**-190 dBV²/Hz Preamplifier for Low Frequency Noise Measurements**

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**Abstract.** Low cost highly sensitive preamplifier was made by using the commercially available operational amplifier AD797 which has the input noise equivalent power of -190 dBV²/Hz with 80 dB amplification.

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**INTRODUCTION**

The AD797 of Analog Devices Co. has the low input noise of 0.9 nV/(Hz)¹/² and low total harmonic distortion of -120 dB at audio frequencies. In order to improve the input sensitivity of the preamplifier, we used 16 AD797 in parallel to the feedback resistance of 10/100 Ω for each input stage followed by the same single AD797 2nd stage amplifier. Each stage amplifies 40 dB, and the input noise power must be reduced to 1/4 for 16 parallel amplifiers, 0.23 nV/(Hz)¹/² (-193 dBV²/Hz). Each device requires DC current of 30 mA at ±12 V, 12W in total, and fairly large heat sink is necessary to reduce the heating up of the device. The highest sensitivity of about -190 dBV²/Hz is realized between 100 Hz and 10 kHz. The input impedance of this amplifier is 1.5 kΩ with the capacitance of 320 pF.

**HIGHLY SENSITIVE PREAMPLIFIER**

The preamplifier is the key device in noise measurements and the highly sensitive wide range reliable preamplifier is necessitated to improve the measuring technology. Typical preamplifier #113 of PAR/EG&G has the input sensitivity of 1nV/(Hz)¹/² below 100 Hz [1], but we may need further sensitivity to detect more small noise levels in a wider frequency range. The extension to the lower frequency limit is required especially in measuring small level RTS noises, and to the higher frequency limit in assigning the shallow trap levels at elevated temperatures.
We used parallel connection of 16 AD797 operational amplifiers to reduce the input equivalent noise level [2], [3], followed by a single summing amplifier together with the zero balance circuit and 80 dB gain, as is shown in Fig. 1. The amplifier AD797 made by Analog Devices has the sensitivity of 0.9 nV/(Hz)^{1/2} with the low total harmonic distortion of -120 dB at audio frequency. Low feedback resistances (10 Ω, 1 kΩ) were used in the non-inverting amplifier circuit to reduce the input noise and obtain 40 dB gain. Input noise equivalent power is expected to decrease to 1/16^{1/2}, 0.25 nV/(Hz)^{1/2}.

![Noninverting amplifier circuits](image1)

**FIGURE 1.** Preamplifier Block Diagram.

The coupling capacitor in the input terminal is set 1.1 mF and the resistance 15 kΩ.

The first stage output voltage includes DC voltages induced by the offset voltages and drifts [4], as well as by the leakage currents within the coupling capacitors and the circuit boards. These DC voltages are eliminated by the zero correction feedback circuit in the second stage. In order to reduce the thermal fluctuations appearing in the low frequency region below 1 Hz, 16 operational amplifiers are enclosed in the 8-Lead Standard Small Outline Package (SOIC) and further effectively cooled down by the heat sink via a gel sheet, as shown in Fig. 2. The amplifiers are powered using batteries at ±6V. Figure 3 shows the printed circuit board of the amplifier.

![Attachment of AD797 to heat sink](image2)

**FIGURE 2.** Attachment of AD797 to heat sink.
RESULTS

The noise power spectrum density of our preamplifier was measured by a dynamic signal analyzer HP35665A. The output noise power spectrum densities are shown in Fig. 4 for 1. shorted input, 2. input resistance 10 Ω, 3. 10 Ω with coupling capacitor 1.1 mF, 4. 10 Ω with 11mF. The noise equivalent power of the shorted input indicates -190 dBV^2/Hz above 100 Hz, while the equivalent input resistance changes by frequency between 10 Ω and 1.5 kΩ in the presence of the coupling capacitors.

FIGURE 4. Noise power spectrum density of preamplifier
The resistor thermal noises are shown for various resistors in Fig. 5. The thermal noise for $10 \, \Omega$ resistor, $-188 \, \text{dBV}^2/\text{Hz}$, is clearly discriminated from the shorted input noise. In the low frequencies below 10 Hz, the noise increased by the increase of offset voltage for higher input resistance. The maximum input voltage to the preamplifier was $100 \, \mu\text{V}$ rms.

![Noise power spectrum density of resistance noise (10 Ω, 100 Ω, 1 kΩ)](image)

**FIGURE 5.** Noise power spectrum density of resistance noise (10 Ω, 100 Ω, 1 kΩ)

**CONCLUSION**

The most sensitive preamplifier ever reported was made by AD797. This preamplifier has the noise equivalent power of $-190 \, \text{dBV}^2/\text{Hz}$, and the thermal noise of $10 \, \Omega$ resistor is apparently discriminated from the background. Further extension to the low frequency below 10 Hz will definitely improve the noise measurement technology.

**REFERENCES**