JFET Op Amps Equal Low Noise Bipolars and Have Picoamp Current Noise

by Alexander Strong

The LT1792 and LT1793 are single JFET op amps that offer both very low voltage noise (4nV/√Hz for the LT1792 and 6nV/√Hz for the LT1793) and low current noise (10fA/√Hz for the LT1792 and 0.8fA/√Hz for the LT1793), providing the lowest total noise over a wide range of transducer impedance. Traditionally, op amp users have been faced with a choice: which op amp will have the lowest noise for the transducer at hand. For high transducer impedance, the LT1792/LT1793 JFET op amps will win over the lowest voltage noise bipolar op amps due to lower current noise. The current noise ($2qI_B$) of an amplifier is a function of the input bias current (I_B). For lower transducer impedance, bipolar op amps usually win over typical JFET op amps due to lower voltage noise for the same tail current of the differential input pair. The LT1792/LT1793 op amps are designed to have voltage noise that approaches that of bipolar op amps. All of these op amps are unconditionally stable for gains of one or more, even with capacitive loads of 1000pF. The low offset voltage of 250µV and high DC gain of four million allow the LT1792/LT1793 to fit into precision applications. Voltage noise, slew rate and gain-bandwidth product are 100% tested. All of the specifications are maintained in the SO-8 package.

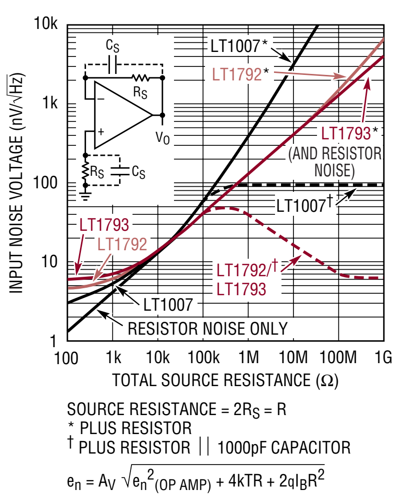


Figure 1. Comparison of LT1792/LT1793 and LT1007 input voltage noise vs source resistance

The combination of low voltage and current noise offered by the LT1792/LT1793 makes them useful in a wide range of applications, especially with high impedance, capacitive transducers such as hydrophones, precision accelerometers and photo diodes. The total noise in such systems is the gain times the square root of the sum of the op amp input–referred voltage noise squared, the thermal noise of the transducer (4kTR) and the op amp's bias current noise times the transducer resistance squared ($2qI_B \times R^2$). Figure 1 shows total input voltage noise versus source resistance. In a low source resistance application (<5k), the op amp's voltage noise will dominate the total noise. In this region of low source resistance, the LT1792/LT1793 JFET op amps are way ahead of other JFET op amps; only very low noise bipolar op amps such as the LT1007 and LT1028 have the edge. As source resistance increases from 5k to 50k, the LT1792/LT1793 will match the best bipolar or JFET op amp for noise performance, since the thermal noise of the transducer (4kTR) will dominate the total noise. A further increase in source resistance, to above 50k, brings us to the region where the op amp's current noise ($2qI_B \times R_{SOURCE}$) will dominate the total noise. At these high source resistances, the LT1792/LT1793 will outperform the lowest noise bipolar op amp due to the inherently low current noise of FET input op amps. In some conditions it may be necessary to add a capacitor in parallel with a source resistor to cancel the pole that is caused by the source impedance and the input capacitance (14pF for the LT1792 and 1.5pF for the LT1793). Observe what happens to noise with source resistances over 100k; the overall noise for the LT1792 and LT1793 actually decreases.

Table 1. LT1792/LT1793 specifications

Parameter	LT1792	LT1793	Units
V_{OS} (Max)	0.56	0.73	mV
I_B (Max)	450	10	pA
e_N (1kHz)	4.2	6	nV/√Hz
i_N (1kHz)	10	0.8	fA/√Hz
GBWP (f_O = 100kHz)	6	5	MHz
I_S	4.2	4.2	mA

The high input impedance JFET front end makes the LT1792 and LT1793 suitable for applications where very high charge sensitivity is required. Figure 2 illustrates the LT1792 and LT1793 in inverting and noninverting modes of operation. A charge amplifier is shown in the inverting mode example; here the gain depends on the principle of charge conservation at the input of the amplifier. The charge across the transducer capacitance, C_S, is transferred to the feedback capacitor, C_F, resulting in a change in voltage, dV, equal to dQ/C_F, resulting in a gain of C_F/C_S. For unity gain, the C_F should equal the transducer capacitance plus the input capacitance of the amplifier and R_F should equal R_S. In the noninverting mode example, the transducer current is converted to a change in voltage by the transducer capacitance; this voltage is then buff-

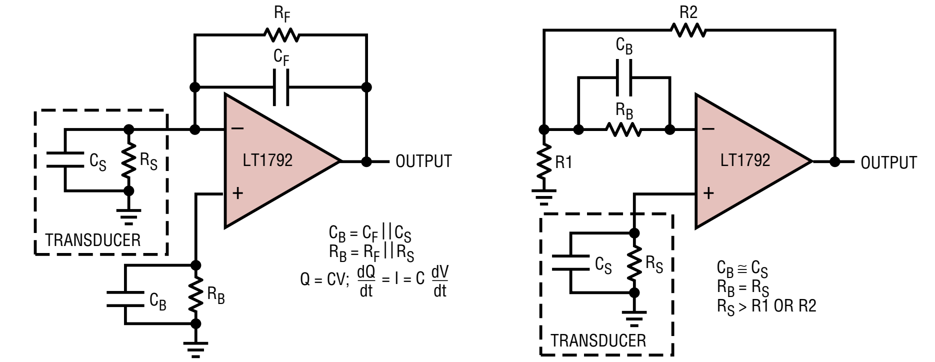


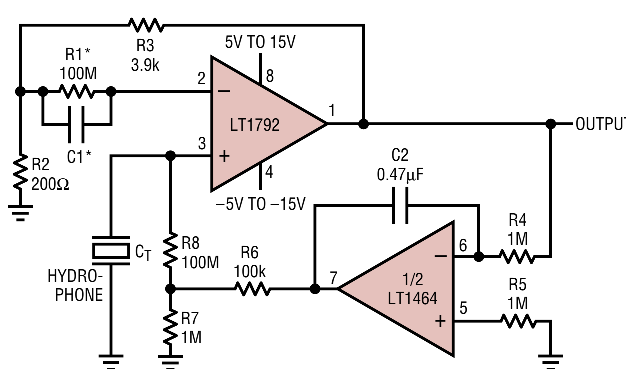
Figure 2. LT1792/LT1793 inverting and noninverting gain configurations

ered by the amplifier, with a gain of 1 + R2/R1. A DC path is provided by R_S, which is either the transducer impedance or an external resistor. Since R_S is usually several orders of magnitude greater than the parallel combination of R1 and R2, R_B is added to balance the DC offset caused by the noninverting input bias current and R_S. The input bias currents, although small at room temperature, can create significant errors over increasing temperature, especially with transducer resistances of up to 1000M or more. The optimum value for R_B is determined by equating the thermal noise ($4kTR_S$) to the current noise times R_S, ($2qI_B$) R_S, resulting in $R_B = 2V_T/I_B$ ($V_T = kT/q = 26mV$ at 25°C). A parallel capacitor, C_B, is used to cancel the phase shift caused by the op amp input capacitance and R_B.

The LT1792 has the lowest voltage noise ($4nV/\sqrt{Hz}$) of the two, which makes it the best choice for transducer impedances of 5k or less. For transducer impedances over 100M, the LT1793, with a typical input bias current of only 3pA, will have lower output noise than the LT1792. The LT1793 has the additional advantage of very high input resistance (10^{13} ohms). Unlike most JFET op amps, the LT1792 and LT1793 have input bias currents that remains almost constant over the entire common mode range. The specifications for the LT1792 and LT1793 are summarized in Table 1.

The low noise of the LT1792 and LT1793 is achieved by maximizing the g_m of the input pair. The polygate JFETs have a higher g_m-to-area ratio than standard, single-gate JFETs. This is done by maximizing the tail current and the size of the input JFET geometeries. Forty percent of the total supply current is used as the tail current for the LT1792 and LT1793. These op amps are best used with very high impedance transducers. The low noise hydrophone amplifier in Figure 3 is an application where the LT1792 excels. The AC current output of the hydrophone is converted to a voltage output by the 100M input resistor (R8). This signal is amplified by the R3/R2 ratio. DC leakage currents at the output of the hydrophone are subtracted by the servo action of the feedback amplifier. This amplifier need not have the low voltage noise of the LT1792; therefore, it can be chosen to minimize the overall system supply current. The LT1464 has less than an order of magnitude of supply current of the LT1792 and LT1793 and picoampere input bias current. This allows the time constant of this loop to be set using high value resistors and less expensive low value capacitors.

The LT1792 and LT1793 op amps are in a class by themselves when amplifying low level signals from high impedance sources. The design and process have been optimized to produce both low power consumption and low current and voltage noise. Most competing JFET op amps will have higher voltage noise or much higher supply current. Practically all bipolar op amps will have higher current noise. No other op amp will deliver the noise performance for a given supply current. For applications where low noise and power are issues, the LT1792 and LT1793 are the best choices.



DC OUTPUT ≤ 2.5mV FOR T_A < 70°C
OUTPUT VOLTAGE NOISE = $128nV/\sqrt{Hz}$ AT 1kHz (GAIN = 20)
C1 ≈ C_T ≈ 100pF TO 5000pF; R4C2 > R8C_T; *OPTIONAL

Figure 3. Low noise hydrophone amplifier with DC servo

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