Johnson Noise Measurement

Aim of Experiment

To measure the Johnson noise of a given resistor at room temperature and compare its properties with Nyquist theory.

Requirements

Noise Fundamental kit, CRO, Digital multimeter.

Experiment 1

Seeing and Quantifying Johnson Noise

Procedure

1. Connect the power supply to High Level Electronics box (HLE).
2. Select the source resistor R_{in} Low Level Electronics box (LLE) to see its Johnson noise.
3. Select the appropriate R_f resistor at LLE.
4. To see the Johnson noise select R_{in} 100K Ω and $R_f = 1\text{K}\ \Omega$ which gives you gain factor of 6. Additional amplification stage with gain factor of 100 is connected internally at LLE.
5. Measure room temperature.
6. Connect the coaxial cable to the oscilloscope and see the noise.
7. Now connect the output of the LLE to the input of the HLE. Select the low pass, high pass filter and gain of HLE to see the Johnson noise on CRO and save it.
8. Square (Multiplier module) the output as shown in figure.

9. Connect the noise signal to the A input and chose A×A on the toggle switch.
10. Take care not to keep any heavy electronic devices like, CRO, CPU, mobile, etc., near Low Level Electronics box during all the experiments.

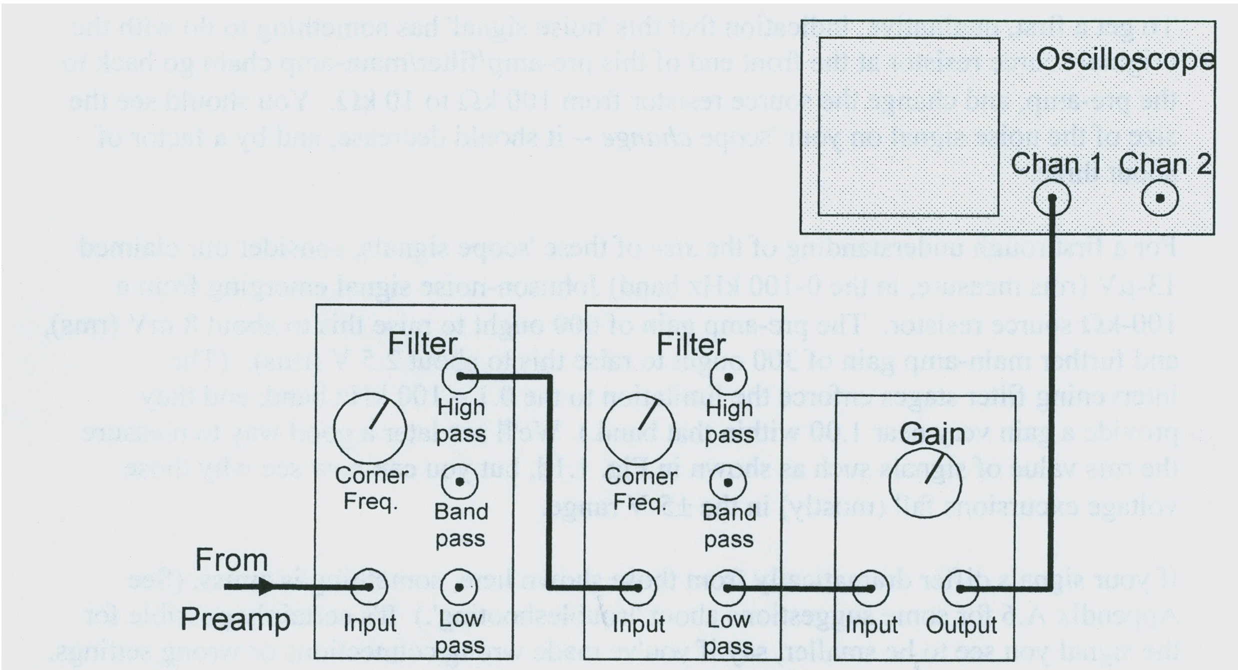

Figure 1: Connection Diagram

$$V_{out} = \frac{V_{in}^2(t)}{10V}$$

V_j is the actual instantaneous Johnson noise voltage generated by the source resistor. At the output of the preamplifier you have the signal

$$V_{out} = 6 \times 100 \times V_j(t)$$

After the filter stage, you have the 10Hz-100KHz bandwidth selected and after the main amplifier, you have signal

$$V_{out} = G_2 \times 600 \times V_j(t)$$

Where G_2 is the main amplifier gain, (say 300). Then after the squarer, you have the signal

$$V_{out} = \frac{[300 \times 600 \times V_j(t)]^2}{10V}$$

Finally, using the $< \ldots >$ brackets to indicate a time averaging, what you have displayed on meter is the average signal.

$$V_{meter} = \frac{[300 \times 600]^2 \times < V_j^2(t) >}{10V}$$

From this reading and meter reading, you can work backward to find $< V_j(t) >$, the mean-square voltage present (within your chosen bandwidth) across the source resistor.

Graphs

Results

Experiment 2

Johnson Noise Dependence on Resistance

Procedure

1. Make connection as shown in figure 2.
2. Select source resistor R_{in}.
3. Select a fixed bandwidth (say 10Hz - 100KHz).
4. Measure room temperature.
5. Select gain on High Level Electronic box(HLE).
6. Take observation of different values of R.

Now you can take noise data for your resistor. Once you have values for $< V_j^2(t) >$ each corrected for amplifier noise, you can plot those values as a function of R. Since both axes values vary over many order of magnitude, a log-log is appropriate. The vertical axis has unit of volt squared and the horizontal axis has unit of ohm(Ω). Nyquist theory predicts a first-power law dependence on resistance R, namely,

$$< V_j^2(t) >= (4KT\Delta f)R$$

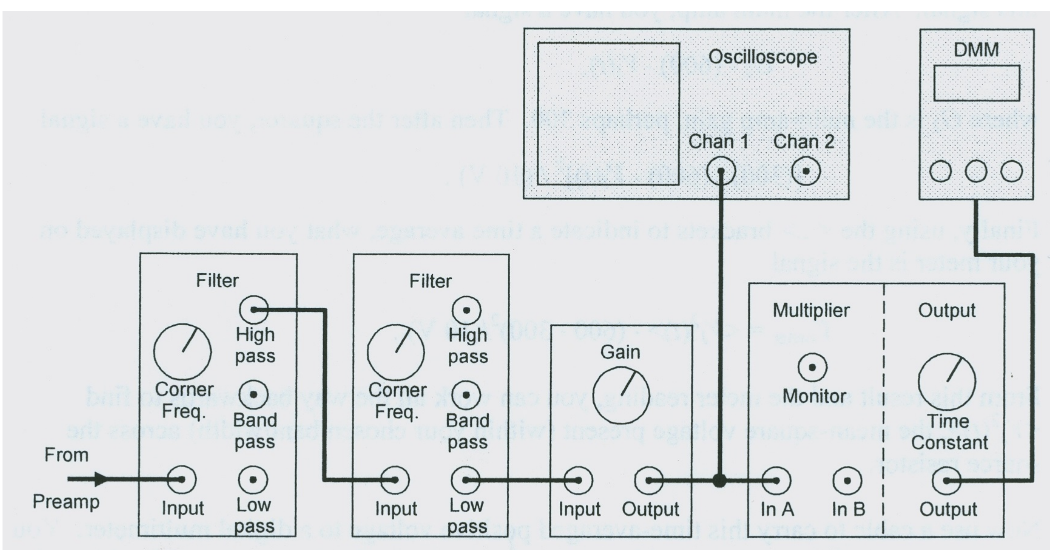

Figure 2: Connection Diagram

Observation Table

Obs.No.	Resistance	Observed Output Voltage	Calculated Output Voltage

Graphs

Results

Experiment 3

Johnson Noise Dependence on Bandwidth

Procedure

1. Make connection as shown in figure 2.
2. Select source resistor R_{in}.
3. Select a fixed R (say 10KΩ).
4. Measure room temperature.
5. Select gain on High Level Electronic box(HLE).
6. Take observation of different values of low and high pass filter.

The goal is to see how the choice of bandwidth matters. The noise generated by resistor is 'white noise'. It is uniformly distributed at all frequencies. But we subsequently modify it by placing a band pass filter made from a low pas and high pass filter.

$$< V_j^2(t) >= (4KTR)\Delta f$$

Observation Table

Obs.No.	Low pass (Hz)	High pass (Hz)	Bandwidth (Hz)	Observed Output Voltage(V)	Calculated Output Voltage(V)

Graphs

Results