Lab 1 Requirements

immediate

ABSTRACT

Keywords:

5.2

0.1 To do

Generate $\nu = 100\ kHz$ sine wave with $V_{pp} = 100\ mV$, set and plot waves at different sampling rates ν_s to explore different Nyquist zones.

5.3

0.2 To do

Plot real and imaginary parts of above data as a voltage spectrum, then as a power spectrum. Finally, take the inverse Fourier transform of the power spectrum, and calculate the Auto Correlation Function (ACF) from the voltage time series.

0.3 To explain

- why voltage spectra are complex
- what real vs. imaginary parts of spectrum represent
- meaning of negative and positive frequencies
- why redone voltage spectra of the same waves may not look identical
- why real spectra are positive or negative
- why an imaginary spectra have a larger amplitude than its real component
- the kind(s) of symmetry power spectra points exhibit
- when we use power spectra vs. when we use voltage spectra

5.4

0.4 To do

Plot the power spectrum when $N_{freq} >> N_{time}$ (meaning we have few samples of a large data set).

0.5 To explain

- why power spectrum is nonzero at frequencies near the input frequency

1 5.5

1.1 To do

Combine 2 function generators in a power splitter using close frequencies, and plot the power spectrum.

1.2 To explain

- how close 2 frequencies can be while still being distinguishable (i.e. determine the resolution)
- how resolution depends on the number of samples in the data
- how the sample number relates to the time interval spanned by each sample
- a quantitative definition for resolution (math derivation possibly?)

2 5.6

2.1 To do

Take Nyquist-sampled time series and calculate the power spectrum for a frequency range $\geq \pm 4\frac{\nu_s}{2}$

2.2 To explain

- what the added factor of 4 does (i.e. the meaning of a Nyquist window and its relationship to sampling frequency)
- how different Nyquist windows compare (noting the violation of the Nyquist criterion in some windows)

3 5.7

3.1 To do

Connect the noise generator to a filter and take voltage data using the ADC. Plot a histogram of the voltages and overplot the expected Gaussian function. Compute the power spectrum of each block of samples as well as the overall average power spectrum. Plot the power spectrum for a block of data, compare it to the overall average, then plot groups of blocks as $N = (2,4,8,16)$ where N represents the number of blocks of data to be grouped. Calculate the ACF for all samples in a block, zooming in on delays of ≤ 2000 samples. Derive the power spectrum from the ACF and compare it to the Fourier-derived power spectrum.

3.2 To determine

- mean voltage, variance, and standard deviation of a data block
- knowing that comparison of a block of data to the overall average data is a statement of Signal-to-noise Ratio (SNR), and knowing that SNR α N^x, determine what x represents and whether it satisfies the Central Limit Theorem
- compare the Full Width Half Max (FWHM) of the ACF to the FWHM of the power spectrum and determine the relationship between these quantities

4 6.4

4.1 To explain

why the imaginary component of a power spectrum may be nonzero

5 7.1

5.1 To do

Build a Double-SideBand Mixer (DSB). A signal generator will be the local oscillator (LO) with frequency ν_{LO} and another will be the radio frequency (RF) signal generator with frequency $\nu_{RF} = \nu_{LO} \pm \delta\nu$. Choose $\delta\nu$ that is roughly 5 percent of ν_{LO}. Choose input power level of 0 dBm^3. Sample the mixer output. For the two cases $\nu_{RF} = \nu_{LO} \pm \delta\nu$, plot the power spectra vs. frequency. Plot the waveform for one of the cases. Take the Fourier transform of the waveform, remove the sum frequency component by zeroing the real and imaginary portions (Fourier filtering). Recreate the signal from the filtered transform by taking the inverse transform and plotting the filtered signal vs. time.

Figure 1. An example image of a frog.

5.2 To explain

- why the ν_{RF} power spectra vs. frequency plots look the way they do, mentioning the ”upper and lower sideband” explicitly.
- if the waveform looks like an oscilloscope trace
- why the Fourier filtered signal looks the way it does

6 7.2

6.1 To do

Plot a power spectrum using a logarithmic vertical axis.

6.2 To explain

- if a ”forest of lines” is visible, and if the ”stronger” lines are harmonics of the main line

7 7.3

7.1 To do

Build a Single-Sideband (SSB) Mixer with a 90^o phase delay after building one with a delay as close to 0 as possible. Take time series data for the upper and lower sidebands of ν_{RF} and calculate the power spectra for both setups.

7.2 To determine

- if a possible and negative $\delta\nu$ can be observed in each setup

2. Goals

The goals of this lab—the results your report should demonstrate you have achieved—are as follows.

- Sample electronic signals and convert them into digital signals. Demonstrate the phenomenon of aliasing and quantitatively relate that to the Nyquist criterion.
- Correctly use and display Discrete Fourier Transforms (DFTs) to determine the frequency power spectrum of a time series. Correctly calculate and label frequency and power axes in plots and demonstrate understanding of how frequency ranges and resolutions are determined from the duration and cadence of samples in a time series.
- Demonstrate understanding of negative frequencies. Motivate and measure how complex inputs to a Fourier Transform break the positive/negative frequency degeneracy.
- Identify and characterize noise in electronic measurements and explore how it behaves under the Fourier Transform.
- Apply the convolution/correlation theorem, explain how spectral leakage in a power spectrum can be understood in this framework, and test the relationship between autocorrelation functions and power spectra.
- Derive the basics of mixing for frequency conversion (the heterodyne technique) and explore how electronic mixers differ from ideal ones. Construct double- and single-sideband mixers and use measurements to demonstrate the theoretical and practical differences in their operation.

Figure 2. Actual Requirements for the Lab Report