PHY 305F – ELECTRONICS LABORATORY I
Fall Semester 2003

EXPERIMENT 7
ELECTRONIC NOISE
Lab notebook is due at 1 PM in MP238 on December 1

NOTE: Lab notebook for Experiment 6 is also now due at 1 PM on December 1

LEARNING OBJECTIVES:

The sensitivity and precision of any physical measurement is ultimately limited by noise in the signals being observed and in the equipment used to measure these signals. This lab illustrates some of the aspects of noise described in the lecture.

(1) To become familiar with various types of noise that present problems to the experimenter.

(2) To gain some insights into precautions needed to reduce noise.

REFERENCES:

A.J. Diefenderfer and B.E. Holton, Principles of Electronic Instrumentation, 3rd Edition, Chapter 15.

P. Horowitz and W. Hill, The Art of Electronics, 2nd Edition, pages 428-466.

R.E. Simpson, Introductory Electronics for Scientists and Engineers, 2nd Edition, Chapter 8.

L.R. Fortney, Principles of Electronics, Analogue and Digital, pages 543-552.

G. Rizzoni, Principles and Applications of Electrical Engineering, 3rd Edition, pages 689-699.

WHAT TO DO:

(1) Noise pickup in room MP238 as seen on a CRO:
Look at the various noise signals around the room using your CRO. You might also try the 100 MHz bandwidth CRO. There are various input configurations you can use:
- your hand holding the CRO input lead, with your other hand near or far from a power cord (this maximizes 60 Hz power line voltage pickup)
- a short (60 cm) single wire hanging from the CRO input terminal
- a short (60 cm) single wire hanging from the CRO input terminal with a 10 Ω resistor in parallel with the input (this emphasizes high frequency pickup and suppresses lower frequencies)
- the same short wire forming a circular loop from the CRO input terminal to ground (this emphasizes magnetic field pickup).

Identify which frequencies stand out, selecting sweep speeds from 10 ms/cm to 0.5 μs/cm.

(2) Noise pickup in room MP238 as analyzed on a spectrum analyzer:

Look at the frequency spectrum of the signals observed under the conditions pointed out in part (1). As a guide to the easier use of the spectrum analyzer, set the RF attenuation to 0 dB and adjust the IF gain to keep the display on the screen. You may use sweep rates from 100 ms for fast screen response to 2 s to see good averaging of the spectral trace. Adjust the resolution and the sweep rate to enable the details of the peaks to be seen for each RF frequency (horizontal scale) setting. Look at the following frequency ranges at the corresponding RF frequency setting:

0 → 25 kHz	1 kHz/div
0 → 2 MHz	50 kHz/div
0 → 200 MHz	5 MHz/div
0 → 1 GHz	20 MHz/div

Note that it appears that the spectrum analyzer has a filter at the front end to eliminate 60 Hz sensitivity. This is probably done to make it more useful. Note also that the analyzer seems to produce its own noise from its switching power supply. This signal is best seen using the loop for an antenna positioned near the cathode ray tube face, and appears as the harmonics of 19 kHz. Observe what wire configurations and shielding configurations reduce the various components of the noise picked up in the room.

In both parts (1) and (2), identify the various noise sources.

(3) Intrinsic noise (viewed in room MP221B):

Room 221B has less than 10% of the radiated signal in room 238. This is probably due to the grounded wire mesh surrounding the room plus the room not being so directly in the line of FM signals in the downtown towers. The comparatively quiet conditions of this room make it more conducive to studying lower level noise such as Johnson noise. In this room, you have available to you two set-ups of low-noise differential amplifiers with RMS-measuring voltmeters that can be connected to their output. The amplifiers are equipped with band-pass filters so that you can set their high and low cut-off frequencies. The differential inputs reduce extraneous signal pickup by subtracting signals induced in the cables from each other while still responding to the difference voltage produced by the resistor at the end of the cables.

(a) For a fixed bandwidth, look at the noise voltage (using both RMS voltmeter and oscilloscope display) appearing across the decade resistance box as you vary the resistance from 0 to 10 kΩ. Notice the apparent "frequency" of the noise as viewed on the CRO. Recall that the Johnson noise is predicted to obey the law:

$$\langle V_{noise} \rangle_{RMS} = \sqrt{4kTRB} \quad \text{or} \quad \langle P_{noise} \rangle = kTB .$$

Assuming that the noise you see with R = 0 must be due to amplifier random (white) noise of constant noise power $P_a(B)$ or noise RMS voltage $V_a(B)$ for a fixed bandwidth B, and that the total noise power is the sum of the Johnson noise power and the amplifier noise power:

$$\langle V_{total\ noise} \rangle_{RMS} = \sqrt{4kTRB + V_a(B)^2} \ .$$

So you should be able to test the R dependence of the Johnson noise.

(b) Varying the amplifier bandwidth from 10 Hz to 1 MHz for one value of R, test the bandwidth dependence of the noise.

(c) Test the temperature dependence of the Johnson noise using the 10 kΩ composition resistor at room temperature and immersed in liquid nitrogen.

(d) If available, bring the spectrum analyzer into the room and look at the frequency distribution of the noise as filtered through the amplifier's bandwidth.

COMMENTS:

Part (1) of this lab can be done on your own. In parts (2) and (3) you will have to share the one spectrum analyzer and the two amplifiers. Thus, some of you should start by doing part (1), some by doing part (2), and some by doing part (3). In any case, you will also have to team up in pairs to do parts (2) and (3).

At each step in this experiment, be sure that you understand what you see and explain in your lab notebook what is happening. Record all your observations in your lab notebook, and include a discussion of your observations in your lab write up.