ECE 6416 Orientation Project

Object

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

Parts

A solderless breadboard is required for the laboratory. It can be purchased from the Barnes and Noble Bookstore, the Engineers Bookstore, or from the ECE Honorary Society Eta Kappa Nu. An elementary wire jumper kit and a formated high quality 3.5 inch floppy disk are also required.

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 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.

- **Agilent 35670A 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 10^{-6} Hz 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. Each pc is connected to the internet but is not on a domain. Under no circumstance is the Windows Messenger to be enabled or used.

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 Procedures

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 V (default value), and a rms amplitude of 1 V.

4. Turn on the **HP 3400** voltmeter, **HP 427A** voltmeter, and the **Agilent 34401A Digital Multimeter**.

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 35670A Dynamic Signal Analyzer**. 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.

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

10. Use the **Dynamic Signal Analyzer** to measure the output voltage from the function generator. Press **Marker**, **Marker to Peak.**

All of the voltages measurements should be close.

Resistance and Capacitance Measurement

1. Obtain a $15\,\mathrm{k\Omega}$ resistor (5% resistor color code brown green orange) and a $0.01\,\mu\mathrm{F}$ capacitor (labeled 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, i.e. the frequency at which the gain is reduced by a factor of $1/\sqrt{2}$.

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 35670A 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**, **PLOT/PRINT DESTINATION**, and switch the plot dump destination from to **File**. Put the extension .HGL on the 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, insert it into a Windows PC, start Microsoft Word, Insert Picture, from file, and select the floppy disk. Import the picture. Right click it and edit. Double click and change the scale to 50 %. Print the result.

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. Press Channels and switch from 2 to 1 and then frequency, span, 100 kHz.

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

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

6. Observe the spectra. Is it reasonably white?

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

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

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

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

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

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

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

13. Press **BAND POWER**. The value indicated should be close to the value of $1\,\mathrm{V}$ rms, which in decibels is $0\,\mathrm{dB}$.

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

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

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

17. Print the display. Select PDF and print the display.

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

19. Adjust the volts per division to $1\,\mathrm{V}$ per division for both oscilloscopes.

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

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

22. Change the noise source to pink noise and repeat the above.

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

Noise–Function Generator Source

1. Turn on the **HP33120A** function generator and set it for High Z. 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 $1\,\mathrm{V}$ rms. Repeat the above noise measurements.

Noise–Arbitrary Waveform Generator

1. Open Mathcad. Use the following code 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.

   (a) To input the data array into Mathcad, select Insert/Component/File Read or Write/Read from a file/File Format/Text Files/Browse. Then select the white noise file. Click Open/Finish. You will see the file icon displayed with a red rectangle on the left. Put the curs on on the rectangle and type D (for data array).

   (b) On separate lines below the file icon, type

   N:last(D)
   i:0;N-1
   Max:max(D)
   Min:min(D)

   You will find the colon will be replaced with a colon followed by an equal sign (:=), which is the Mathcad symbol for a definition. The semicolon will be replaced by two periods (..), which is the Mathcad symbol for defining a range variable.
   (c) Create the normalized data array d by typing

   d[i:(D[i-(Max-Min/2)*2/(Max-Min)

   The "[i" causes the index variable i to be attached to the d as a subscript.

   (d) Type d= to display the normalized data array. Use the mouse to move the array down so that it does not cover any lines above it. Highlight the array by clicking on the upper left shaded square. Click Edit/Copy. This will copy the array to the clipboard. You can then paste it into Intuitlink and download the array into the function generator.

   (e) The lines between the file icon and the displayed array in the Mathcad sheet will look like the following:

   $$N := \text{last}(D)$$

   $$i := 0.. \, N - 1$$

   $$Max := \text{max}(D)$$

   $$Min := \text{min}(D)$$

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

2. After the Mathcad array has been imported into Intuitlink, export the data to the HP33120A Function/Arbitrary Waveform Generator. Repeat the noise measurements.

3. Repeat the above for the pink noise data.

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

Noise–Transistor Noise Source

1. Assemble the circuit shown below. Use either a 2N3904 or 2N4401 NPN BJT transistors. A $100\,\mu\text{F}$ electrolytic capacitor and series $51\,\Omega$ (5%) resistor should be used for a power supply

decoupling network on the breadboard. Transistor Q_2 is operated at the onset of base-emitter junction reverse breakdown where it generates a noise that is called micro-plasma avalanche noise. You should try both a 2N3904 and a 2N4401 transistor for Q_2 and determine which generates the most noise.

Q_1, Q_2 2N4401
R_1 5.6 kohm
R_2 56 kohm
R_3 100 kohm
C_1, C_2 10 ufd
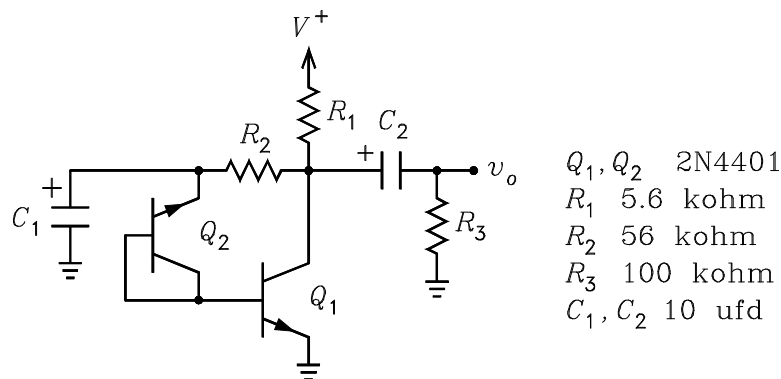
2. Repeat the above noise measurements on this source.

Laboratory Report

1. Present the data taken using tables and plots.

2. Compare the probability density function and cumulative density function measured for the various noise sources with the theoretical expressions for Gaussian noise with an rms value of 1 V. Which noise source was the best? Which was the worst?

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