ANALOG DEVICES

AN-940
APPLICATION NOTE

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Low Noise Amplifier Selection Guide for Optimal Noise Performance

by Paul Lee

INTRODUCTION

When evaluating an amplifier's performance for a low noise application, both internal and external noise sources must be considered. This application note briefly discusses the fundamentals of both internal and external noise and identifies the tradeoffs associated in selecting the optimal amplifier for low noise design.

EXTERNAL NOISE SOURCES

External noise includes any type of external influences, such as external components and electrical/electromagnetic interference. Interference is defined as any unwanted signals arriving as either voltage or current, at any of the amplifier's terminals or induced in its associated circuitry. It can appear as spikes, steps, sine waves, or random noise. Interference can come from anywhere: machinery, nearby power lines, RF transmitters or receivers, computers, or even circuitry within the same equipment (that is, digital circuits or switching-type power supplies). If all interference is eliminated by careful design and/or layout of the board, there can still be random noise associated with the amplifier and its circuit components.

Noise from surrounding circuit components must be accounted for. At temperatures above absolute zero, all resistances act as noise sources due to thermal movement of charge carriers called Johnson noise or thermal noise. This noise increases with resistance, temperature, and bandwidth. Voltage noise is shown in Equation 1.

$$V_n = \sqrt{4kTBR} \tag{1}$$

where:
V_n is voltage noise.
k is Boltzmann's constant (1.38×10^{-23} J/K).
T is the temperature in Kelvin (K).
B is the bandwidth in hertz (Hz).
R is the resistance in ohms (Ω).

Current noise (noise associated with current flow) is shown in Equation 2

$$I_n = \sqrt{\frac{4kTB}{R}} \tag{2}$$

where:
I_n is current noise.
k is Boltzmann's constant (1.38×10^{-23} J/K).
T is the temperature in Kelvin (K).
B is the bandwidth in hertz (Hz).
R is the resistance in ohms (Ω).

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Resistors

For the purposes of this application note, the resistor noise is limited to thermal (Johnson) noise. To keep a low level of this type of noise, resistance values should be as low as possible because RMS voltage of thermal (Johnson) noise is proportional to the square root of the resistor value. For example, a 1 kΩ resistor has a thermal noise of ~4 nV/√Hz at room temperature.

For an in-depth analysis and low noise designs, other types of resistor noise should be accounted for, such as contact noise and shot noise. A few practical notes follow and they should be considered when selecting a resistor.

- Choose the largest practical wattage resistors, as the contact noise is decreased with a larger volume of material.
- Choose low noise resistive element material
  - Resistive elements composed of pure metals and/or metal alloys in bulk exhibits low noise characteristics. Such as Vishay Bulk Metal® foil technology resistors (such as, S102C, Z201)
  - Wirewound technology resistors composed of metal alloys have similar noise characteristics as Bulk Metal foil technology, but are much more inductive.
  - Metal film technology resistors as thin film are noisier than Bulk Metal foil or wirewound technology resistors because of significant noise contributions from occlusions, surface imperfections, and nonuniform depositions.
  - Thick film and carbon composition resistors are the nosiest resistors.

Reactances

Reactances, such as capacitors and inductors, do not generate noise, but the noise current through reactances develops noise voltage as well as the associated parasitic.

Practical Tips

Output noise from a circuit can be reduced by lowering the total component resistance or by limiting the circuit bandwidth. Temperature reduction is generally not very helpful unless a resistor can be made very cold, because noise power is proportional to the absolute temperature,

$$T(x) \text{ in Kelvin} = x°\text{C} + 273.15° \quad (3)$$

All resistors in a circuit generate noise. The effect of generated noise must always be considered. In practice, only resistors in the input and feedback paths (typically in high gain configurations) are likely to have an appreciable effect on total circuit noise. The noise can be considered as coming from either current sources or voltage sources (whichever is more convenient in a given circuit).

INTERNAL NOISE SOURCES

Noise appearing at the amplifier's output is usually measured as a voltage. However, it is generated by both voltage and current sources. All internal sources are generally referred to the input, that is, treated as uncorrelated or independent random noise generators in series or in parallel with the inputs of an ideal noise-free amplifier (see Figure 1). Because these noise sources are considered random and/or exhibit Gaussian distribution behavior, it is important to take proper care when summing the noise sources as discussed in the Summing the Noise Sources section.

If the same noise appears at two or more points in a circuit (that is, input bias current cancellation circuitry), the two noise sources are correlated noise sources and a correlation coefficient factor should be included in the noise analysis. Further analysis of correlated noise is limited in this application note as typical correlation noise sources are less than 10% to 15% and they can usually be disregarded.

Internal amplifier noise falls into four categories:

- Input-referred voltage noise
- Input-referred current noise
- Flicker noise
- Popcorn noise

Input-referred voltage noise and input-referred current noise are the most common specifications used for amplifier noise analysis. They are often specified as an input-referred spectral density function or the rms noise contained in Δf bandwidth and usually given in terms of nV/√Hz (for voltage noise) or pA/√Hz (for current noise). The /√Hz is needed because the noise power adds with (is cumulative over) bandwidth (Hz) or the voltage and current noise density adds with square root of the bandwidth (√Hz) (see Equation 1 and Equation 2).

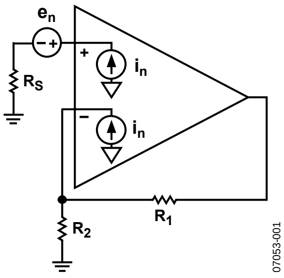

Figure 1. Op Amp Noise Model

INPUT-REFERRED VOLTAGE NOISE

Input-referred voltage noise (e_n) is typically viewed as a noise voltage source.

Voltage noise is the noise specification that is usually emphasized; however, if input impedance levels are high, current noise is often the limiting factor in system noise performance. It is analogous to offsets, where the input offset voltage often bears the blame for output offset, when in reality the bias current causes the output offset where input impedances are high.

Note the following points about input-referred voltage noise:

- Op amp voltage noise can be lower than 1 nV/√Hz for the highest performance amplifiers.
- Although bipolar op amps traditionally have less voltage noise than FET op amps, they also have substantially greater current noise.
- Bipolar amplifier noise characteristics are dependent on the quiescent current.
- Present day FET op amps are capable of obtaining both low current noise and voltage noise similar to bipolar amplifier performance, though not as low as the best bipolar input amplifiers.

INPUT-REFERRED CURRENT NOISE

Input-referred current noise (i_n) is typically seen as two noise current sources pumping currents through the two differential input terminals.

Shot noise (sometimes called Schottky noise) is current noise due to random distribution of charge carriers in the current flow through a potential barrier, such as a PN junction. The shot noise current, i_n, is obtained from the formula

$$i_n = \sqrt{2 I_B q B} \tag{4}$$

where:
I_B is the bias current in ampere (A).
q is the electron charge in coulomb (1.6 × 10^{-19} C).
B is the bandwidth in hertz (Hz).

The current noise of a simple bipolar and JFET op amp is typically within 1 dB or 2 dB of the shot noise of the input bias current. This specification is not always listed on data sheets.

Note the following points regarding input-referred noise:

- The current noise of typical bipolar transistor op amps, such as the OP27, is about 400 fA/√Hz, where I_B is 10 nA, and does not vary much with temperature except for bias, current-compensated amplifiers.
- The current noise of JFET input op amps (such as the AD8610: 5 fA/√Hz at I_B = 10 pA) while lower, doubles for every 20°C chip temperature increase, because JFET op amp bias currents double for every 10°C increase.
- Traditional voltage feedback op amps with balanced inputs usually have equal (correlated and uncorrelated) current noise on both their inverting and noninverting inputs.
- Many amplifiers, especially those amps with input bias current cancellation circuits, have considerably larger correlated than uncorrelated noise components. Overall, noise can be improved by adding an impedance-balancing resistor (matching impedances on both positive and negative input pins).

FLICKER NOISE

The noise of op amps is Gaussian with constant spectral density (white noise), over a wide range of frequencies. As frequency decreases, the spectral density starts to rise because of the fabrication process, the IC device layout, and the device type at a rate of about 3 dB per octave for CMOS amplifiers, 3.5 dB to 4.5 dB per octave for bipolar amplifiers, or up to 5 dB per octave for JFET amplifiers.

This low frequency noise characteristic is known as flicker noise or 1/f noise because the noise power spectral density goes inversely with frequency (1/f). It has a −1 slope on a log plot. The frequency at which an extrapolated −3 dB per octave (for a CMOS-type amplifier) spectral density line intersects the broadband constant spectral density value is known as the 1/f corner frequency and is a figure of merit for the amplifier (see Figure 2). Bipolar and JFET amplifiers typically have lower 1/f corner frequency than CMOS amplifiers.

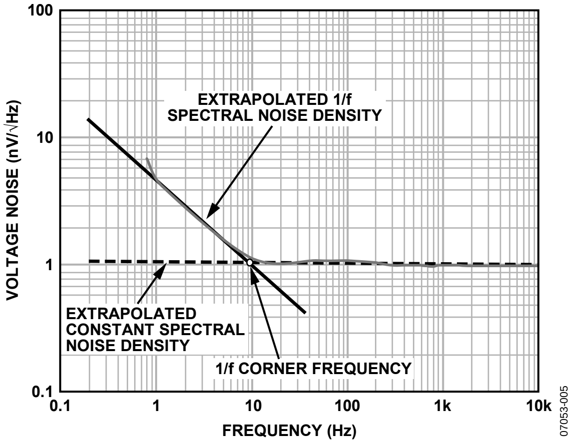

Figure 2. Spectral Noise Density

POPCORN NOISE

Popcorn noise (not specified or advertised) is an abrupt shift in offset voltage or current lasting for several milliseconds with amplitude from several microvolts to hundreds of microvolts. This burst or pop is random. Low temperatures and high source resistances usually produce the most favorable conditions for popcorn noise. Although the root cause of popcorn noise is not absolute, both metallic contamination and internal or surface defects in the silicon lattice can cause popcorn noise in ICs. Although considerable work has been done to reduce the sources of popcorn noise in modern wafer fabrication, it cannot be eliminated. Further analysis of popcorn noise is beyond the scope of this application note.

SUMMING THE NOISE SOURCES

If the noise sources are uncorrelated (that is, one noise signal cannot be transformed into the other), the resulting noise is not their arithmetic sum, but the square root of the sum of their squares.

$$V_{ni,\,TOTAL} = \sqrt{(e_n)^2 + (R_S \times i_n)^2 + V_n\,(R_{EX})^2} \qquad (5)$$

where:

$V_{ni,\,TOTAL}$ is the total noise referred-to-input (RTI).
e_n is input-referred voltage noise.
i_n is input-referred current noise.
R_S is an equivalent source or input resistance to the amplifier.
$V_n\ (R_{EX})$ is voltage noise from external circuitry.

Note the following:

- Any resistance in the noninverting input has Johnson noise and converts current noise to a voltage noise.
- Johnson noise in feedback resistors can be significant in high resistance circuits.

Figure 3 visually shows the Equation 5 as the summation of vectors by using the Pythagorean Theorem.

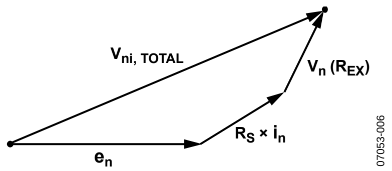

Figure 3. Vector Summation of Noise Sources

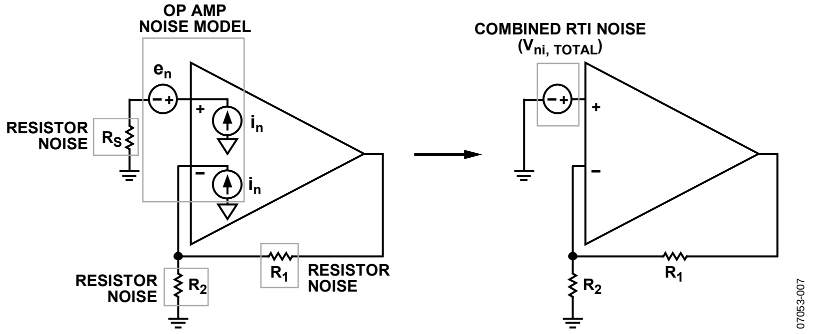

Figure 4. Simplifying the Amplifier Noise Circuit

NOISE GAIN

The noises previously discussed can be grouped into referred-to-input (RTI) noise of the amplifier circuit. To calculate the total output noise of the amplifier circuit, the total combined noise on the input must be multiplied by the amplifier circuit's noise gain. Noise gain is the gain of the amplifier's circuit for referred-to-input noise and it is typically used to determine the stability of the amplifier circuit.

To simplify the noise gain calculation, the noise sources in the simple amplifier circuit in Figure 1 can be reduced to a single total RTI noise source ($V_{ni, TOTAL}$), as shown in Figure 4. It is a common practice to lump the total combined RTI noise to the noninverting input of the amplifier.

$$V_{no, TOTAL} = G_N \times V_{ni, TOTAL}$$

where:
$V_{no, TOTAL}$ is the total referred-to-output (RTO) noise.
$V_{ni, TOTAL}$ is the total referred-to-input (RTI) noise

$$G_N = 1 + \frac{R_1}{R_2}$$

where:
G_N is the noise gain.
R_1 is the feedback equivalent impedance.
R_2 is the gain setting equivalent impedance.

In some cases, the noise gain and the signal gain are not equivalent (see Figure 5). Note that the closed-loop bandwidth is determined by dividing the gain bandwidth product (or unity gain frequency) by the noise gain of the amplifier circuit.

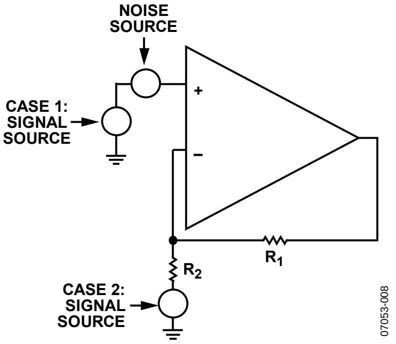

Figure 5. Signal Gain vs. Noise Gain

Case 1: In a noninverting configuration, both the signal gain and the noise gain are equal to $1 + R_1/R_2$.

Case 2: In an inverting configuration, signal gain is equal to $-(R_1/R_2)$, but the noise gain is still equal to $1 + R_1/R_2$.

SELECTING LOW NOISE OP AMP

If an op amp is driven with a source resistance, the equivalent noise input becomes the square root of the sum of the squares of the amplifier's voltage noise, the voltage generated by the source resistance, and the voltage caused by the amplifiers current noise flowing through the source impedance.

For very low source resistances, the noise generated by the source resistance and amplifier current noise contribute insignificantly to the total. In this case, the noise at the input is effectively only the voltage noise of the op amp.

If the source resistance is high, the Johnson noise of the source resistance may dominate both the op amp voltage noise and the voltage due to the current noise. However, note that, because the Johnson noise only increases with the square root of the resistance, while the noise voltage due to the current noise is directly proportional to the input impedance, the amplifier's current noise always dominates for a high enough value of input impedance. When an amplifier's voltage and current noise are high enough, there may be no value of input resistance for which Johnson noise dominates.

An amplifier can be selected where its noise contribution is negligible compared to the source resistance by using a figure of merit, $R_{S,\,OP}$, of an op amp. It can be calculated by using an amplifier's noise specification.

$$R_{S,\,OP} = \frac{e_n}{i_n} \qquad (7)$$

where:
e_n is input-referred voltage noise.
i_n is input-referred current noise.

Figure 6 shows a comparison of the voltage noise density of a number of high voltage (up to 44 V) op amps from Analog Devices, Inc., vs. $R_{S,\,OP}$ at 1 kHz. The diagonal line plots the Johnson noise associated with resistance.

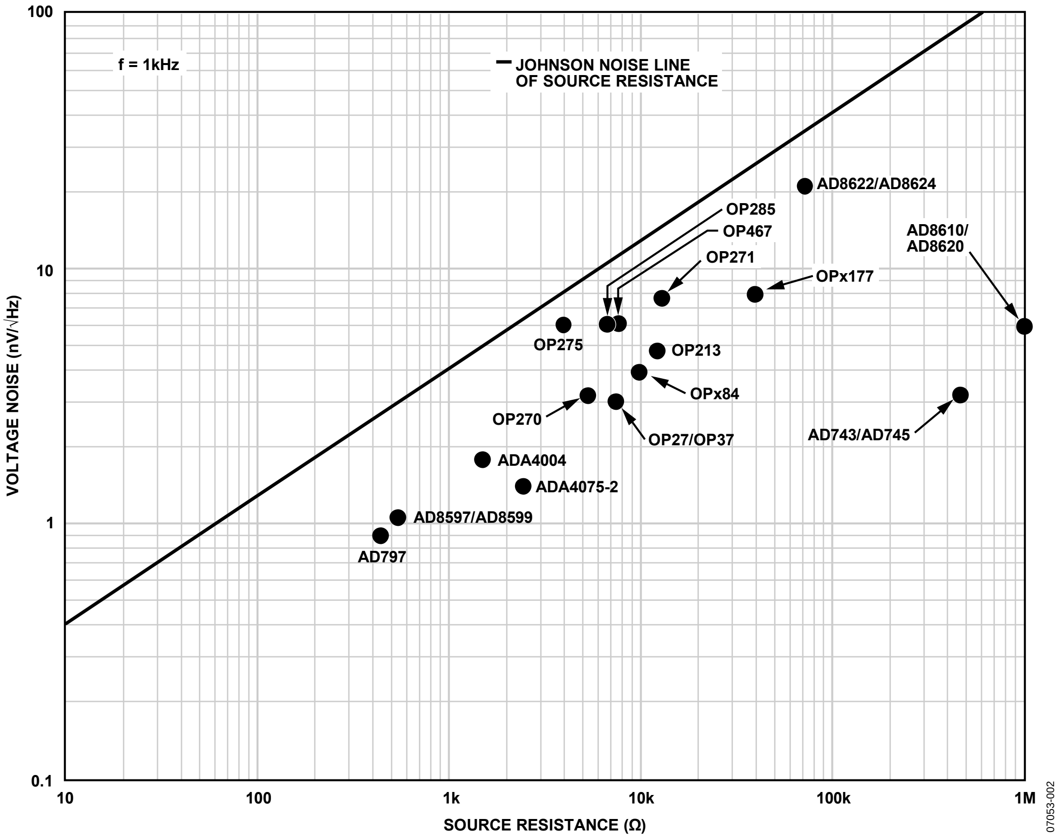

Figure 6. Analog Devices Op Amp Noise Plot

Similar types of graph can be constructed for a chosen frequency from the data in the op amp data sheet (see Figure 8). For example, the AD8599 has an input-referred voltage noise of 1.07 nV/√Hz and an input-referred current noise of 2.3 pA/√Hz at 1 kHz. The $R_{S,\,OP}$ is about ~465 Ω at 1 kHz. In addition, note the following:

- The Johnson noise associated with this device is equivalent to a source resistor of about 69.6 Ω (see Figure 6).
- For a source resistance above ~465 Ω, the noise voltage produced by the amplifier's current noise exceeds that contributed by the source resistance; the amplifier's current noise becomes the dominant noise source.

To use the graph (see Figure 7), follow Step 1 through Step 4.

1. Typically, the source resistances are known (such as sensor impedances). If the resistances are not known, calculate them from the surrounding or preceding circuit components.
2. Locate the given source resistance, such as 1 kΩ, on the Johnson noise line.
3. Create a horizontal line from the point located in Step 2 to the right of the plot.
4. Create a line down and to the left from the point located in Step 2) by decreasing one decade of voltage noise per one decade of resistance.

Any amplifiers below and to the right of the lines are good low noise op amps for the design as highlighted in the shade of gray in Figure 7.

For the example shown in Figure 7, the following devices are good candidates for the design: AD8597, AD8599, AD797, ADA4075-2, ADA4004, OP270, OP27/OP37, AD743/AD745, and OP184.

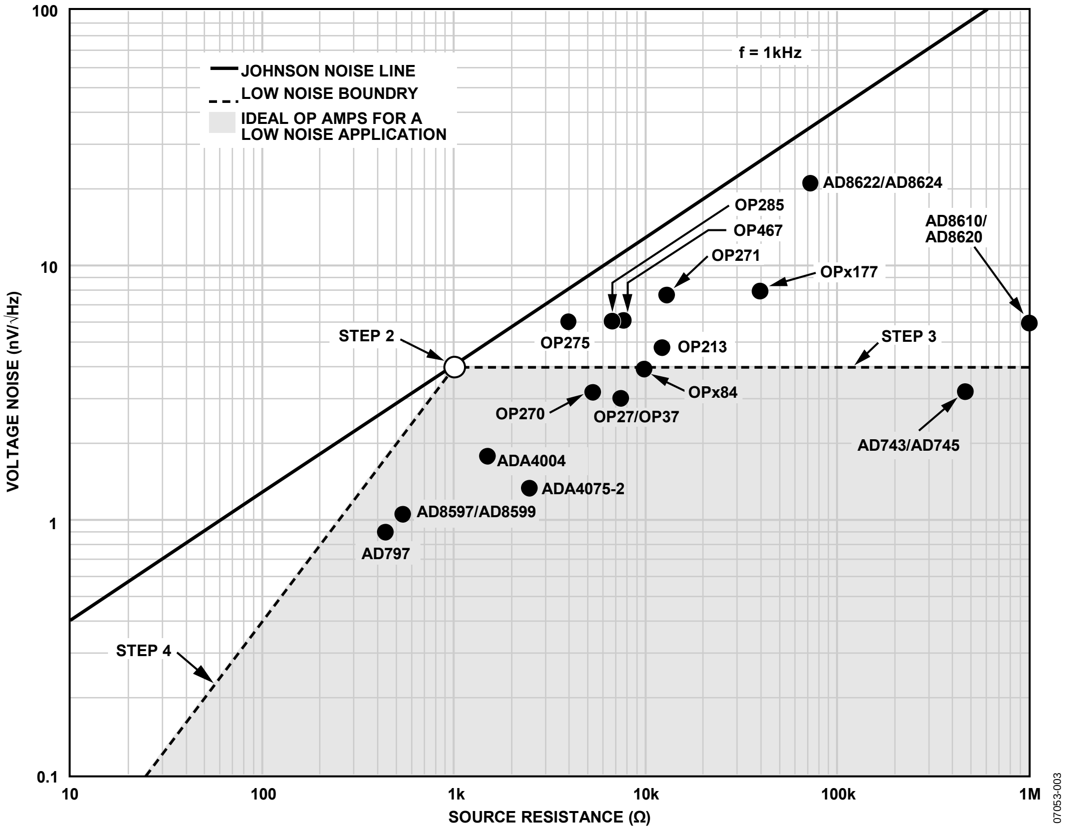

Figure 7. Selecting Op Amp for Low Noise Design

CONCLUSION

Consider all potential noise sources when evaluating an amplifier's noise performance for low noise design.

The key noise contribution of an op amp is dependent on source resistance as follows:

- $R_S >> R_{S, OP}$; input-referred current noise dominates.
- $R_S = R_{S, OP}$; amplifier noise and resistor noise are equal
- $R_S << R_{S, OP}$; input-referred voltage noise dominates.

In summary, reduce or eliminate interference signals by

- Proper layout techniques to reduce parasitics.
- Proper ground techniques, such as isolating digital and analog ground.
- Proper shielding.

For resistive noise sources, use the following rules:

- Restrict bandwidth to only what is necessary.
- Reduce resistor value where possible.
- Use low noise resistors, such as bulk metal foil, wirewound, and metal film technology resistors.
- Reduce the number of resistive noise sources where possible.
- Use Figure 8 and Figure 9 to assist with the selection of an Analog Devices low noise amplifier using the criteria described in this application note.

For more information on noise, see the article, "Noise Optimization in Sensor Signal Conditioning Circuit" available at http://www.analog.com/noiseoptimization.

PART NUMBER	V_{SY} (V)	V_{OS} MAX (µV)	TCV_{OS} (µV/°C)	GBP (MHz)	SLEW RATE (V/µs)	I_{SY}/AMP MAX (mA)	e_n @ 1kHz (nV/√Hz)	i_n @ 1kHz (pA/√Hz)	$R_{S, OP}$ @ 1kHz (Ω)	1/f CORNER (Hz)	I_B MAX (nA)	I_{SC} (mA)	CMRR MIN (dB)	PSRR MIN (dB)	NUMBER OF AMPS
AD797	10 TO 36	40	0.2	8	20	10.5	0.9	2	450	60	900	80	120	120	1
AD8597/ AD8599	9 TO 36	120	0.8	10	15	5.7	1.07	2.3	465	9	200	52	120	120	1/ 2
ADA4004-1/ ADA4004-2/ ADA4004-4	10 TO 36	125	0.7	12	2.7	2.2	1.8	1.2	1500	5	90	25	110	110	1/ 2/ 4
AD8676	10 TO 36	50	0.2	10	2.5	3.4	2.8	0.3*	—	10	2	40	111	106	2
AD8675	10 TO 36	75	0.2	10	2.5	2.9	2.8	0.3*	—	10	2	40	114	120	1
AD8671/ AD8672/ AD8674	10 TO 36	75	0.3	10	4	3.5	2.8	0.3*	—	10	12	30	100	110	1/ 2/ 4
ADA4075-2	±4.5 TO ±18	1000	0.3	6.5	12	2.25	2.8	1.2	2333	5	100	40	110	106	2
OP27	8 TO 44	100	0.3	8	2.8	5.7	3.2	0.4	8000	2.7	80	30	100	140	1
OP37	8 TO 44	100	0.3	40	17	4.7	3.2	0.4	8000	2.7	75	30	100	140	1
OP270 OP470	9 TO 36	75	0.2	5	2.4	3.25	3.2	0.6	5333	5	20	15	106	110	2/ 4
AD743	9.6 TO 36	1000	2	4.5	2.8	10	3.2	0.0069	463,768	50	0.4	40	80	90	1
AD745	9.6 TO 36	500	2	20	12.5	10	3.2	0.0069	463,768	50	0.25	40	90	100	1
OP184/ OP284/ OP484	3 TO 36	100	0.2	4.25	4	2	3.9	0.4	9750	10	450	10	86	90	1/ 2/ 4
AD8655/ AD8656	2.7 TO 5.5	250	0.4	28	11	4.5	4	—	—	3000	0.01	220	85	88	1/ 2
OP113 / OP213/ OP413	4 TO 36	150	0.2	3.4	1.2	3	4.7	0.4	11,750	10	600	40	96	100	1/ 2/ 4
SSM2135	4 TO 36	2000	—	3.5	0.9	3	5.2	0.5	10,400	3	750	30	87	90	2
ADA4528-1	2.2 TO 5.5	2.5	0.002	4	0.45	1.7	5.6*	0.7*	8000	NONE	0.4	30	135	130	1
OP285	9 TO 36	250	1	9	22	2.5	6	0.9	6667	125	350	30	80	85	2
AD8610/ AD8620	10 TO 27	100	0.5	25	60	3.5	6	0.005	1,200,000	1000	0.01	65	90	100	1/ 2
OP275	9 TO 44	1000	2	9	22	2.5	6	1.5	4000	2.24	350	14	80	85	2
OP467	9 TO 36	500	3.5	28	170	2.5	6	0.8	7500	8	600	40	80	96	4
ADA4627-1	9 TO 36	200	1	19	84	7.500	6.1	0.0016	3,812,500	250	5	45	106	106	1
OP471	9 TO 36	1800	4	6.5	8	2.75	6.5	0.4	16,250	5	60	10	95	95	4
OP1177/ OP2177/ OP4177	5 TO 36	60	0.2	1.3	0.7	0.5	7.9	0.2	39,500	10	2	25	120	120	1/ 2/ 4
AD8510/ AD8512/ AD8513	9 TO 36	400	1	8	20	2.5	8	—	—	100	0.08	70	86	86	1/ 2/ 4
AD8651/ AD8652	2.7 TO 5.5	350	4	50	41	14	8	0.025	320,000	10000	0.01	80	80	76	1/ 2
AD8646/ AD8647/ AD8648	2.7 TO 5.5	2500	1.8	24	11	1.5	8	—	—	1000	0.001	120	67	63	1/ 2(SD)/ 4
AD8605/ AD8606/ AD8608	2.7 TO 5.5	300	1	10	5	1.2	8	0.01	800,000	500	0.001	80	85	80	1/ 2/ 4
AD8691/ AD8692/ AD8694	2.7 TO 6	2000	1.3	10	5	1.05	8	0.05	160,000	3000	0.001	80	70	80	1(SD)/ 2(SD)/ 4(SD)
OP162/ OP262/ OP462	2.7 TO 12	325	1	15	13	0.8	9.5	0.4	23,750	10	600	30	70	60	1/ 2/ 4
OP07	6 TO 36	75	0.3	0.6	0.3	4	9.6	0.12	80,000	100	4	30	106	94	1
OP07D	8 TO 36	150	0.5	0.6	0.2	1.3	10	0.074	135,135	8	1	30	120	115	1
AD8677	8 TO 36	130	0.5	0.6	0.2	1.3	10	0.074	135,135	8	1	30	120	115	1
AD8615/ AD8616/ AD8618	2.7 TO 5.5	500	1.5	24	12	2	10	0.05	200,000	1000	0.001	150	80	70	1/ 2/ 4
AD8519/ AD8529	2.7 TO 12	1100	2	8	2.9	1.2	10	0.4	25,000	80	300	70	63	60	1/ 2
AD8665/ AD8666/ AD8668	5 TO 16	2500	3	4	3.5	1.55	10	0.1	100,000	1000	0.001	140	90	98	1/ 2/ 4
AD8622/ AD8624	4 TO 36	125	0.5	0.56	0.48	0.250	11	0.15	73,333	20	200	40	125	125	2/ 4
AD8661/ AD8662/ AD8664	5 TO 16	160	4	4	3.5	1.55	12	0.1	120,000	1000	0.001	140	90	95	1/ 2/ 4
OP97 OP297 OP497	4 TO 40	75	0.3	0.9	0.2	0.38	14	0.02*	1,166,667	200	0.15	10	110	110	1/ 2/ 4
OP777/ OP727/ OP747	3 TO 36	100	0.3	0.7	0.2	0.35	15	0.13	115,384	20	11	30	110	120	1/ 2/ 4

07053-004

*REFER TO DEVICE DATA SHEET FOR SPECIFICATION CONDITIONS.

Figure 8. Analog Devices Low Input Voltage Noise Amplifier Selection Table

PART NUMBER	V_{SY} (V)	V_{OS} MAX (μV)	TCV_{OS} (μV/°C)	GBP (MHz)	SLEW RATE (V/μs)	I_{SY}/AMP MAX (mA)	e_n @ 1kHz (nV/√Hz)	i_n @ 1kHz (fA/√Hz)	$R_{S,\ OP}$ @ 1kHz (Ω)	1/f CORNER (Hz)	I_B MAX (pA)	I_{OUT} (mA)	CMRR MIN (dB)	PSRR MIN (dB)	NUMBER OF AMPS
AD549	10 TO 36	500	10	5	3	0.7	35	0.22	159,090,909	100	0.06	20	90	90	1
AD8627/ AD8626/ AD8625	10 TO 26	750	2.5	5	5	0.850	16	0.5	35,000,000	-	1	15*	76	80	1/ 2/ 4
AD8641/ AD8642 AD8643	5 TO 26	750	2.5	3.5	3	0.290	27.5	0.5	57,000,000	250	1	12*	90	90	1/ 2/ 4
AD820/ AD822/ AD824	5 TO 36	1000	2	1.9	3*	0.900	16	0.8	20,000,000	90	10	15*	74*	70	1/ 2/ 4
ADA4627-1	8 TO 36	200	1	19	84	7.500	6.1	1.6	3,812,500	250	5	45	106	106	1
AD548K/B	9 TO 36	500	5	1	1.8	0.2	30	1.8	16,666,666	700	10	15	82	86	1
AD8610/ AD8620	10 TO 26	100	0.5	25	60	3.500	6	5	1,200,000	1000	10	45	90	100	1/ 2
ADA4062-2 ADA4062-4	8 TO 36	2500	4	1.4	3.3	0.220	36	5	7,200,000	30	50	20	73	74	2/ 4
AD743	9.6 TO 36	1000	2	4.5	2.8	10	3.2	6.9	463,768	50	0.4	40	80	90	1
AD745	9.6 TO 36	500	2	20	12.5	10	3.2	6.9	463,768	50	0.25	40	90	100	1
AD711C	9 TO 36	250	5	4	20	2.8	18	10	1,800,000	200	25	25	86	86	1
AD8605/ AD8606/ AD8608	2.7 TO 6	300	1	10	5	1.2	8	10	800,000	500	1	80	85	80	1/ 2/ 4
OP282/ OP482	9 TO 36	3000	10	4	9	0.250	36	10	3,600,000	40	100	10	70	110	2/ 4
AD8682 AD8684	9 TO 36	1000	10	3.5	9	0.250	36	10	3,600,000	40	20	10	70	92	2/ 4
ADA4000-1 ADA4000-2 ADA4000-4	8 TO 36	1700	2	5	20	1.650	16	10	1,600,000	100	40	28	80	82	1/ 2/ 4
OP97/ OP297/ OP497	4 TO 40	75*	0.3*	0.9*	0.2*	0.38*	14*	20*	1,166,667*	200*	150	10	110*	110*	1/ 2/ 4
AD8651/ AD8652	2.7 TO 5.5	350	4	50	41	14	8	25	320,000	10,000	10	80	80	76	1/ 2
AD8615/ AD8616/ AD8618	2.7 TO 6	500	1.5	24	12	1.3	10	50	200,000	1000	1	150	80	70	1/ 2/ 4
AD8691/ AD8692/ AD8694	2.7 TO 6	2000	1.3	10	5	1.05	8	50	160,000	3000	1	80	70	80	1(SD)/ 2(SD)/ 4(SD)
AD8661/ AD8662/ AD8664	5 TO 6	160	4	4	3.5	1.55	12	100	120,000	1000	1	140	90	95	1/ 2/ 4
OP07	6 TO 36	75	0.3	0.6	0.3	4	9.6	120	80,000	100	4000	30	106	94	1
AD8622/ AD8624	5 TO 36	125	0.5	0.56	0.48	0.250	11	150	73,333	20	200	40	125	125	2/ 4

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*REFER TO DEVICE DATA SHEET FOR SPECIFICATION CONDITIONS.

Figure 9. Analog Devices Low Input Current Noise Amplifier Selection Table

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