Today's portable devices drive a need for smaller, thinner, and more power-efficient electronic components. Cellular-phone form factors have become so thin that the traditional dynamic speaker has become the limiting factor in how thin manufacturers can make their handsets. Ceramic, or piezoelectric, speakers are quickly becoming a viable alternative to dynamic speakers. These ceramic speakers (drivers) can deliver competitive sound pressure levels (SPL) in a thin and compact package, potentially replacing traditional voice-coil dynamic speakers. Some of the differences between dynamic and ceramic speakers are summed up in Table 1.

Table 1: Advantages and Disadvantages of Ceramic and Dynamic Speakers

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Efficient</td>
<td>Large Drive Voltage</td>
<td>Inexpensive</td>
<td>Wide Manufacturing Tolerance</td>
</tr>
<tr>
<td>Thinner</td>
<td>Noised</td>
<td>Power Technology</td>
<td>Efficient</td>
</tr>
<tr>
<td>Tight Manufacturing Tolerances</td>
<td>Restricted Low Frequency Response</td>
<td>Acoustic Frequency Response</td>
<td>Thicker Solution Size</td>
</tr>
<tr>
<td>Smaller Acoustic Cavity</td>
<td>Capacitive Load</td>
<td></td>
<td>Larger Acoustic Cavity Necessary</td>
</tr>
</tbody>
</table>

Amplifier circuits which drive ceramic speakers have different output-drive requirements than those which drive traditional dynamic speakers. The construction of the ceramic speaker requires that the amplifier be able to drive a large capacitive load and supply increasingly larger currents at higher frequencies, while maintaining a high output voltage.

Attributes of the ceramic speaker
Ceramic speaker manufacturers use similar technology to that of building multi-layer ceramic capacitors. This manufacturing technique gives speaker manufacturers tighter control over the speaker tolerances, compared to dynamic speakers. Tight construction tolerances become important when attempting to equalize the speaker, and in getting repeatable sonic characteristics from unit to unit.

The ceramic speaker impedance, as seen by a driving amplifier, can be modeled as an RLC circuit with a large capacitance as its main element, Figure 1.
Across most audio frequencies, the ceramic speaker is mostly capacitive. This capacitive nature of the speaker dictates that impedance goes down as the frequency increases. The graph in Figure 2 shows the similarity of ceramic speaker's impedance versus frequency to that of a 1 μF capacitor.

The impedance also has a point of resonance. Above this resonance is where the speaker is most efficient at producing sound. The dip in impedance around 1 kHz indicates the speaker's resonant frequency.

**Sound pressure vs frequency and amplitude**

An alternating voltage placed across the terminals of the ceramic speaker causes the piezoelectric film inside the speaker to deform and vibrate, with the amount of displacement proportional to the
input signal. The vibrating piezoelectric film moves the surrounding air, thus producing sound. Increasing the voltage across the speaker increases the piezo element deflection, creating more sound pressure and thus increased audio volume.

Ceramic-speaker manufacturers typically rate their speakers with a maximum terminal voltage, typically around $15 \text{V}_{\text{p-p}}$. This maximum voltage is the point at which the ceramic element will reach its maximum extensions. Applying a voltage greater than the rated voltage will not result in more sound pressure, but will increase the amount of distortion present in the output signal, Figure 3.

![Figure 3: Ceramic speaker SPL vs frequency](Click on image to enlarge)

By comparing the sound pressure level (SPL) versus frequency and the impedance versus frequency graphs, we see that the piezo speaker is most efficient at producing high SPLs above its self-resonant frequency.

(Part 2 of this article will look at amplifier requirements, efficiency, real power dissipation, and analysis, you can read it at [www.planetanalog.com/features/showArticle.jhtml;?articleID=205900397](http://www.planetanalog.com/features/showArticle.jhtml;?articleID=205900397))

(Editor's note: the x-axis in Figure 2 originally was labeled in "Hz", instead of "kHz"; we regret the error.)

About the author

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