ECE 6416
Low-Noise Electronics
Orientation Experiment

Object

The object of this experiment is to become familiar with the instruments used in the low noise laboratory.

Parts

The following parts are required for this experiment:

1. A solderless breadboard. It can be purchased from the Barnes and Noble Bookstore at Georgia Tech or The Engineers Bookstore.

2. One wire jumper kit. It can be purchased at either bookstore.

Instruments

There are 6 stations in the lab. Each has almost identical equipment.

- **Hewlett-Packard 3400A True RMS AC Voltmeter**. This is a true rms analog voltmeter. It correctly measures the rms value of a voltage (assuming that the bandwidth of the signal is less than the bandwidth of the meter).

- **Hewlett-Packard 427A Voltmeter**. This is an averaging analog voltmeter. It correctly measures the rms value of sine waves with no dc level. For all other types of signals a correction factor must be used.

- **Hewlett-Packard 3468B DMM**. This is a digital rms voltmeter. When set to ac, it correctly measures the rms value of an input signal (assuming that the bandwidth of the signal is much less than that of the meter).

- **Hewlett-Packard 3312A Function Generator**. This is an analog function generator that has several modulation features.

- **Hewlett-Packard 33120A Function Generator**. This is a digital function generator that has numerous programmable features and can be interfaced with a computer. It can also be used to obtain the frequency response of circuits.

- **Hewlett-Packard 6235A Triple DC Power Supply**. This is a basic dc power supply that is used to power electronic circuits.

- **Tektronix 2245A Oscilloscope**. This is a four channel 100 MHz oscilloscope. It is a smart analog oscilloscope, which means that it has time and voltage cursors as well as the autoset feature.

- **Tektronix 754D Oscilloscope**. This is a four channel 500 MHz oscilloscope. It is a digital oscilloscope with a phosphor display.

- **Hewlett-Packard 35665A Dual Channel Dynamic Signal Analyzer**. This is a programmable dual input digital spectrum analyzer. It samples the input signal and performs a Fast Fourier Transform on the sampled data. The spectrum is then displayed. Numerous signal processing features such as averaging and peak hold are incorporated into this instrument. It also has a source of white Gaussian noise (source output) which is digitally generated. It is an extended audio spectrum analyzer which evaluates signals in the band from $1\,\mu$H to $100\,$kHz. It is the basic instrument that is used to examine noise spectra.

- **PC**. Each station has a dedicated pc that is used to control the digital instruments at that station.

In addition to the equipment at each station there are three stand alone instruments:

- **Phillips 6300A RCL Meter**. This is a microprocessor based instrument that measures the impedance of a circuit component and determines whether it is a resistor, capacitor, inductor, or neither, and displays the component value. The measurement is made at the frequency of 1 kHz. No other measurement frequencies can be used.

- **Hewlett-Packard 4263B LCR Meter**. This is also a digital meter used to measure component values.

- **Tektronix 370A Curve Tracer**. This is a digital curve tracer used to obtain the terminal characteristics of active devices.

- **TIMS Communications Simulator**. This is a modular instrument used to simulate blocks of communications systems.

Laboratory Procedure

Voltage Measurement

1. Turn on the **HP 33120A** function generator.

2. Set the function generator for **High Z**. (**Shift**, **Enter**, right or left arrow until **SYS Menu** is found, down arrow, right or left arrow until **OUT TERM** is found, down arrow, right or left until **HIGH Z** is found, **ENTER**).

3. Set the function generator to produce a sine wave with a frequency of 1 kHz, a dc level of 0 (default value), and a rms amplitude of 1 V.

4. Turn on the **HP 3400** voltmeter, **HP 427A** voltmeter, and **HP 3468B** DMM.

5. Measure the ac value of the output voltage of the function generator with each. Note any discrepancy between the readings.

6. Turn on the **Tektronix 2245A** and **Tektronix 754D** oscilloscopes.

7. Measure the output voltage of the function generator with each oscilloscope.

8. Turn on the **HP 35665A Dynamic Signal Analyzer**.

9. Connect the output of the function generator to the Channel 1 input of the Dynamic Signal Analyzer. Nothing should be connected to the other two inputs at this time.

10. Set the Dynamic Signal Analyzer **SPAN** to 10 kHz (**Freq**, **SPAN**, 10 kHz).

11. Use the Dynamic Signal Analyzer to measure the output voltage from the function generator.

All of the voltages measurements should be close.

Resistance and Capacitance Measurement

1. Obtain a $15\,\text{k}\Omega$ resistor (5% resistor color code brown green orange) and a $0.01\,\mu\text{F}$ capacitor (103k or .01). The printed value is the nominal value of these components.

2. Use the **Philips RCL** meter and the **Hewlett-Packard 4263B LCR** meter to measure the actual value of these components.

First Order Circuit

1. Use the resistor and capacitor along with the **HP 33120A** function generator to assemble a first order RC low pass filter.

2. Use the oscilloscopes to determine the $-3\,\mathrm{dB}$ frequency.

3. Exchange the resistor and capacitor to form a first order high pass filter and repeat.

4. Turn off the **HP 33120A** function generator and remove all leads connected to it.

5. Connect a BNC to BNC jumper from the **SOURCE** output of the **HP 35665A Dynamic Signal Analyzer** to the **Channel 1** input of the analyzer.

6. Connect the **SOURCE** output to the input of the low pass filter and **Channel 2** to the output of the low pass filter.

7. Set the **INSTRUMENT MODE** to **SWEPT SINE**.

8. Set the **SOURCE** level to $1\,\mathrm{V}$ rms.

9. Set the **DISPLAY FORMAT** to **BODE**.

10. Press **Freq** and **Sweep Mode** to **LOG**. Press **START**.

11. After the frequency response has been plotted, press **PLOT/PRINT**, **MORE SETUP**, and switch the plot dump destination from **HPIB** to **File**.

12. Insert a *high quality* formatted floppy disk into the disk drive of the signal analyzer.

13. Press **RETURN** and then press **START PLOT/PRINT**.

14. Remove the floppy disk and use the pc to print it with the software package **View Companion**.

15. Remove the BNC connector for **Channel 2**.

Noise–Signal Analyzer Source

1. Press **Preset** on the signal analyzer.

2. Connect the **SOURCE** out to the **Channel 1** input.

3. Turn the source on and set it to random noise with a level of $1\,\mathrm{V}$ rms.

4. Press **Trace Coordinates** and set it to log.

5. Observe the spectra. Is it reasonably white?

6. Turn the averaging on and use the default number of averages of 10.

7. Position the cursor to the middle of the screen and record the voltage level indicated as V_{dB}.

8. Press **Disp Format** and then **Measurement State**.

9. Record the measurement bandwidth Δf, **BW** (it is a function of the frequency span).

10. The volts per root hertz of the noise source is then given by

$$v_n = \frac{10^{V_{\mathrm{dB}}/20}}{\sqrt{\Delta f}}$$

11. Press **Marker Func**, **BAND**, **BAND MARKER**, and select the start as $0\,\mathrm{Hz}$ and the stop and $115\,\mathrm{kHz}$.

12. Press **BAND POWER**. The value indicated should be close to the value of 1 V rms which in decibels is 0 dB.

13. Measure the source output with the three voltmeters and record the values.

14. Connect the source output to the **Channel 1** input of the signal analyzer.

15. Press **Instrument Mode**, **Histogram**, **Measurement Data** and select **CDF**.

16. Print the display. Select pdf and print the display.

17. Connect the source output to the **Channel 1** input of the oscilloscopes.

18. Adjust the volts per division to 1 V per division for both oscilloscopes.

19. Switch the digital oscilloscope from storage to non storage and note the difference between the displays.

20. Use the **Tektronix** software **Wavestar** to print the display that appears on the digital oscilloscope.

21. Remove the connection from the **SOURCE** output on the signal analyzer to the Channel 1 input.

Noise–Function Generator Source

1. Connect the output of the **HP33120A** function generator to the **Channel 1** input on the signal analyzer. Select noise as the output and set the level to 1 V rms. Repeat the above noise measurements.

Noise–Arbitrary Waveform Generator

1. Open Mathcad. Use the code in Fig. 1 to import the white noise data. After the data has been pasted from Mathcad to Intuilink, export the data to the **HP33120A Function/Arbitrary** Waveform Generator. Repeat the noise measurements.

2. Repeat the above for the pink noise data.

3. Turn off the **HP33120A** and remove all leads connected to it.

Noise–TIMS Noise Source

1. Connect the Noise Source on the **TIMS Communications Simulator** to the TIMS voltmeter with a banana plug to banana plug connector. Adjust the noise level until it is 1 V rms. Repeat the above noise measurements.

Noise–Transistor Noise Source

1. Assemble the circuit shown in Fig. 2. Use either 2N3904 or 2N4401 NPN BJT transistors. The rail voltage should be +15 V. A power supply decoupling cap (100 μF electrolytic) and a series resistor of 51 Ω (5 %) should be used at the point the power supply connects to the bread board. Transistor Q_2 is operated in its reverse breakdown region for the base-emitter junction and emulates a Zener diode. When it exhibits breakdown, it generates a large amount of avalanche noise that is amplified by CE stage formed by Q_1. You should try both a 2N3904 and a 2N4401 transistor for Q_1 and determine which generates the most noise.

2. Repeat the above noise measurements on this source. Because there is a dc offset at the output of the circuit, you must either use an ac coupling capacitor in series with its output with a resistor to ground at the output side of the capacitor. Recommended values are 10 μF and 100 kΩ. Alternately, the measuring instruments can be operated in the ac coupled mode.

$D :=$

	0
1086	1.62
1087	0.41
1088	1.95
1089	0.65
1090	0.67
1091	-1.16
1092	0.22
1093	0.79
1094	1.05
1095	0.77

Insert Component. Input table.
Import data.

$N := last(D)$

$i := 0.. N - 1$

$d_i := D_i$

Define vector to be table entry.

$Max := max(d)$

$Min := min(d)$

Normalize Data for Function Generator from -1 to + 1

$$d_i := \left(d_i - \frac{Max + Min}{2} \right) \cdot \frac{2}{Max - Min}$$

Type "d=" put pointer into displayed vector, right click, select all copy selection.
Paste into Intuitlink.

Figure 1: Mathcad code used to import the white noise data.

Q_1, Q_2 2N4401
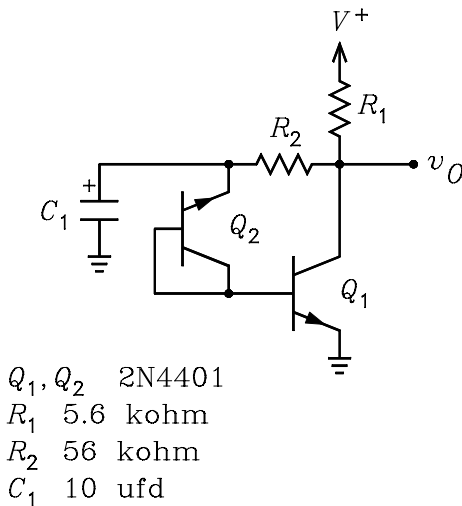R_1 5.6   kohm
R_2 56   kohm
C_1 10   ufd

Figure 2: Two transistor noise generator.

Laboratory Report

1. Present the data taken using tables and plots.

2. Compare the pdf and cdf measured for the various noise sources with the theoretical expressions for Gaussian noise with an rms value of $1\,\mathrm{V}$. Which noise source was the best? Which was the worst? Did the spectral density of the pink noise exhibit the correct slope of $-10\,\mathrm{dB}$ per decade?

3. What was the largest value of the noise voltage observed with the oscilloscopes? Which source produced it?