Op Amp Noise—the non-inverting amplifier

JANUARY 7, 2013 < HTTPS://WWW.EDN.COM/OP-AMP-NOISE-THE-NON-INVERTING-AMPLIFIER/>
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COMMENTS 8 < HTTPS://WWW.EDN.COM/OP-AMP-NOISE-THE-NON-INVERTING-AMPLIFIER/#COMMENTS>

Building on last month's discussion of resistor noise < http://www.edn.com/electronics-blogs/the-signal/4402494/resistor-noise-reviewing-basics--plus-a-fun-quiz> , let's check out some basics of amplifier noise. The non-inverting op amp configuration is most common for low noise applications so we'll make that the focus.

Modeling the input source as a voltage source with a series resistance (figure 1), we know that the source resistance, R_S , has a noise proportional to the root of its resistance (the straight line in figure2). The goal of a low noise amplifier is to contribute minimal additional noise to that generated by the source resistance.

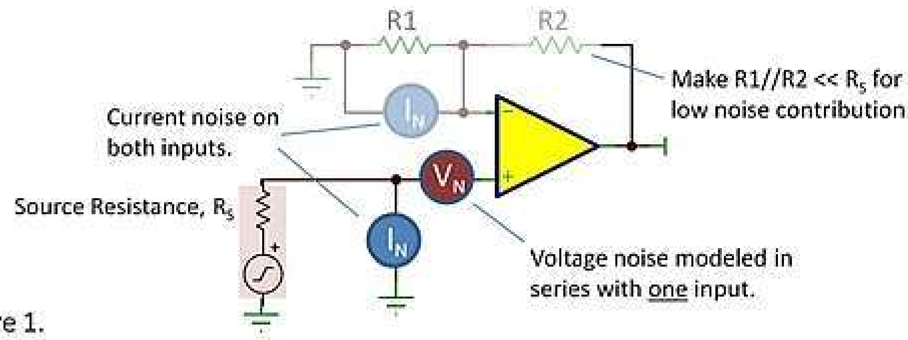

Figure 1.

The amplifier noise is modeled as a voltage noise in series with one input and current noise sources connected to each input, figure 1. Think of the voltage noise as just a time-varying component of offset voltage. Likewise, the current noise is a time-varying component of input bias current, one on each input. We'll ignore the current noise at the inverting input in this circuit—we can usually make its noise contribution minimal.

Figure 2 shows the total input-referred noise of the circuit for two op amps—the BJT-input **OPA209 < http://www.datasheets.com/search/partdetail/opa209aid/texas-instruments>** and JFET-input **OPA140 < http://www.datasheets.com/search/partdetail/opa140aid/texas-instruments>** . Each is shown relative to the noise of the source resistance at 25°C. The three sources of noise are summed by root-sum-of-squares for each op amp. You may have seen this graph in some op amp data sheets.

As the source resistance is decreased, its attendant Johnson noise decreases (by the inverse of the root of the resistance) and at some point the amplifier's voltage noise dominates. The total noise flattens to a value equal to the voltage noise of the amplifier. As the source resistance is increased, the current noise flowing through the source resistance creates noise that increases linearly, rising more rapidly and eventually exceeding the noise of the source resistor. So with high source resistance, the current noise effects dominate.

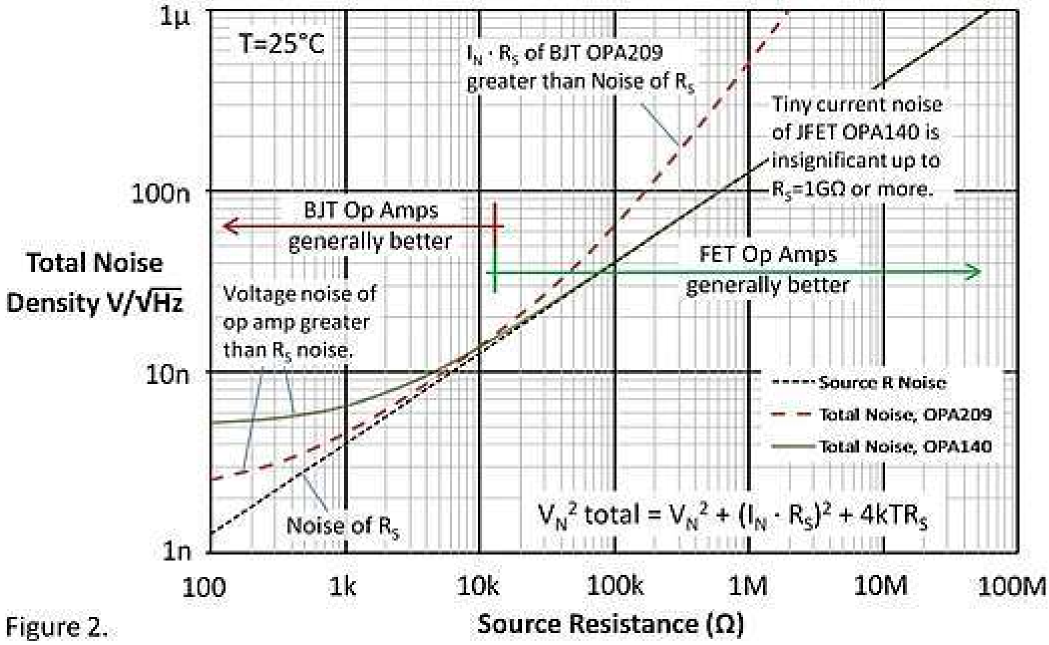

Figure 2.

The greatest challenges in low noise amplifier design often come with low source resistance—2kΩ and lower. The lower source resistance noise in this region demands amplifiers with very low voltage noise. In general, bipolar (BJT-input) amplifiers excel in this range. Notice also that the total noise of the OPA209 in figure 2 dips nearest to that of the source resistance at a "sweet spot." This source resistance of best noise performance occurs at $R_S = V_N / I_N$.

FET-input amplifiers contribute little additional noise with source resistance above 20kΩ, or so. Current noise of a FET op amp does not generally play an important role until you reach multi-GΩ source resistance. A guideline: Below 10kΩ source resistance, low noise BJT amplifiers generally provide lower noise. Above approximately 10kΩ, FET or CMOS op amps will likely have an advantage.

The feedback network, R1 and R2, also contribute noise but this can generally be made insignificant. The short answer is that if the parallel combination of R1 and R2 is one-tenth of R_S (or less) they will add less than 10% (

Of course, there's much more to know (how many times have I said that?) but an understanding of this frequent case is a good start. Want more? I recommend ***Operational Amplifier Noise: Techniques and Tips for Analyzing and Reducing Noise* < http://www.amazon.com/operational-amplifier-noise-techniques-analyzing/dp/0750685255>** , written by my colleague Art Kay.

Point to Ponder: The OPA140 has a very broad resistance range above 10kΩ where noise performance is excellent. Is there a way to adapt a lower source resistance to take advantage of this region of operation?

Thanks for reading and comments are welcome.

Bruce

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

Other interesting "The Signal" Topics. < http://e2e.ti.com/support/amplifiers/precision-amplifiers/w/design-notes/2235.the-signal-topic-list.aspx?dcmp=hpa-general&hqs=thesignal-topics>

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8 COMMENTS ON "OP AMP NOISE—THE NON-INVERTING AMPLIFI

Guru of Grounding

January 8, 2013

A very well-written and easy-to-understand summary of op-amp noise considerations! Someth that's often forgotten is that the pair of transistors at an op-amp input will always have 1.4 time dB) as much noise as a single transistor, all else being

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Bruce Trump

January 8, 2013

Thanks for the comments, Bill. I'm in agreement with all your points. I first learned about low-Z noise challenges when I tried to build a high performance microphone preamp with op amps i senior year of college, 1970. That failure began long-term inte

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Mark Fortunato

January 9, 2013

Bruce, please keep writing this stuff. I hope the younger engineers are paying attention. I ran this in the mid 80's when I was working on early speech recognition products and we started t OpAmps get below 2nV/rt-Hz. That is when I learned that

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Victorn

January 11, 2013

Bruce,
I'm really rusty, as I havn't done any analog design/calculations since 1995 or so.
But I wanted to share what i still remember….

For low noise with low source resistance, you should consider to design a discrete amp (or at a first stage).

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Bruce Trump

January 11, 2013

Victorn— You are correct that very low resistance sources may benefit from discrete designs. Sometimes a single transistor amplifier is best for the reasons that Bill cited (above). But mainstream op amps are encroaching. (See the OPA211 at 1.1nV/rt-Hz for

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didymus7

January 15, 2013

The one 'fly-in-the-ointment' with the bipolar versus Fet/Mosfet amp noise is the frequency rar your circuit. FET/MosFET amps have a high noise corner, at least 1khz and sometimes as hig 10khz. This means that while you might have a source resis

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Bruce Trump

January 15, 2013

The OPA140, the JFET op amp used in this example, has a 1/f (or flicker) corner of approxima 30Hz, far below your mentioned "at least 1kHz." Many of our modern JFET and CMOS op am have corner frequencies below 1kHz.
Still, your point is an important

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edwinpettis

January 16, 2013

Bob Pease wrote quite a few app notes and at least several columns on op amp noise and amplifier configurations. There are also a number of very low noise amplifier designs given in app notes, particularly with the LM394 dual transistors which had an

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