# Resistor Noise—reviewing basics, plus a Fun Quiz

DECEMBER 2, 2012 < HTTPS://WWW.EDN.COM/RESISTOR-NOISE-REVIEWING-BASICS-PLUS-A-FUN-QUIZ/>
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The noise performance of amplifier circuits is greatly affected by the ***Johnson noise*** of resistors—the source resistance and feedback resistors. Most everyone seems to know that resistors have noise but may be a bit foggy on some of the details. Here's a bite-sized review in preparation for future discussions on amplifier noise:

The Thevenin noise model for a resistor consists of a noiseless resistor in series with a noise voltage, figure 1.

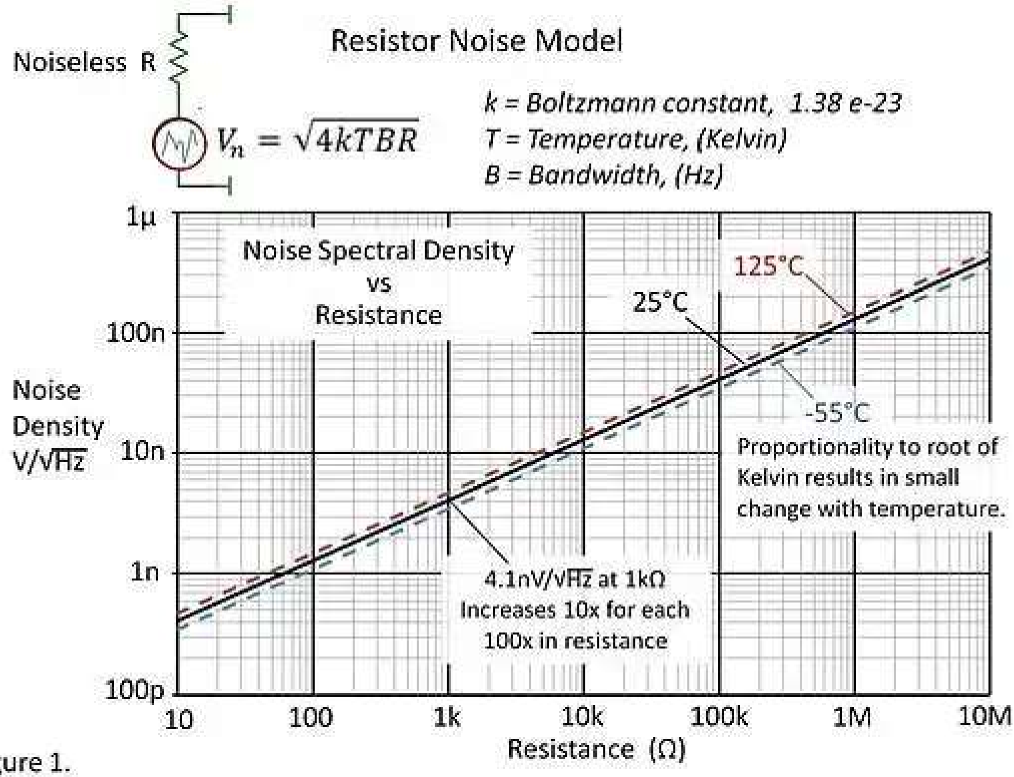


Figure 1.



The noise voltage is proportional the root of the resistance, bandwidth and temperature (Kelvin). We often quantify the noise in a 1Hz bandwidth, its *spectral density* . The theoretical noise of a resistor is "white," meaning that it is spread uniformly over frequency. It has equal noise voltage in every equal slice of bandwidth.



The noise in each 1Hz band sums randomly according to the root of the sum of the squares. We often refer to the spectral density in volts/root-Hz. The numerical value is the same as for a 1Hz bandwidth. For white noise it's convenient to multiply by the square-root of a bandwidth to sum the random contribution of each 1Hz band. To measure or quantify the *total noise* , you need to limit the bandwidth. Without a known cutoff frequency you don't know how much noise you are integrating.

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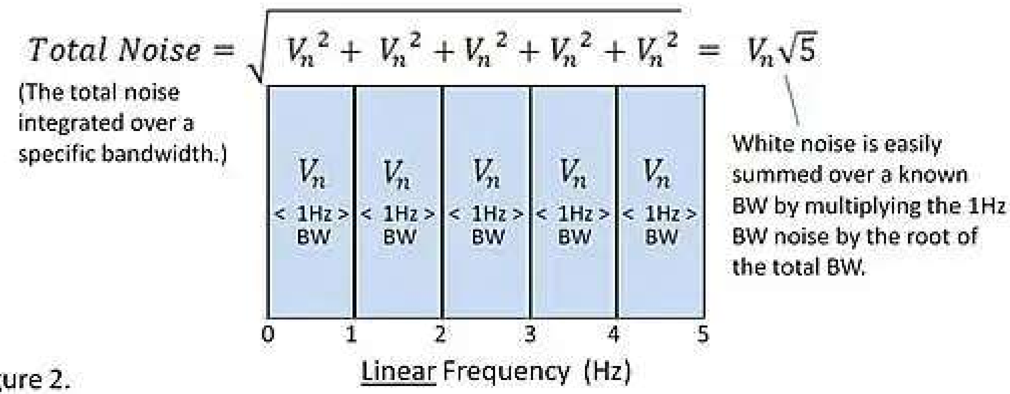


Figure 2.

We instinctively think of spectral plots as having a logarithmic frequency axis—a Bode plot. Note that a Bode plot has more Hertz of bandwidth on the right side than the left side. Considering total noise, the right side of a Bode plot may be much more important than the left side.

Resistor noise is also *Gaussian* , a description of its *amplitude distribution, a probability density function* . It's Gaussian because it's created by the summation of a gazillion little random events. The **Central Limit Theorem < http://en.wikipedia.org/wiki/central-limit-theorem>** explains how this becomes Gaussian. The RMS voltage of AC noise is equal to ±1σ of the amplitude distribution. For 1V RMS noise, there is a 68% (±1σ) probability that the *instantaneous* voltage will be within a ±1V range. A common misconception is to relate or equate **white** and **Gaussian** but they're unrelated. Filtered resistor noise, for example, is not white but it remains Gaussian. Binary noise is definitely not Gaussian but it can be white. Resistor noise is white *and* Gaussian.

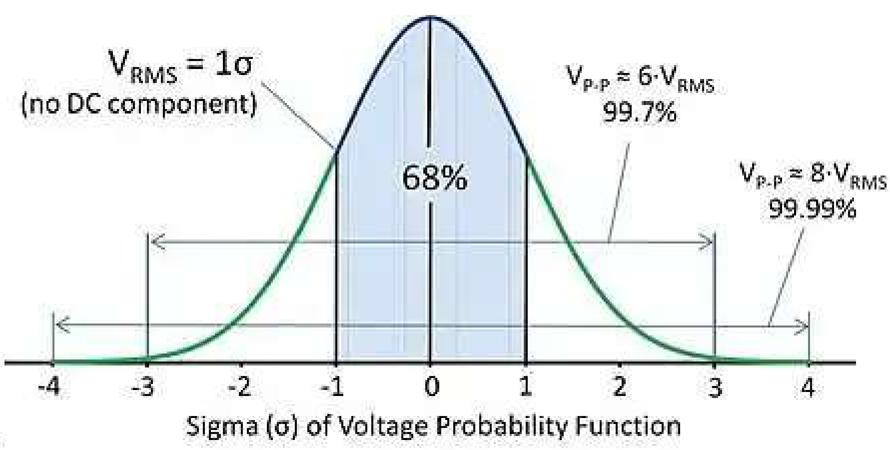


Figure 3.

Purists like to rant that Gaussian noise does not have a defined peak-to-peak value—it's infinite, they say. True enough because the tails of a Gaussian distribution reach to infinity so any voltage is possible. As a practical matter, the likelihood of noise spikes beyond ±3x the RMS value is pretty small. Many folks use an approximation of 6x the RMS for the peak-to-peak value. You can add a large additional guard-band by using 8x without greatly changing the value.

Some fun points to ponder: The noise voltages of two resistors in series sum randomly and result is the same noise as for the sum of the resistor values. Similarly, the noise of resistors in parallel results in the noise of the parallel resistance. If it worked out differently, it would be problematic as you think about bisecting a physical resistor and combining them in series or parallel. It all works out. 🙂

A large value resistor lying on your desk will not arc and spark from unlimited self-generated noise voltage. Stray parallel capacitance will limit the bandwidth and the total voltage. Similarly, the high noise voltage you might imagine on insulators is shunted by parallel capacitance and the resistance of conductors around them.

***Fun Quiz***— What is the total open-circuit noise voltage on a resistor that has a stray parallel capacitance of 0.5pF? The solution details will be **posted here < http://e2e.ti.com/support/amplifiers/precision-amplifiers/w/design-notes/2241.resistor-noise-quizthe-solution.aspx>** after someone comments with a correct answer.

Sorry, but I've run beyond my self-imposed word limit. If you've made it this far, thanks for reading! Comments (and answers) are welcome.

Bruce email: (Email for direct communications. Comments for all, below.)

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## 10 COMMENTS ON "RESISTOR NOISE—REVIEWING BASICS, PLUS QUIZ"

### Bruce Trump

December 4, 2012

Reader Gokul emailed me with a correct answer to the quiz question– 90.7uV. Thanks, Gokul can read an explanation of the answer in the "posted here" link above. — Bruce

↳ **Log in to Reply**

### wreeve

December 9, 2012

This is a very nice "bite-sized" review of resistor noise. Now, about that pesky constant 4 in th resistor noise model equation and why it disappears when the resistor is hooked up to a matc load resistor at the same temperature …..

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**daniel i**

December 10, 2012

89.6uV
the R drops out of the equation due to the fact that the bandwidth gets limited at the same rat
the noise increases as a function of higher resistance. BW(noise)=1/4RC etc etc

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**loberotator**

December 10, 2012

Strictly, the answer is 90.7 uV x sqrt(T/298 K), since you do not specify the temperature. I am
sure why you use 298 K as your fiducial temperature either; for noise figure measurements th
effective noise temperature is referenced to 290 K. There is a

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**amaktoomamu**

December 10, 2012

Thanks for this review article.
Fun quiz answer is famous Ke Tee over Cee !

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**Hugo.Coolens**

December 16, 2012

Don't forget your square root: it's sqrt(kT/C)

regards,
Hugo

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**manjunathdm**

March 6, 2013

i have 2 resistors in parallel , how to find the noise of the parallel resistors .????

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**David ZHU**

September 22, 2013

my answer is 91.6uVrms,of course that maybe not so accurate!!!

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**Jess.Stuart**

October 3, 2013

The statement “The RMS voltage of AC noise is equal to ±1σ of the amplitude distribution.” is correct. The RMS value of a waveform, is just the DC value that has equivalent power, which proportional to voltage squared. You must transform the Norma

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## houyh

April 8, 2014

Let X be the instantaneous noise voltage, then Var(X) = E(X^2) – E(X)^2, where the latter terr simply zero. That proves the variance equals the squared RMS value for any zero-mean signa including Gaussian white noise. I am just curious about how you g

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