



## Audio Noise Reduction Through the Use of Bulk Metal® Foil Resistors – "Hear the Difference"

### Introduction

As sound reproduction requirements become more demanding, the selection of circuit components becomes more exacting and the resistors in the signal path are critical. Amplifiers and pre-amplifiers, as well as volume controls, are likely sources for noise and signal distortion if the correct resistor selection is not made.

This paper describes the noise generation within the various available resistor types and quantifies the noise insertion to expect from each type.

### Noise

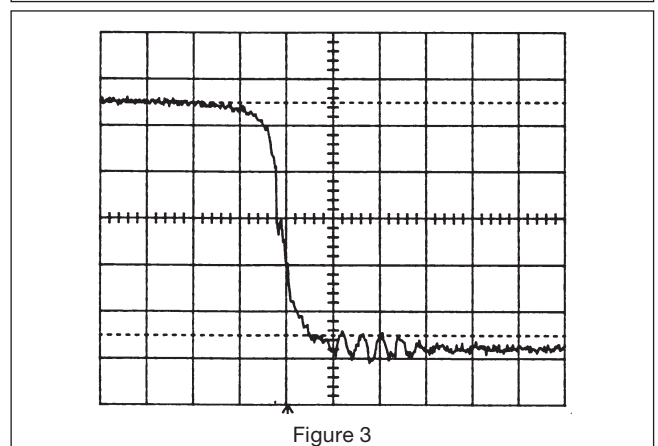
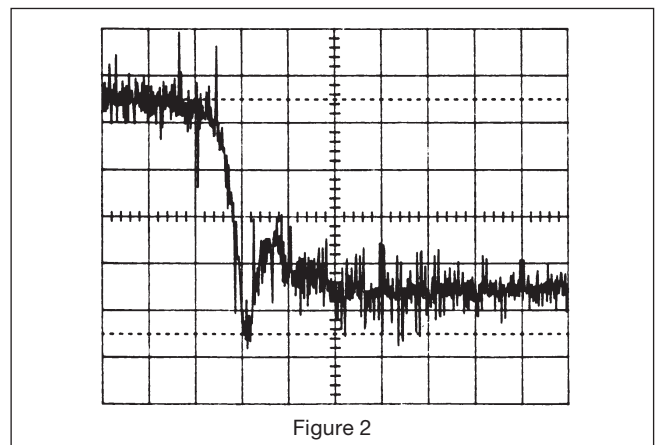
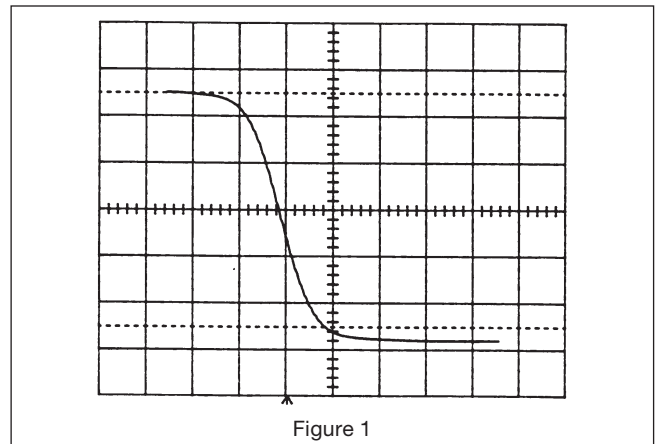
Noise is an unwanted AC signal that may be superimposed upon any fundamental signal including DC. In audio work the noise destroys the fidelity of sound reproduction and in the worst case can be totally unacceptable even to the untrained ear. Figure 1 shows a simple waveform segment. In Figure 2 a compliment of commercial parts yields a discernible amount of noise, while in Figure 3 the noise has been "cleaned up" by replacing the commercial parts with noise free components.

Resistors are noise sources to various degrees depending upon how they are made (resistor technology). As the systems become more and more sophisticated, better resistors are required. The hi-fidelity end of the sound reproduction industry is the primary target for noise free resistors. This is where component selection and circuit layout are done with purity of signal in mind and where designers can "hear the difference."

There are two types of noise to consider. Thermal noise is due to the random motion of electrons within the resistive conductor. The voltage developed by thermal agitation sets a limit on the smallest voltage that can be amplified without being lost in a background of noise. The equation for thermal noise is:

$$E^2 = 4KTR (f_2 - f_1)$$

Where: K = BOLTSMAN'S constant  
T = Absolute temperature (Kelvin)  
R = Resistance of the conductor  
(f<sub>2</sub> - f<sub>1</sub>) = Band width





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The other type of noise is current noise, which is the bunching and releasing of electrons associated with current flow, and is present in resistors to varying degrees depending upon technology employed. Resistances composed of metal or metal alloys display the lowest combined noise level.

Current noise is measurable and is expressed as a function of the input voltage. The magnitude is micro volts per volt applied. A noise index is expressed in decibels and the equation converting  $\mu\text{V}/\text{V}$  to dB is:

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

Table one equates the two:

<b>Table 1</b>	
dB	micro volts/volt
15	5.6
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

### Resistor Selection

Persons interested in the quality of sound reproduction usually have a “trained ear” sufficiently perceptive to detect the insertion of noise and/or distortion of the original signal caused by the resistors in the preamp, audio amplifier, and/or volume control of a sound reproduction system. Audio engineers (who were not already using foil resistors) were sampled and asked to replace their previous resistor selection with foil resistors and “hear the difference.” In this high-end market there are no instruments to measure the fidelity of reproduction, so the “trained ear” is relied upon. All audio engineers sampled heard the difference. Below are comments from audio

engineers who are now using Vishay foil resistors:

*“I am (now) a user of Vishay resistors... They are the best in the industry... most notably for their sonic performance.”*

Emanuel Go, First Sound, Inc.

*“...Of all the different things I tried [to reduce noise], these [Vishay] resistors made a bigger difference compared to anything else....”*

Guy Hammel, Placete Engineering

*“We did a demonstration comparing foil to thin film and there was a hands down difference with the foil providing better sound, better resolution, and quieter outputs.... Changing one resistor in the preamp feedback was enough for us to tell that it was a superior part.”*

Victor Tiscareno, AudioPrism

### Bulk Metal® Foil Technology: - 40 dB

Resistors made of metal alloys are resistive as a result of the intergranular boundaries between conductive metallic crystals in the alloy. These boundaries are quite long and therefore mask any local site distortions. The signal-to-noise ratio with these resistors is the best available.

Foil resistors are a pattern etched in metal. This planar geometry and the two axis design permits the current paths to be laid out in parallel producing self canceling of inductance. Also, path-to-path capacitance is in series resulting in a minimum of lumped internal capacitance. These low inductance/capacitance resistors cause the least amount of peak-to-peak distortion with no measurable noise insertion. Foil resistors are the first choice for noise-free operation.

### Wirewound Technology: - 38 dB

Wirewound resistors are made of alloys similar to foils, so the only noise insertion comes from the tabs used to connect the fine wire to the coarse external leads. The major objection to wirewounds, however, is the inductance that chops the peaks and fails to replicate the higher frequencies of the second and third harmonics.

### Metal Film Technology: - 32 dB to - 16 dB

Metal films are made by evaporating or sputtering a layer of nickel chromium onto a ceramic substrate. The thickness of the layer is value dependent and may be from 10 Angstrom to 500 Angstrom thick. The thicker it is



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(lower the value), the less noise insertion. Higher values are noisier because the occlusions, surface imperfections, and non-uniform depositions are more significant to the production of noise when the layer is thin.

Unlike foil resistors where the lines are generated by precise photo etching, here the spiral of resistance is generated by either grinding (which leaves a ragged edge) or laser adjusting (which leaves a curl edge with eddy-current paths), both of which are a source of noise.

#### Thick Film: - 18 dB to - 10 dB

Thick film networks, discrete resistors, and chip resistors made of thick film can have unacceptable noise levels. The resistive path in this product is an “ink” of glass frit with ruthenium oxide added and screened onto a ceramic substrate. The conduction path is through the oxide particles as they touch one another in the fired glass binder. These “touching sites” are locations for the bunching and releasing of electrons and are the reason these resistors are noisy.

#### Carbon Composition: - 12 dB to + 6 dB

These resistors were the backbone of the radio and television industry prior to World War II, but declined in use through

the early sixties as metal films took over. They eventually gave way completely to discrete metal film resistors as prices of metal films came down and the prices of carbon compositions went up. While noise reduction was not necessarily the driving factor, a significant size reduction accompanied this evolutionary step. Carbon composition resistors are made of carbon particles in a diallyl phthalate plastic binder and the conductive path is from particle to particle touching each other along the path. Unlike the glass binder of the thick film resistor, the plastic binder is subject to mechanical movement relative to the carbon due to the forces from voltage strain, moisture ingress, mechanical strain, and thermal strain. These strains cause the conduction sites at the point of contact to vary the resistivity or even open up. The current thus bounces around from one path to another with audible output. “Popcorn noise” as well as the current noise previously discussed is not uncommon.

#### Conclusion

Signal purity can be a function of the selection of resistor technology for pre-amp and amplifier applications. Vishay Bulk Metal<sup>®</sup> Foil resistors offer the best performance for low noise audio applications.



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