

# DESIGN NOTES

## Updated Operational Amplifier Selection Guide for Optimum Noise Performance – Design Note 140

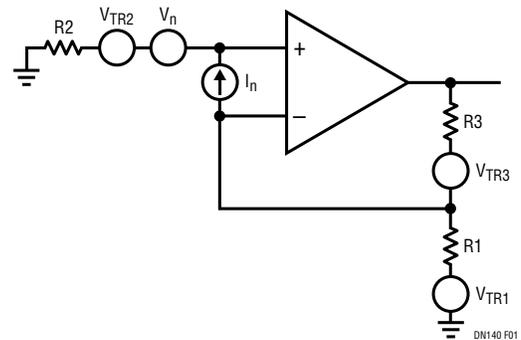
Frank Cox

Eight years ago, George Erdi wrote a very useful Design Note (DN6) that presented information to aid in the selection of op amps for optimum noise performance, in both graphical and tabular form. Design Note 140 is an update of DN6. It covers new low noise op amps as well as some high speed op amps. Although a great deal has changed in eight years, especially in electronics, noise is still a critical issue in op amp circuit design and the LT<sup>®</sup>1028 is still the lowest noise op amp for low source impedance applications.

The amount of noise an op amp circuit will produce is determined by the device used, the total resistance in the circuit, the bandwidth of the measurement, the temperature of the circuit and the gain of the circuit. A convenient figure of merit for the noise performance of an op amp is the spectral density or spot noise. This is obtained by normalizing the measurement to a unit of bandwidth. Here the unit is 1Hz and the noise is reported as “nV/√Hz.” The noise in a particular application bandwidth can be calculated by multiplying the spot noise by the square root of the application bandwidth.

Some other simplifications are made to facilitate comparison. For instance, the noise is referred to the input of the circuit so that the effect of the circuit gain, which will vary with application, does not confuse the issue. Also, the calculations assume a temperature of 27°C or 300°K.

The formula used to calculate the spot noise and the schematic of the circuit used are shown in Figure 1. Figures 2 through 4 plot the spot noise of selected op amps vs the equivalent source resistance. The first two plots show precision op amps intended for low frequency applications, whereas the last plot shows high speed voltage-feedback op amps. There are two plots for the low frequency op amps because at very low frequencies (less than about 200Hz) an additional noise mechanism, which is inversely proportional to frequency, becomes important. This is called 1/f or flicker noise. Figure 2 shows slightly higher levels of noise due to this contribution.



WHERE:  $V_{TR1}$ ,  $V_{TR2}$  AND  $V_{TR3}$  ARE THERMAL NOISE FROM RESISTORS

$$R_{eq} = R2 + \left( \frac{(R1)(R3)}{R1 + R3} \right)$$

$$4kT = (16.56)(10)^{-21} \text{ J}$$

AND  $V_n$  IS THE VOLTAGE SPOT NOISE AND  $I_n$  IS THE CURRENT SPOT NOISE OF THE OP AMP AS GIVEN ON THE DATA SHEET.

$$V = \sqrt{(4kT)R_{eq} + V_n^2 + I_n^2(R_{eq}^2)}$$

IS THE INPUT REFERRED SPOT NOISE IN A 1Hz BANDWIDTH.

Figure 1

Studying the formula and the plots leads to several conclusions. The values of the resistors used should be as small as possible to minimize noise, but since the feedback resistor is a load on the output of the op amp, it must not be too small. For a small equivalent source resistance, the voltage noise dominates. As the resistance increases, the resistor noise becomes most important. When the source resistance is greater than 100k, the current noise dominates because the contribution of the current noise is proportional to  $R_{eq}$ , whereas the resistor noise is proportional to the  $\sqrt{R_{eq}}$ .

For low frequency applications and a source resistance greater than 100k, the LT1169 JFET input op amp is the obvious choice. Not only does the LT1169 have an extremely low current noise of  $0.8\text{fA}/\sqrt{\text{Hz}}$ , it also has a very low voltage noise of  $6\text{nV}/\sqrt{\text{Hz}}$ . The LT1169 also has excellent DC specifications, with a very low input bias current of 3pA (typical), which is maintained over the input common mode range, and a high gain of 120dB.

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High speed op amps, here defined by slew rates greater than  $100\text{V}/\mu\text{s}$ , are plotted in Figure 4. These op amps come in a wider range of speeds than the precision op amps plotted in Figures 2 and 3. The faster parts will generally have slightly more spot noise, but because they will most likely be selected on the basis of speed, a selection of parts is plotted. For example, the LT1354–LT1363 (these are single op amps; duals and quads are available) are close in noise performance and consequently cluster close together on the plot, but have a speed range of 12MHz GBW to 70MHz GBW.

The same information is presented in tabular form in Table 1.

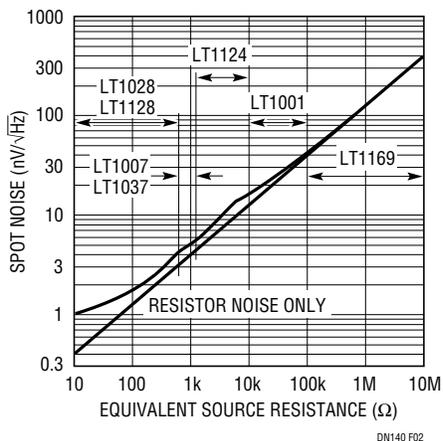


Figure 2. 10Hz Spot Noise vs Equivalent Source Resistance

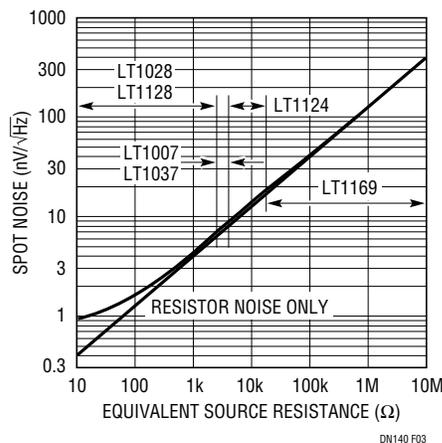


Figure 3. 1kHz Spot Noise vs Equivalent Source Resistance

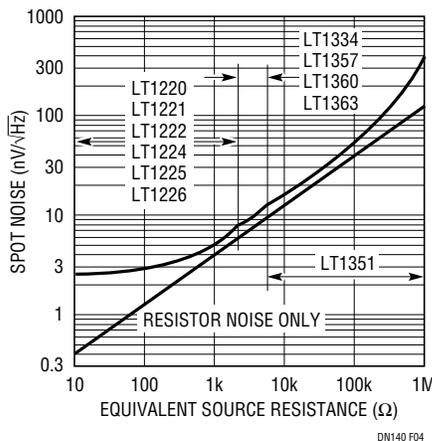


Figure 4. 10kHz Spot Noise vs Equivalent Source Resistance (High Speed Amplifiers)

Table 1. Best Op Amp for Lowest Noise vs Source Resistance

SOURCE R ( $R_{eq}$ )	BEST OP AMP		
	10Hz PRECISION	1000Hz PRECISION	10kHz HIGH SPEED
0Ω to 500Ω	LT1028, LT1115, LT1128	LT1028, LT1115, LT1128	LT1220/21/22/24/25/26
500Ω to 1.5k	LT1007, LT1037	LT1028, LT1115, LT1128	LT1220/21/22/24/25/26
1.5k to 3k	LT1124/25/26/27	LT1028, LT1115, LT1128	LT1220/21/22/24/25/26
3k to 5k	LT1124/25/26/27	LT1007, LT1037	LT1220/21/22/24/25/26
5k to 10k	LT1124/25/26/27	LT1124/25/26/27	LT1354/57/60/63
10k to 20k	LT1001/02	LT1113, LT1124/25/26/27	LT1354/57/60/63
20k to 100k	LT1001/02	LT1055/56/57/58, LT1113, LT1169	LT1351
100k to 1M	LT1022, LT1055/56/57/58, LT1113, LT1122, LT1169	LT1022, LT1055/56/57/58, LT1113, LT1122, LT1169, LT1457	LT1351
1M to 10M	LT1022, LT1055/56/57/58, LT1113, LT1122, LT1169	LT1022, LT1055/56/57/58, LT1113, LT1122, LT1169, LT1457	

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