Application Note

Noise Performance of Minisense 100 using B&K 2635 Charge Preamplifier

1. Introduction

It is not easy using conventional instrumentation to evaluate the electronic noise performance of a piezo film vibration sensor in isolation, as the basic performance of the device depends heavily on what form of electrical load is connected across its terminals. A conventional digital oscilloscope or dynamic signal analyzer presents a relatively low input impedance (1 M ohm), and therefore will not allow the true performance of the sensor to be measured at low frequencies. With physically small components such as the Minisense 100 (with capacitance in the region of 240 pF), this problem is quite severe. Some form of preamplifier or buffer is required, to allow the full bandwidth of sensitivity (and noise) to be detected. This note summarizes results obtained using a charge-mode preamplifier.

2. Instrumentation used:

1 off Minisense 100H (p/n 1005939-1)
1 off Brüel & Kjær Type 2635 Charge Amplifier
1 off Hewlett-Packard 3561A Dynamic Signal Analyzer

The charge amplifier was set to an arbitrary sensitivity of 1.0 pC/unit, with output gain 100 mV/unit, giving effective sensitivity of 100 mV/pC. The lower limiting frequency (LLF) was set to 0.2 Hz. This setting gives –10% sensitivity at 0.2 Hz, and is equivalent to a –3 dB frequency of 0.1 Hz.

The 3561A analyzer was set up (in most cases) to perform free-running RMS averages using Hanning window, and to calculate voltage spectral density results (sqrt[mag/BW]).

3. Determining preamplifier noise floor

To check the performance of the preamplifier "alone" (i.e. without contribution from any piezoelectric effect), the noise level was measured using a passive capacitor of value equivalent to the Minisense sensor (243 pF).

This test was performed on two different frequency spans: 40 Hz (each time record 10 s in duration), and 4 Hz (100 s time records). The results from both data sets are shown on the plot below, together with a simulated curve which was fitted the data sets. The numerical approximation was based on conservative values of noise at 8 log-spaced frequencies.

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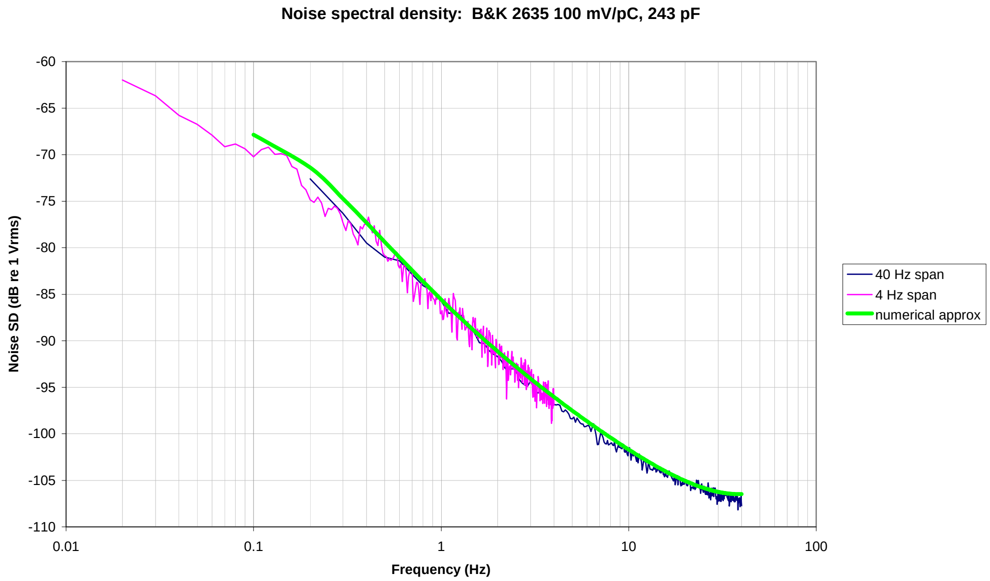
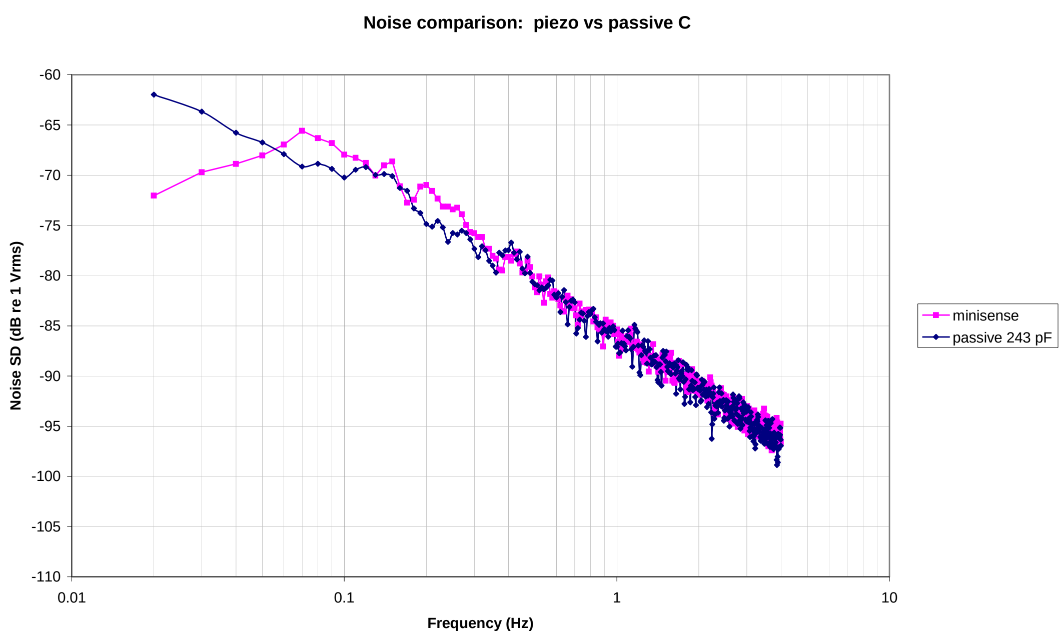


As might be expected, the noise increases in magnitude as the frequency decreases. It appears to "level out" at the upper end. Note that the typical sensitivity of the Minisense component begins to increase at higher frequencies (due to resonance at 75 Hz), and has already reached +3 dB at approximately 42 Hz.

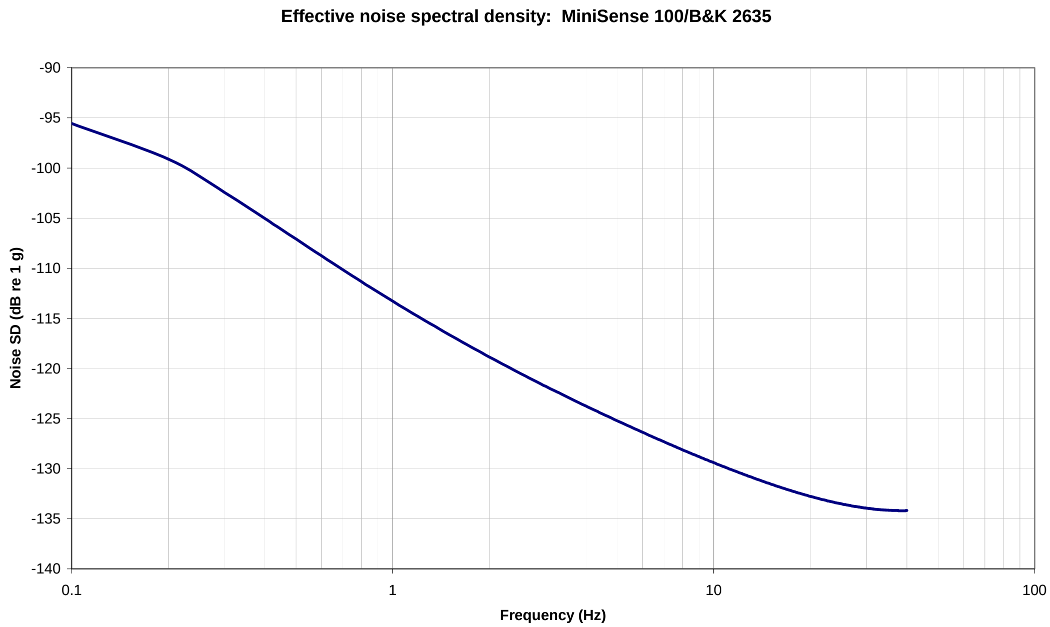
4. Comparison of piezo sensor with passive capacitor

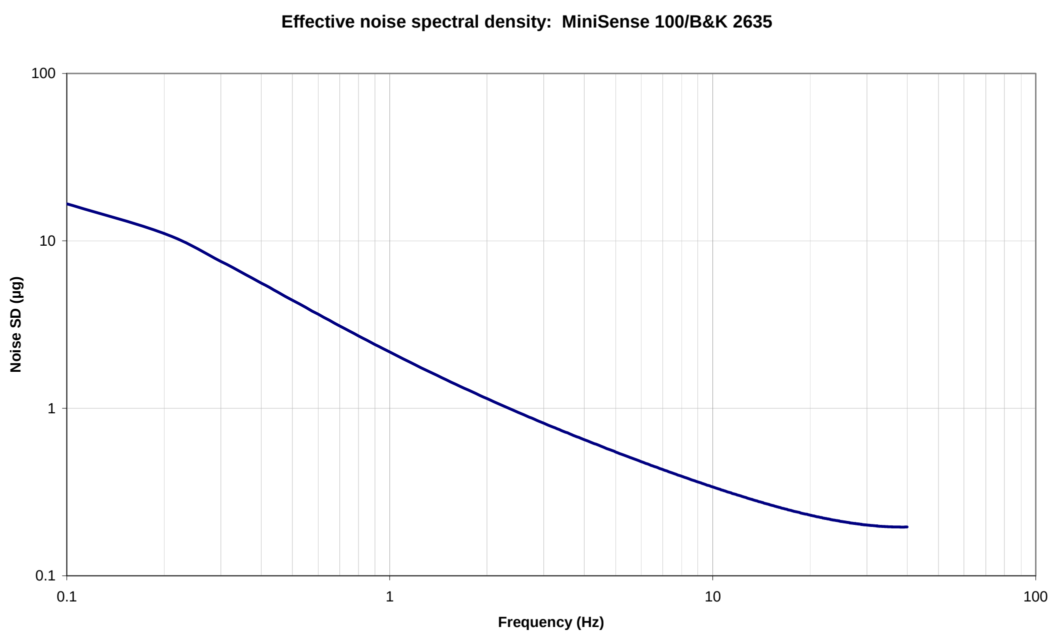
Next, the Minisense component was connected to the preamplifier in place of the passive capacitor, and the 4 Hz span test was repeated. This range was chosen to minimize any influence of acoustic noise or vibration which could have been present, despite the test being run in a quiet room with solid floor. The piezo sensor was supported in a fashion which should have prevented any seismic deflection of the mass. Only a slight increase in noise signal was observed between 0.05 Hz and 0.3 Hz. The two plots are overlaid below:



5. Converting voltage spectral density to units of acceleration

The above plots show voltage spectral density as measured at the output of the charge amplifier. The sensitivity of the Minisense was known to be 1 V/g, and its capacitance measured at 243 pF, giving a charge sensitivity of 243 pC/g. Therefore, the charge amplifier output can be scaled by the 100 mV/pC gain setting and 243 pC/g device sensitivity to give equivalent noise in units of g (acceleration) for this combination of sensor and preamplifier (both log and lin units are shown below):





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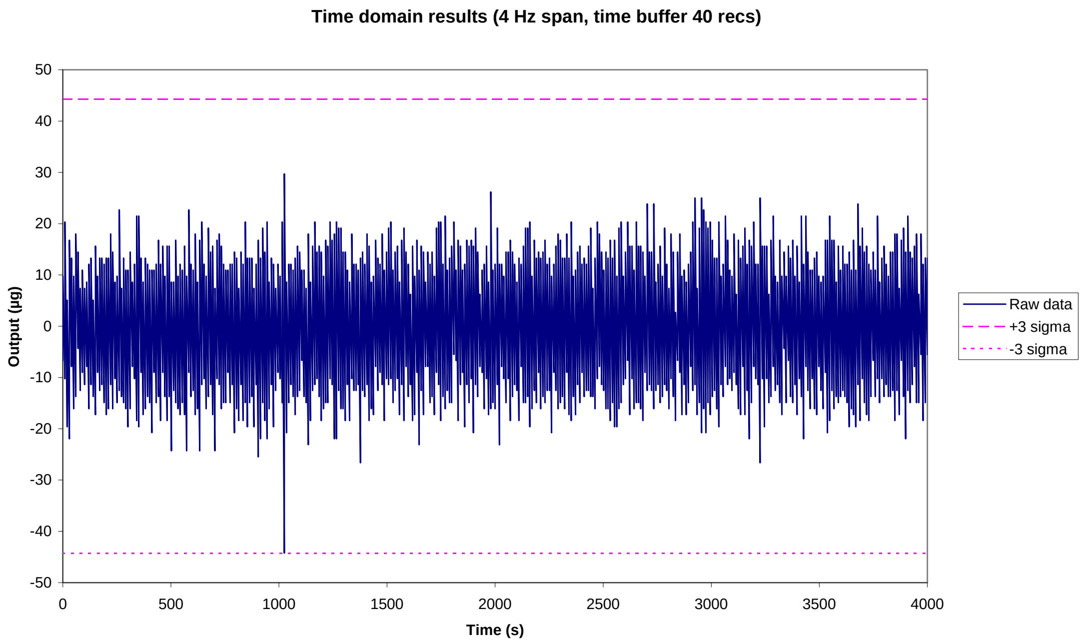
Note that the effective noise floor is quite impressive: around 2 µg at 1 Hz, and around 0.3 µg at 10 Hz. However, in any real application, the full time-domain picture may be as or more important than the above spectral plots.

6. Time-domain signals

Since noise is known to be strongest at low frequencies, a "worst-case" situation (frequency span of 4 Hz, overall measurement time of 4,000 s) was examined. Once again, the output voltage of the charge amplifier was scaled to give units of g (acceleration). After removal of a steady DC offset voltage of 2 mV, a quasi-random signal of 14.8 µg RMS (= standard deviation) was measured. The full trace, with +/- 3 sigma levels overlaid, is shown below:



From the above waveform, it is clear that although signals in the 1 µg magnitude range may be resolvable in the frequency domain, it would be virtually impossible to detect these from simple inspection in the time domain. (Note as an example: it would be very difficult to conclude whether the negative-going transient signal at 1025 s in the above trace, value –44 µg, resulted from pure electronic noise, or was a valid acceleration event).