Two-wire remote sensor preamp

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This Design Idea implements a remote sensor preamp (e.g., for a piezoelectric transducer) which transfers both signal and power over a single wire pair or coax.

![Diagram of a remote preamplifier](image)

**Figure 1** A remote preamplifier

The **AD822ARZ** is a true single-supply operational amplifier with rail-to-rail output, and with very low input current and low frequency noise, ideal for operating with high impedance signal sources. The AD822 has single-supply capability from 5V, making it a good choice here.

R6 provides a matching load to the piezoelectric sensor. R5 and D1 protect IC1-1 from high voltage spikes, which are possible from piezoelectric sensors. IC1-1 provides primary gain (approximately 1+R7/R8 in the operating frequency range) and part of the gain-frequency characteristic. R8 & C6 suppress subsonic frequencies (cutoff frequency of 1/2πR8C6) and provide linearization of the frequency response of the sensor. The combination R7-C5 suppresses frequencies above the operating frequency range (a cutoff frequency 1/2πR7C5). Additional lowpass filters are R10-C9 and R13-C11. The main highpass filter is a second-order filter which provides suppression of subsonic frequencies, built around IC1-2. The output of the preamp is the open collector of Q2. A load for Q2 (Rg: 1.5kΩ) is placed at the receiver.
The preamp’s power supply involved the following considerations: The divider R2, R9, C7 provides offsetting voltage of half the supply (R2=R9) for both parts of IC1 (through R6, R11). The quiescent current $I_q$ of the AD822 assuming a 5V power supply is 1.6mA maximum. Investigation has shown that a collector current $I_c$ of the output transistor (without signal) should be several times $I_q$. $R_{14}$ is used to set $I_q$, calculated as $R_{14} < \frac{(V_s/2 - V_{EB})}{I_q} = \frac{(5V/2 - 0.68V)/1.6mA}{1.14k\Omega}$ ($0.68V$ is a type emitter-base voltage ($V_{EB}$) for these transistors in active mode). So, let $R_{14}$ be 560Ω. Thus, the collector current $I_c$ of the output transistor is $(V_s/2 - V_{EB})/R_{14}$. The base current of $Q_2$ is small enough to be ignored, given the $h_{FE}$ of a BC847C is not less than 420. So, $I_c = \frac{(5V/2 - 0.68V)/560\Omega}{1.14k\Omega} = 3.25mA$. The maximum current through the collector load (without signal) is: $I_{max} = I_c + I_q = 3.25mA + 1.6mA = 4.85mA$.

Investigations show that using typical voltage regulator ICs is not feasible due to the high level of noise which will be reflected in the load resistor. Simulations do not show this phenomenon. The best solution is the simple Q1 circuit. The output voltage $Vs$ at Q1’s emitter is:

$$Vs = (V_{ext} - R_g*I_{max})*R_3/(R_3+R_4) - V_{EB}$$

($V_{ext}$ is the external DC voltage (15V), $V_{EB} = 0.68V$.)

$$Vs = (15V - 1.5k\Omega*4.85mA)*68k\Omega/(20k\Omega+68k\Omega) - 0.68V = 5.3V$$

This value is approximate; in reality, $Vs$ will be less because the formula does not take into account Q1’s base and voltage divider current. It is suggested that $R_3$-$R_4$ divider current be a minimum of 10x more than the base current of Q1. The AC component on the collector of Q1 is filtered out by $C_4$. $C_4$’s value should be chosen depending on the lowest operating frequency of the preamplifier. The corner frequency, $1/2\pi R_3C_4$, should be at least 10x lower than the low end of the preamp’s passband.

The $R_1$-$C_3$ network is optional; if present, $C_3$ should be lowered if a wider HF bandpass is desired. $C_9$ is optional too; it affects the high-frequency range. The value of the decoupling capacitor $C_1$ can be decreased to 10uF if desired.

The preamp as shown provides 26dB gain ($R_g=1.5k\Omega$) with a passband of about 8Hz - 36Hz. The maximum AC output voltage is about 5Vp-p ($\pm2.4V$ from a quiescent point of about 7.8VDC). The current draw of the real devices is 4.8mA.

This solution has worked reliably and consistently on 28 units so far, with wire lengths up to 150m. See below.