3V, 68μF at 4V, and 100μF at 3V.

KEMET Electronics,
Greenville, S.C.
Circle 317
Fig. 3. A growing trend with passive components is the migration to small case sizes. AVX’s TACmicrochip series of tantum chip capacitors deliver up to 10 µF in an 0402 case.
Integrating passives can drastically reduce the size of an ordinary circuit board (top). Here, four capacitors and six resistors have been removed from the surface and put into an extra layer of circuit board (bottom). Resistors are copper connection points bridged by a resistive film, and capacitors are conductive plates separated by a thin film of dielectric material.

Size Matters

After the board is laminated, holes are drilled and plated to form vias that connect the integrated components to other boards. Some commercial processes would require separate capacitor and resistor layers.
Fig. 5. Cross-section of the PlugNDrive™ insulated metal substrate technology (IMST).
A Very Flat Filter

Inductors are angled away from each other to avoid crosstalk in this low-pass filter that fits between the layers of a circuit board. Designed by one of the authors, and built by Integral Wave Technologies (Fayetteville, Ark.) for NASA's Langley Research Center, the thickest part of this filter is less than 6 μm. Capacitors are made from a thin-film oxide, inductors from copper.

Inductors:
- 612 nH
- 0.824 nF
- 0.722 nF
- 0.309 nF

Capacitors:
- 6.38 nF
- 0.309 nF
- 0.309 nF
- 0.715 nF
- 0.722 nF

Output

Ground

Input