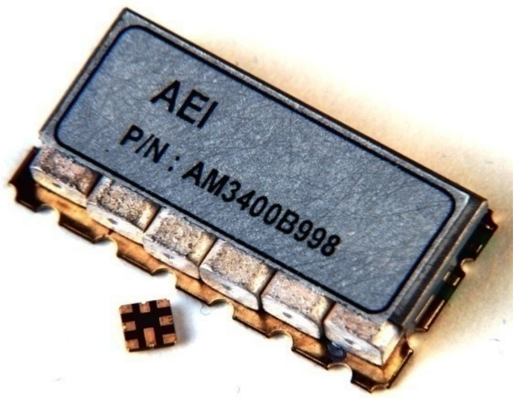
Ceramic Filters

Like all types of RF and microwave filters, ceramic filters have unique characteristics that differentiate them from their counterparts and make them useful for specific applications.

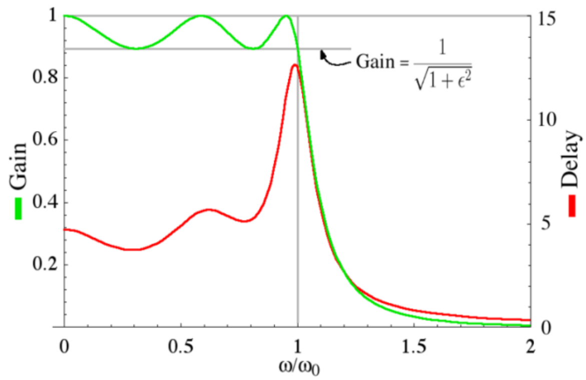
Ceramic filters are less expensive to produce than either LC or cavity-type filters and are smaller than all but Surface Acoustic Wave (SAW) or Bulk Acoustic Wave (BAW) filters (Figure 1).



1. SAW filter compared to ceramic filter

They can be realized in bandpass configurations as well as duplexers, although not broadband lowpass or highpass filters because their ceramic resonators are inherently narrowband.

Their maximum input power is about 5 W and useful frequency range is 400 MHz to 6 GHz, the higher frequency being achieved by using ceramic material of various dielectric constants to optimize the size of the resonators.



2. Chebyshev filter response

Most ceramic filters have Chebyshev responses (Figure 2), although it is possible to produce an elliptic response as well when extremely high sharp transitions between passband and rejection points are required.

As ceramic filters are surface-mountable, they are well-suited for automated assembly techniques and are available on tape-and-reel.

Bandwidths of 20% or more are achievable in ceramic filters, with stopband attenuation of more than 70 dB depending on the number of sections and design approach.

Their overall strengths and weaknesses are listed in Table 1. Key parameters that must be addressed when specifying a ceramic bandpass filter are shown in Table 2.

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Table 1 – Ceramic filter characteristics at a glance

Advantages	Disadvantages
• Small size	• Relatively high low-frequency limit (400 MHz)
• Reasonable insertion loss	• Maximum operating frequency of about 6 GHz
• Low cost	• Can be unstable over temperature when made from high-dielectric-constant ceramics
• Good choice for low-power applications (5-7 W)	• Both monoblock and discrete types requires a good ground connection
• Suitable for either low-volume or high-volume applications	Comebacks at the third harmonic
• Minimal tuning required	Can be used only in low-power applications

Table 2 – Key parameters when specifying ceramic bandpass filters

• Center frequency
• Passband frequency
• Bandwidth (0.5, 1, or 3 dB)
• Insertion loss at center frequency and attenuation
• Low-side rejection frequency and attenuation
• High-side rejection frequency and attenuation
• Return loss (VSWR) at center frequency or passband
• Power handling

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Whether their construction is discrete or monoblock (Figure 3), the fundamental components of ceramic filters are resonators that are one quarter wavelength of the filter's center frequency, along with a capacitive coupling network.

To create a resonator, powdered ceramic is placed in a mold and heated in a very-high-temperature oven until the powder hardens to form the shape of the mold.

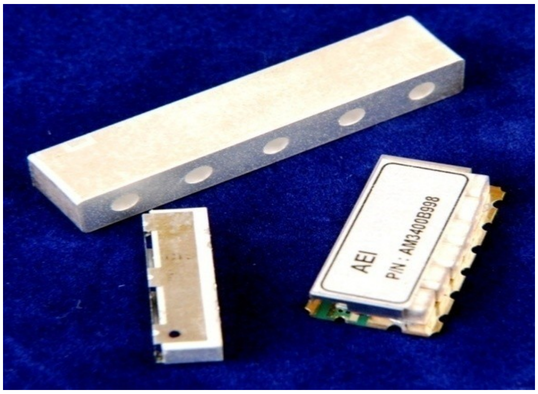
The mold's dimensions reflect the required characteristics of the filter. Discrete resonators are rectangular with a hole in the middle that runs parallel to their length and are coated with silver on the outside, one end, and the hole within the ceramic block, to form a shorted quarter-wave transmission line.

The length of the resonator for a particular frequency is determined by the dielectric constant of the ceramic.

The dielectric constant of the ceramic material affects many other characteristics of the filter, especially performance over temperature, which is important for outdoor and other applications in which wide temperature changes occur.

The ceramic material normally used in these filters has a dielectric constant ranging from 30 to 90 although other dielectric constants are used in special applications.

The higher the ceramic's dielectric constant, the more sensitive it will be to temperature extreme shifts, and the Q factor in generally lowers, depending on the operating frequency.



3. Monoblock and discrete ceramic filters

Ceramics resonators made out of lower dielectric constants result in larger filters, but generally are less sensitive to temperature large temperature variations, and the Q generally is higher, which also depend on the operating frequency.

As an example, when subjected to temperature cycling, a filter with resonators that have a dielectric constant of 30 will exhibit only a slight shift in center frequency, while the center frequency of a filter with a dielectric constant of 90 may dramatically shift -- sometimes outside the operating bandwidth. In summary, a high-dielectric-constant ceramic filter will not tolerate applications in which it will be exposed to wide temperature extremes.

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The required specifications determine the type of ceramic to be used. That is, one application might require very high Q and stability over wide temperature ranges and can tolerate the resulting size, such as military applications in which a shift in frequency might cause performance to be altered, and interference or transmission might not be optimum.

Other applications such as a product used in a controlled environment, such as base stations, cell phones, which are equipped with compensating devices.

Insertion loss specifications will also determine the type of dielectric to be used, since the low dielectric material normally will translate into a better Q factor, and a high dielectric material into a lower Q factor, which will effect the insertion loss.

To achieve the sharpest transitions between the passband and rejection points, a ceramic filter must employ a large number of sections, which is normally limited to seven sections as greater numbers would make the filter difficult to fabricate and tune.

Other techniques such as cross coupling might be necessary in order to achieve that high selectivity. However cost might increase due to the extreme customization.

DISCRETE AND MONOBLOCK

As stated earlier, ceramic filters can be fabricated in discrete and monoblock configurations. As its name suggests, the discrete type uses discrete quarter-wavelength resonators staggered in series, with coupling capacitors in between them, which values is determined by the bandwidth requirement.

The final performance characteristics of a discrete-resonator ceramic filter are obtained by tuning the resonators. The resonators are soldered into a PC board used as a carrier, and give access to the RF input and output of the filter.

A monoblock ceramic filter is formed from a single block of ceramic material and its physical characteristics produce the desired resonance frequency and coupling factor. The mold used to fabricate the monoblock incorporates the coupling capacitors used to define the bandwidth.

Performance of monoblock filters is easier to predict but they sometimes still need “tweaking” of the resonators. Their advantage is that they do not need a PC board carrier and can be soldered directly to the host circuit, which reduces cost.

Choosing a discrete or monoblock ceramic filter is largely a function of the quantities needed, because other than the monoblock’s smaller size (since it is not using a carrier PC board) performance of the two types is very similar.

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Since a mold must be manufactured according to the precise dimensions of the filter (which can cost thousands of dollars), they are not cost-effective when small quantities are needed, unless a mold already exists that can be used.

They are analogous to Application-Specific Integrated Circuits (ASICs) produced in a foundry. Once the design of an ASIC is finalized, its features and specifications cannot be changed after fabrication and it becomes cost-effective to produce only in large quantities over which the high cost of its creation can be amortized. However, once the mold is created, large volumes of subsequent identical parts can be produced at lower cost.

In reference to monoblock ceramic filters, this means they are best suited for large quantities. Designers must remember that a monoblock filter must strictly adhere to the filter manufacturer's recommended board layout in order to maintain its transfer function characteristics.

If it is not well soldered to the host circuit board, an erroneous response curve can result. While this is also true of discrete ceramic filters, it is a much more critical requirement for monoblock types.

As the discrete type of ceramic filter is constructed from individual resonators, it is far more amenable to production in very small volumes, as each one is essentially hand-made and tuned.

A discrete ceramic filter will experience the same deterioration of performance as a monoblock type if soldering is not properly performed and if a poor ground system exists in the host PC board.

The most affected parameter will be rejection and a bad ground will result in poor rejection characteristics, which will vary from the manufacturer's datasheet.

A ceramic bandpass filter has an effect called comeback, which produces a duplicate of the bandpass shape at about three times the filter's center frequency.

For example, a 1-GHz bandpass filter will have comeback at around 3 GHz whose shape is like that of the bandpass at 1 GHz, but with higher insertion loss. It can be effectively mitigated through the use of a low-loss lowpass filter that will reject the third-harmonic comeback of the filter.

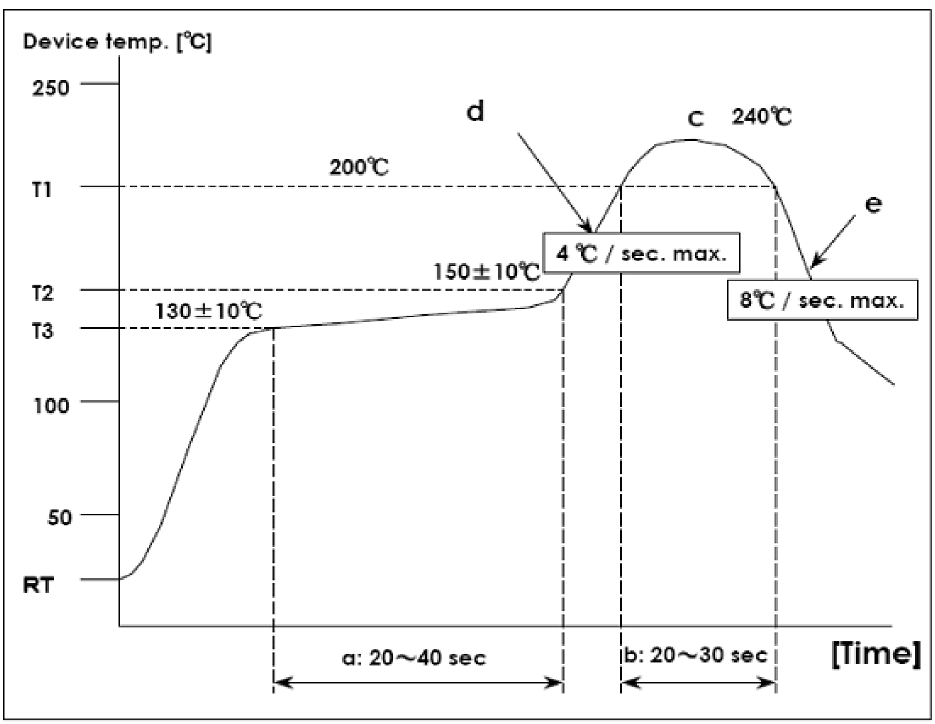
Ceramic Filters

HANDLING OF CERAMIC FILTERS

It is essential that contamination of metallization and terminations be avoided by using tools such as finger cots and plastic tweezers. Placement force of up to 200 g should be applied using a 2-mm (0.08-in.) diameter rod at the center of the part while remains in its tape carrier.

•**Reflow Soldering:** Standard reflow soldering conditions are shown in **Figure 5**:

- T1: 200º C
- T2 : 150 ±10º C
- T3 : 130 ±10º C
- Preheating time: 20 to 40 s
- Main heating time: 20 to 30 s
- Maximum temperature: 230º C ±10º
- Heating rate: 4º/s maximum
- Cooling rate: 8º/s maximum



5 . Standard reflow soldering conditions

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ENVIRONMENTAL SPECIFICATIONS

Anatech Electronics ceramic products are guaranteed to perform within the original specification after being subjected to the following environmental conditions:

- **Operating Temperature Range**: Cycling from -40 to +85°.

- **Temperature Resistance**: Heated to +85 and cooled to -40° C for 96 hr. and measured after 1 hr. at 25 ±5° C at less than 65% relative humidity.

- **Heat Shock Resistance**: Subjected to heat shock of -40 to +85° for five cycles of 30 min. and tested after 1 hr. at 25 ±5° C at less than 65% relative humidity.

- **Humidity Resistance**: Subjected to 95% relative humidity at 60° for 96 hr. and dried at 25 ±5°C at less than 65% relative humidity for 2 hr.

- **Vibration Resistance:** Subjected to vibration in each of three perpendicular planes and frequency is varied from 10 to 50 Hz with amplitude of 1.5 mm for 20 min.

- **Mechanical Shock Resistance**: Subjected to shocks in each of three perpendicular planes (nine tests) with a half-sine-wave shape, magnitude of 20G, and duration of 11 ms.

SUMMARY

Ceramic filters have proven their usefulness in a broad array of applications for many years. As they can be fabricated in ways best suited for both small and large quantities, they offer the system designer a great deal of flexibility. In addition, their small size makes them good choices in situations where space conservation is paramount.

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