

RESISTOR FOILS MOVE TO GREATER CLARITY

The latest resistor technologies, including 'naked' foil resistors, have taken audio clarity to levels which go beyond measurement by instruments alone, as Paul Newman explains

At the highest end of the audio-visual market, in high-fidelity audio, home cinema and professional broadcast applications, instruments alone cannot accurately measure the clarity of sound reproduction. Instead, the highly-trained 'golden ears' of audio's most sound-sensitive engineers are required to detect the subtle changes between different distortion-free signals.

Whilst many factors influence the overall performance of an audio system, an understanding of resistor technologies and their current-noise characteristics, can help engineers to improve the fidelity and clarity of sound reproduction (see Figures 1 and 2). The latest technologies virtually eliminate current noise and inductance to deliver exceptionally high perceived clarity.

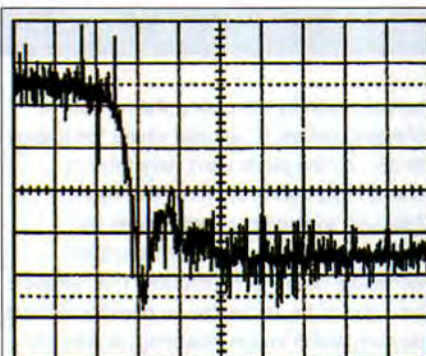


Figure 1: Typical waveform segment showing inserted noise

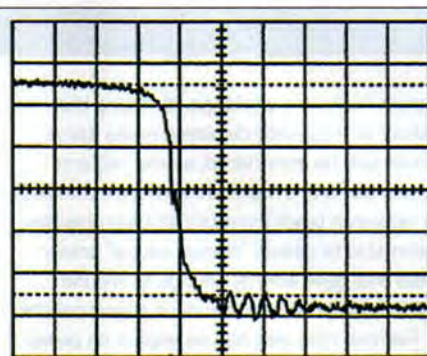


Figure 2: Waveform of noise-free resistors

applied, to produce a noise index which is expressed in decibels (dB):

$$\text{dB} = 20 \times \log (\text{noise voltage} / \text{DC voltage})$$

Table 1 correlates microvolts, per volt applied, to decibels and shows the full range of the noise indices achieved by different resistor technologies.

Carbon composition

At the top of the table for current noise, and therefore at the bottom of the noise performance table, are carbon composition resistors. These use carbon particles in a diallyl phthalate plastic binder with a conductive path which is from particle to particle. The plastic binder is subject to mechanical movement, relative to the carbon, as force is exerted from voltage strain, moisture ingress, mechanical strain, and thermal strain. This causes variations in the conduction points which allow the current to bounce between conductive paths producing an audible 'popcorn' noise. Whilst their non-inductive design has made them popular, carbon composition resistors have a poor noise index ranging from -12dB to +6dB.

Thick film

Thick film resistors provide only a marginal improvement over carbon composition

resistors. Their resistive path is a combination of glass frit and ruthenium oxide which is screened onto a ceramic substrate. Noise is produced as the oxide particles touch one another along the conduction path through the fired glass binder, causing the aggregation and dispersal of electrons. The noise index for thick-film resistors is -18dB to -10dB.

Metal film

The resistive element in metal film resistors is made by evaporating or sputtering a layer of nickel chromium onto a ceramic substrate. The thickness of the layer determines the value of the resistor, and can vary from 10 Angstrom, for the higher resistance values, to 500 Angstrom for lower-value devices. The process of grinding the resistive element leaves a jagged edge, whilst laser adjustment leaves a curled edge: both insert noise into the signal. As the uniformity of the layer affects the amount of noise, the presence of any occlusions or surface imperfections is less significant in the lower-value resistors which have thicker layers of nickel chromium. The noise index for metal-film resistors ranges from -32dB to -16dB.

Wirewound

Wirewound resistors are made using metal

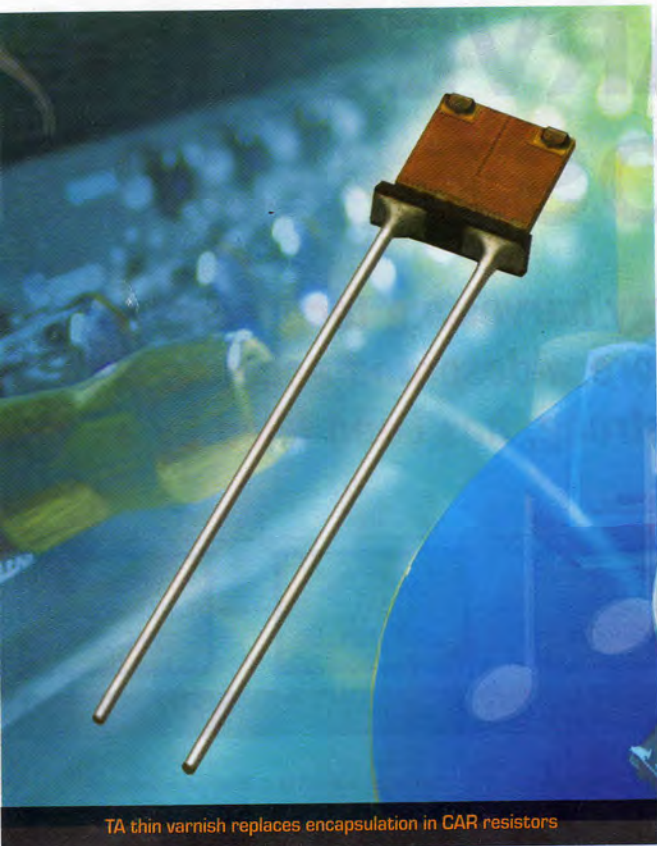
dB	microvolts/volt
10	3.2
5	1.8
0	1.0
-5	0.56
-10	0.32
-15	0.18
-20	0.10
-25	0.056
-30	0.032
-35	0.018
-40	0.010

Table 1: Range of noise indices for audio resistors

Current noise

Current noise is caused by the collection and dispersal of electrons within the current flow. The level of noise within a sound system can vary considerably with the composition of the resistors used in the amplifiers, preamplifiers and volume controls.

As a function of the input voltage, current noise is measured in microvolts, per volt



TA thin varnish replaces encapsulation in CAR resistors

alloys and the only noise insertion is produced by the tabs which are used to connect the fine wire to the coarse external leads. Despite a noise index of just -38dB, however, the inductance in wirewound resistors chops the signal peaks and fails to replicate the higher frequencies of the second and third harmonics, making them less suitable for high-end sound systems.

Bulk Metal foil

Patented by Vishay, Bulk Metal foil resistors are pattern-etched in metal alloys, with intergranular boundaries between conductive metallic crystals in the alloy. The length of these boundaries allows them to mask local distortions to achieve the lowest noise index of -40dB. In addition to achieving no measureable noise insertion, the planar geometry and two-axis design of Bulk Metal foil resistors allow the current paths to be laid out in parallel, producing virtually no inductance. Path-to-path capacitance, in series, also results in minimum lumped internal capacitance. Bulk Metal foil resistors achieve the lowest peak-to-peak distortion with no measurable noise insertion.

Naked Z-Foil

The latest generation of Bulk Metal technology is Z-Foil. These combine a noise index of -40dB with a non-inductive design.

They also add another dimension: In addition to conventional surface-mount packages, Z-Foil resistors are available in 'naked' radial versions. The Charcroft Audio Resistors (CAR) replace conventional encapsulation with a thin varnish to create a 'naked' audio resistor. Although these share the same -40dB rated performance and non-inductive design as encapsulated versions, the 'golden ears' of specialist audio engineers consistently agree that eliminating the encapsulation produces a detectable improvement in the clarity of the sound that they reproduce.

The author works for Charcroft Electronics

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