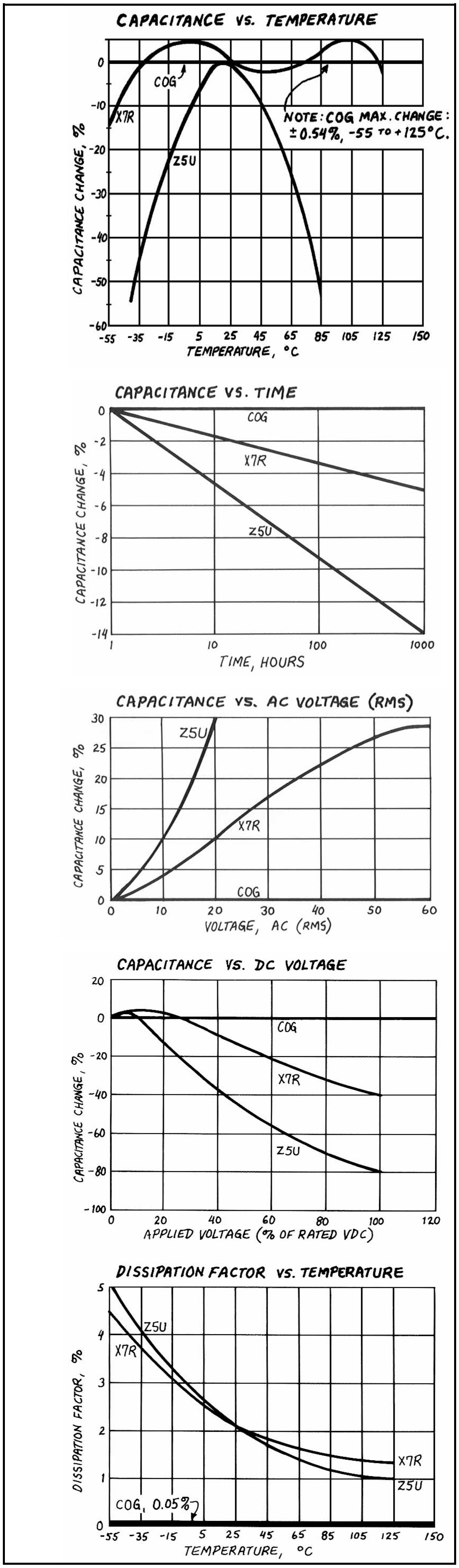

Ceramic Capacitors

Ceramic capacitors have a bad reputation in audio circles. It is only partially deserved. Many engineers are unaware that there are several distinctly different grades of ceramic capacitors, each having a unique formulation of ceramic dielectric, and a unique set of properties. The three most common E.I.A. [1] types are:

1. Ultra-stable: COG dielectric (also called NPO [2]).
2. Stable: X7R dielectric.
3. General purpose: Z5U dielectric.

The COG dielectric is a vastly superior performer. It is also more expensive, particularly in values above a few hundred pF, and is usually dismissed as cost-prohibitive. A common mistake is to shop by price alone and buy the cheaper dielectrics, not realizing the serious performance compromises. The engineer then condemns all ceramics based on the limited experience with only the inferior types. Too Bad! Examination of the performance graphs of figure 1 reveals significant differences between the dielectrics. In each case – capacitance vs. temperature, capacitance vs. time (aging), capacitance vs. applied AC voltage, capacitance vs. DC stress, and dissipation vs. temperature – the X7R and Z5U dielectrics show significant compromises when compared to the COG formulation.

The X7R and Z5U formulations trade off electrical performance for increased volumetric efficiency. To achieve this a ferroelectric material is used. Ferroelectric behavior is complex. An excellent text by Centre Engineering [3] provides a comprehensive discussion of this and other ceramic properties. Essentially, ferroelectricity causes capacitance to change as the applied voltage to the capacitor is changed. In audio applications the AC voltage passing through a ferroelectric dielectric would modulate the capacitance. In resistor/capacitor networks in equalizers and crossovers this modulation causes distortion which increases as the signal frequency approaches the cut-off frequency of the R/C network.

Tests were conducted with the COG, X7R and Y5V ceramic dielectrics (Y5V is similar to the Z5U formulation) to measure total harmonic distortion vs. frequency when used as high-pass and low-pass filters. Figure 2 shows the specific HP and LP filter circuits and the test results. The X7R and Y5V formulations show significant amounts of distortion, but the COG formulation, being non-ferroelectric, shows distortion figures at or very near the residual of the measuring equipment.

An article by Jung and Marsh [4] presented the same test, but with the X7R dielectric only, providing a negative view of ceramic capacitors. The balance of the article is very enlightening, as it enters into relatively unexplored areas of capacitors in audio applications. A more recent paper by Jung [5] makes the distinction between the various ceramic dielectrics and expresses a favorable view of the COG/NPO dielectric.

The COG ceramics were chosen for use in the signal path of the 990 op-amp as manufactured by the John Hardy Company for several reasons. First, their performance is exceptional, as noted. Second, though the higher values are usually considered cost-prohibitive, the low values used in the 990 (62pF, 91pF and 150pF) are cost-competitive with other dielectric types. Third, they are the smallest capacitors available, extremely important when 47 components must be packaged on a 1" square p.c. board.

Hopefully this information will provide a better understanding of ceramic capacitors. Each formulation has its proper place, and for audio applications, the COG dielectric is superior.

References:

1. E.I.A. = Electronic Industries Association.
2. NP0 = Negative-Positive-Zero, indicating a temperature coefficient of capacitance that is neither plus nor minus, but is very close to zero. Tempco = ±30ppm, -55 to +125°C.
3. "TECHNICAL INFORMATION, Ceramic Capacitors." Capacitor catalog, Centre Engineering, 2820 E. College Ave., State College, PA 16801
4. Jung, W., Marsh, R., "Picking Capacitors - Part 1" Audio, 2/80; "Picking Capacitors - Part 2" Audio, 3/80
5. Jung, Walter G., "Topology Considerations for RIAA Phono Preamplifiers". A.E.S. preprint #1719(D1).

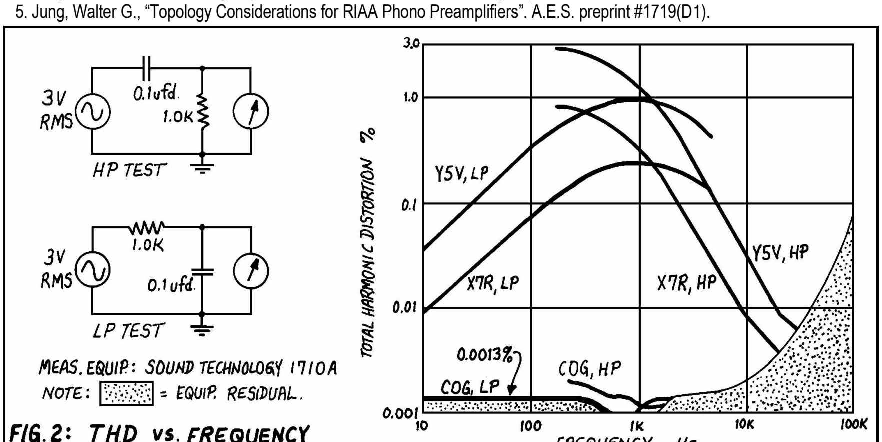

FIG. 2: T.H.D. VS. FREQUENCY