Use resistor noise to characterize a low-noise amplifier

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If you know or can estimate a low-noise amplifier's gain or noise bandwidth, you can measure the other spec using only a handful of resistors and an ac voltmeter (**Reference 1**). The method in this Design Idea uses the Johnson Equation, which describes the amount of noise a resistor generates (**Reference 2**). To find the missing parameter, measure an amplifier's output-noise voltage, first for a shorted input and then using a few resistors of different values. You can download an Excel spreadsheet that can calculate gain or noise bandwidth from the online version of this Design Idea at www.edn.com/110623dia.

To begin the measurement, place a short circuit across the low-noise amp's input terminals and measure the noise voltage with the voltmeter. Next, insert the resistors, one at a time, across the amplifier's inputs and measure the noise voltage at the output of the amplifier. Enter the measured output-noise voltages, the measured values of each resistor's resistance, the ambient temperature, and either the known or the estimated gain of the low-noise amp or the known or estimated effective noise bandwidth into the spreadsheet.

Using each of the measured resistance values, the spreadsheet plots a theoretical "blue" curve representing the Johnson noise in normalized units of nV/$\sqrt{\text{Hz}}$ (**Figure 1**). You can compensate

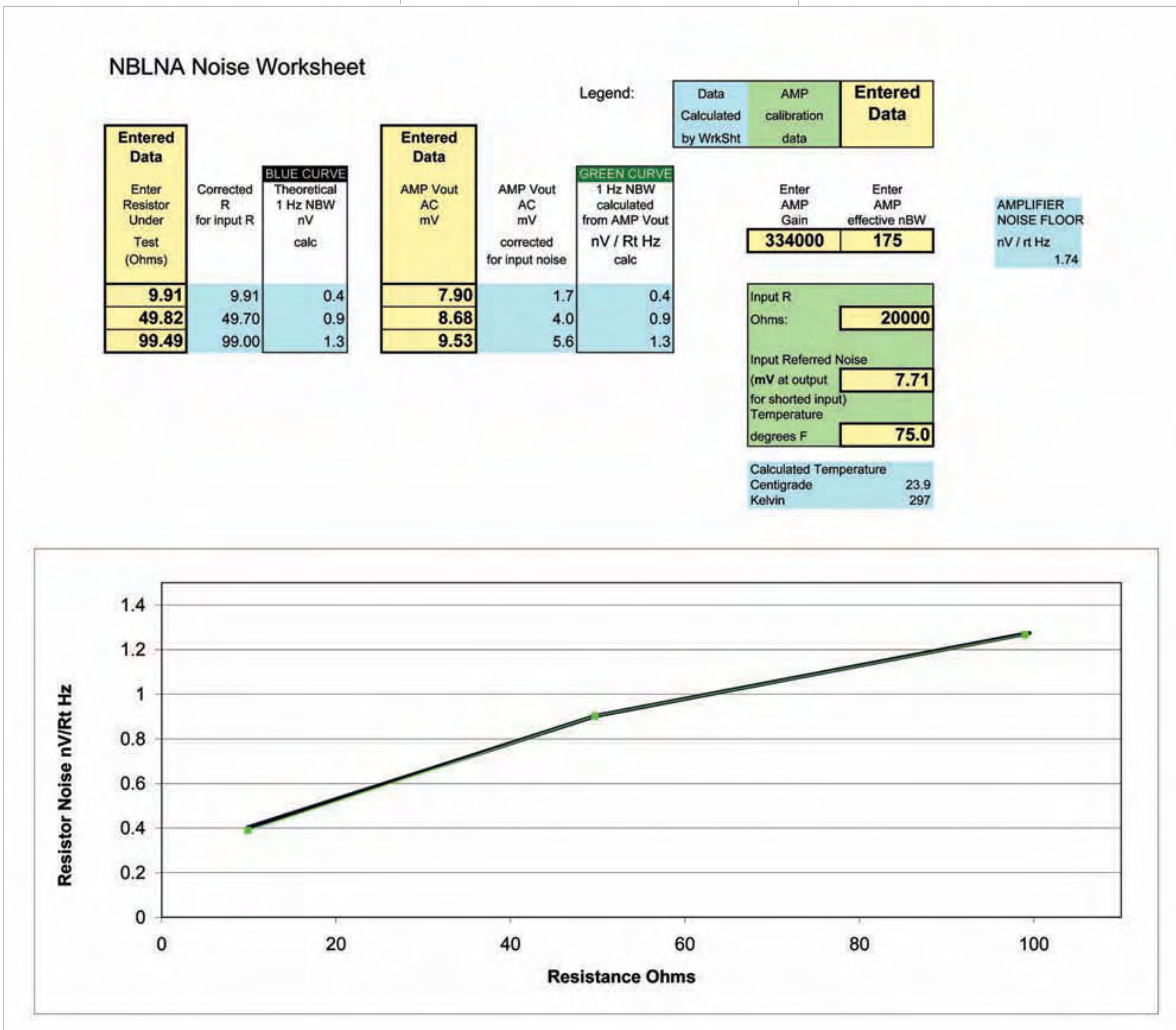

Figure 1 This downloadable spreadsheet lets you characterize an amplifier's gain and noise.

the blue curve for any low-noise-amp input resistance. The graph also shows a “green” curve that represents the amplifier’s calculated “excess” output noise—the measured output minus the amplifier’s uncorrelated input-referred noise. The input-referred noise is an uncorrelated noise signal that adds to any excess input noise as the square root of the sum of the squares of the noise voltages. You can find the amplifier’s input-referred noise using its effective-noise-bandwidth and gain values and measuring the output-noise voltage by short-circuiting the amplifier’s input terminals.

You can use a multimeter, such as Agilent’s (www.agilent.com) 34410A, with a second-display math-average feature to fill in the measured output-noise values (**Reference 3**). After you connect each resistor to the amplifier’s input terminals when the amplifier is on, reset the math average; wait until the new value settles down, which typically takes 10 seconds to approximately one minute; and record the average value for that resistor on the noise worksheet. Use the ohmmeter function to measure the actual resistance value and enter that value into the spreadsheet.

A MULTIMETER HAS A SECOND-DISPLAY MATH-AVERAGE FEATURE THAT CAN BE USED TO FILL IN THE MEASURED OUTPUT-NOISE VALUES. USE THE OHMMETER FUNCTION TO MEASURE THE ACTUAL RESISTANCE VALUE.

Enter the input parameters and measured output-noise values into the spreadsheet. Take a guess at the unknown parameter’s initial value and then vary it until the green curve almost exactly overlaps the theoretical blue curve. When the curves overlap, you’ve found the missing parameter. You can then try what-if scenarios by varying both parameters. EDN

REFERENCES

1 Geller, Joseph M, “On Measuring the Effective Noise Bandwidth of a Filter,” 2007, http://bit.ly/m8YzmW.

2 Johnson, JB, “Thermal Agitation of Electricity in Conductors,” *Physical Review*, Volume 32, July 1928, pg 97.

3 “34410A Digital Multimeter, 6½ Digit,” Agilent Technologies, http://bit.ly/luA7SQ.