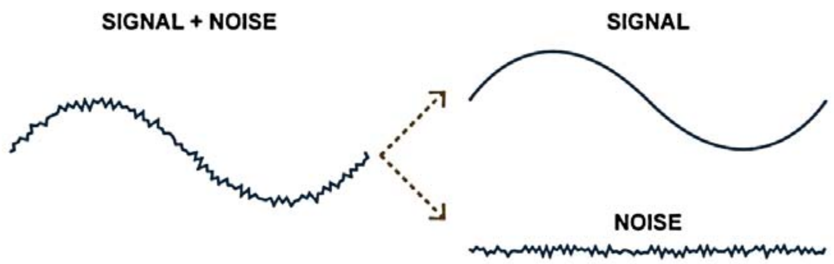
ECSE 308:
Introduction to
Communication Systems and Networks
L1T1: Signals and Noise

Part 1: Presentation of signals and noise

Part 2: Power, Bandwidth & SNR



L1T1: Signals and Noise

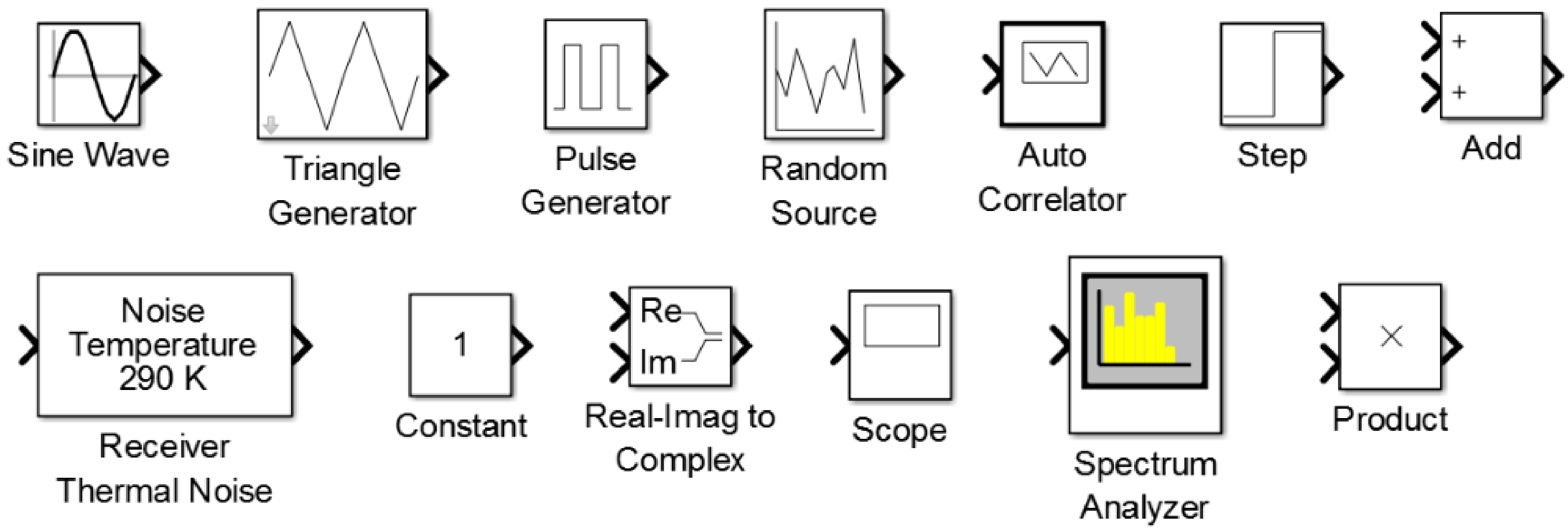
Part 1: Presentation of Signals and Noise

Objectives:

- To understand basic signal and noise concepts:
    - periodic/non-periodic signals,
    - deterministic/random signals,
    - Gaussian/thermal noise.
- To understand time-domain and frequency-domain analysis techniques

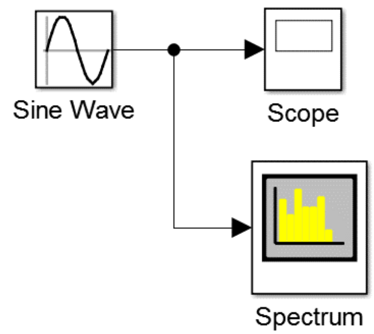
Preparation

- For this lab, the following Simulink blocks will be used.



Periodic signals

- Connect the blocks as illustrated.



- Parameter setup:
  - **Sine Wave Sine type**: Sample based | Amplitude: 0.5 | Samples per period: 1000 | Sample time: 0.0001
  - **Triangle Generator**: Frequency (Hz): 5 | Sample time: 0.0001
  - **Pulse Generator**: Pulse type: Sample based | Period (number of samples): 5000 | Sample time: 0.0001

Periodic signals: Experiment

1. Observe the outputs on **Scope** and **Spectrum**. Plot the sine wave over three periods. Indicate the amplitude, the period, and the frequency of the sine wave. What are the fundamental and harmonic components?

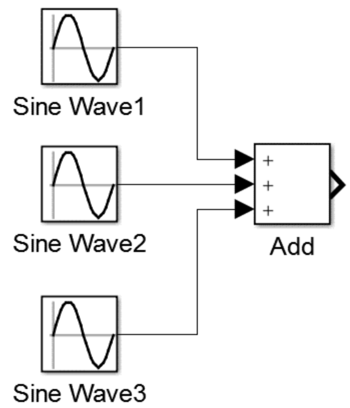
2. Repeat Step 1 with a triangular wave generated by **Triangle Generator**.

3. Repeat Step 1 with a 50% duty cycle square wave generated by **Pulse Generator**.

4. Repeat Step 1 with a 20% duty cycle square wave generated by **Pulse Generator**.

Sum of periodic signals

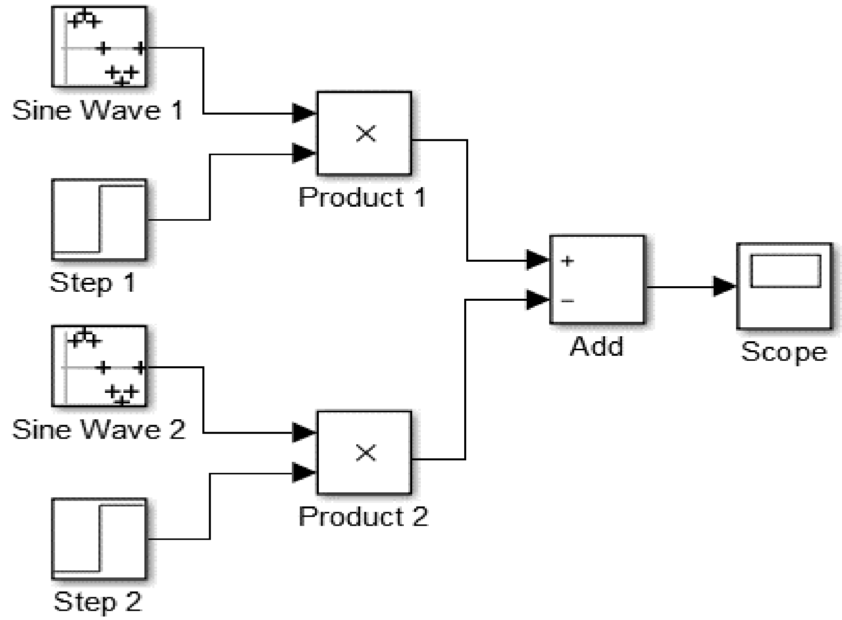
5. Repeat Step 1 with a sum of 3 sine waves as illustrated:



- Parameter setup:
  - **Sine Wave 1**: Sine type: Sample based | Amplitude: 0.5 | Samples per period: 1000 | Sample time: 0.0001
  - **Sine Wave 2**: Sine type: Sample based | Amplitude: 2 | Samples per period: 500 | Sample time: 0.0001
  - **Sine Wave 3**: Sine type: Sample based | Amplitude: 1.5 | Samples per period: 100 | Sample time: 0.0001

Sum of signals

- Connect the blocks as illustrated.

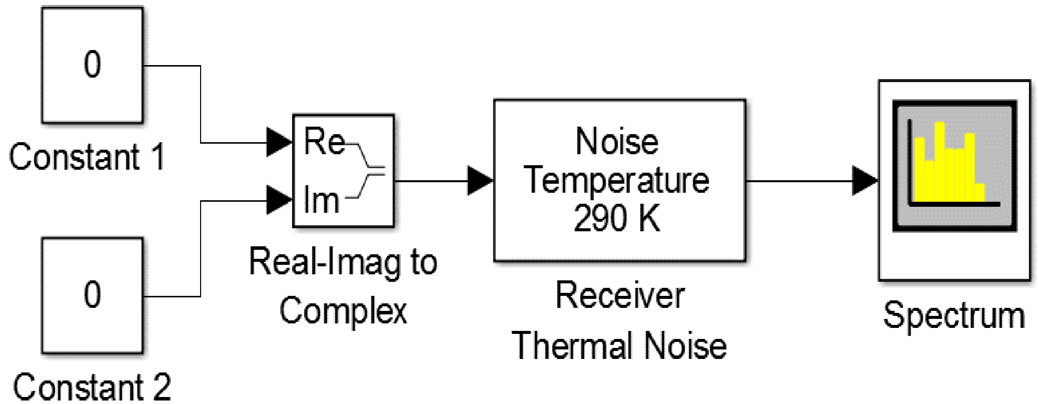


- Parameter setup:
  - **Sine Wave 1**: Amplitude: 0.5 | Samples per period: 1000 | Sample time: 0.001
  - **Step 1**: Step time: 2
  - **Sine Wave 2**: Amplitude: 0.5 | Samples per period: 1000 | Sample time: 0.001
  - **Step 2**: Step time: 4

6. Observe the output on **Scope**. Comment on the periodicity of the sine wave.

Thermal Noise

- Connect the blocks as illustrated.

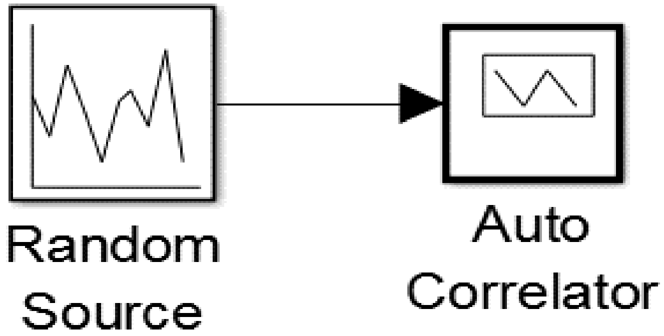


- Parameter setup:
  - **Constant 1:** Constant value: 1 | Sample time: 1e-6
  - **Constant 2:** Constant value: 1 | Sample time: 1e-6
  - **Receiver Thermal Noise:** Specification method: Noise temperature | Noise temperature (K): 290 | Initial seed: randseed

7. What is the bandwidth and the power spectral density of the thermal noise? To obtain an accurate estimate of the power spectral density, you may set the Averages in the Trace options of **Spectrum** to the sampling rate, i.e., the inverse of the sample time.

Noise Power

- Connect the blocks as illustrated.



- Parameter setup:
  - **Random Source:** Source type: Gaussian | Sample time: 0.001
  - **Auto Correlator:** Length of buffer: 1024 | Sample time: 0.001

8. Observe the output on **Auto Correlator**. Vary the variance of the source. Explain how the peak value of the output on **Auto Correlator** is related to the variance, and thus the noise power.
9. Explain the difference between random signals and deterministic signals such as sine waves, triangular waves, etc. in terms of mathematical characterization.

L1T1: Signals and Noise

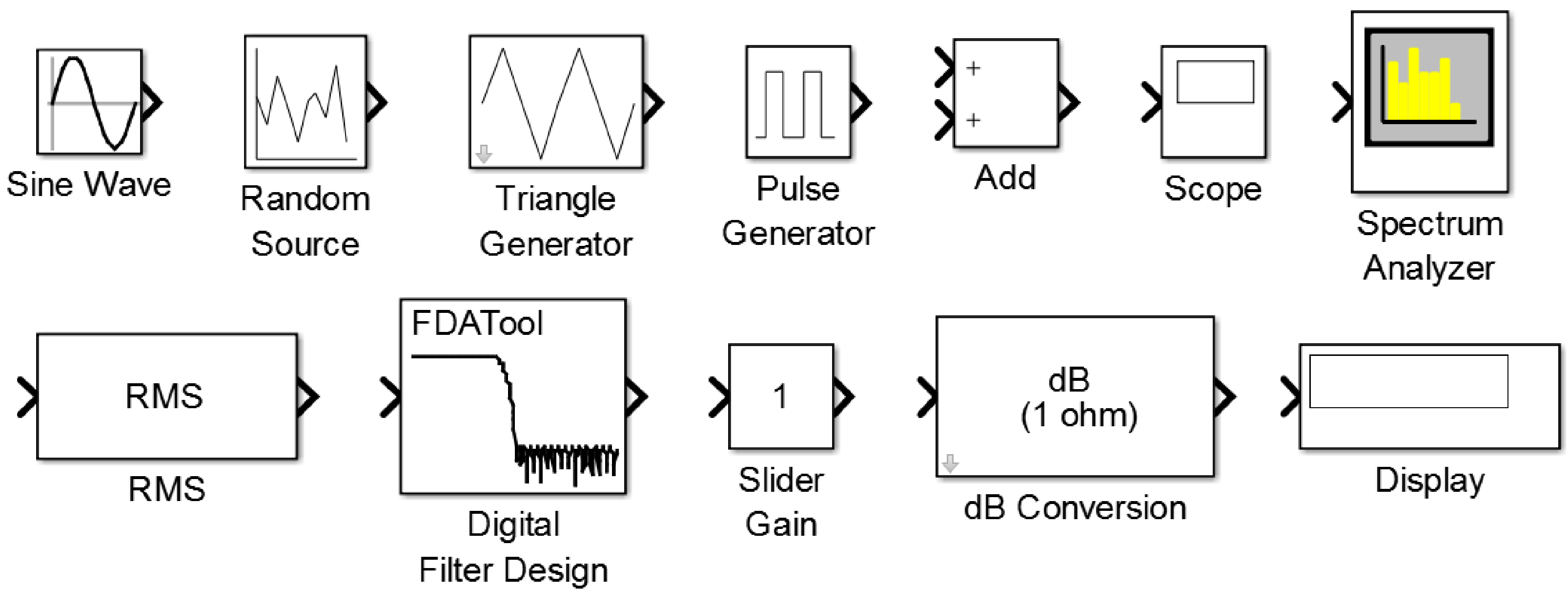
Part 2: Power, Bandwidth & SNR

Objectives:

- To understand the power and the bandwidth of a deterministic/random signal.
- To understand signal-to-noise power ratio (SNR), and filtering.

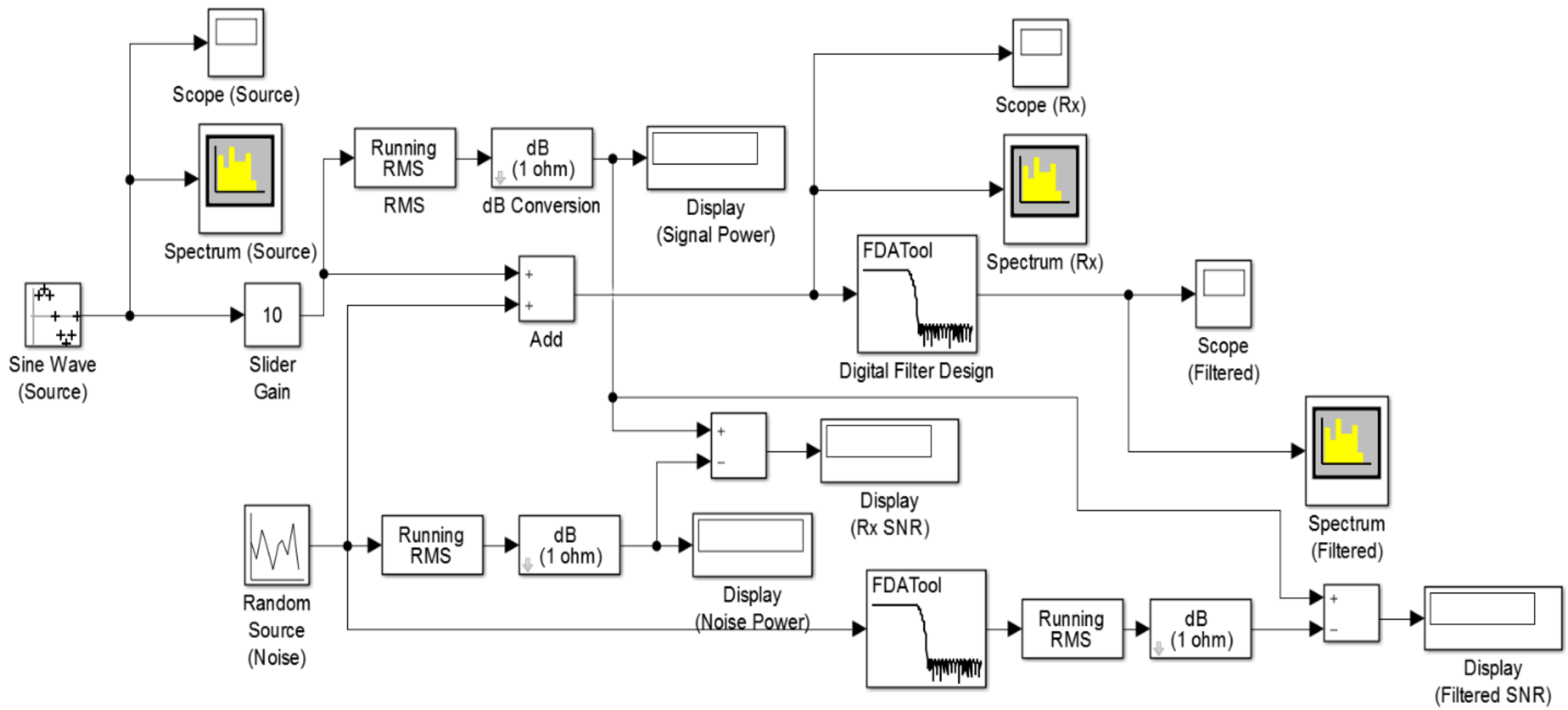
Preparation

- For this lab, the following Simulink blocks will be used.



SNR Measurement

- Connect the blocks as illustrated.



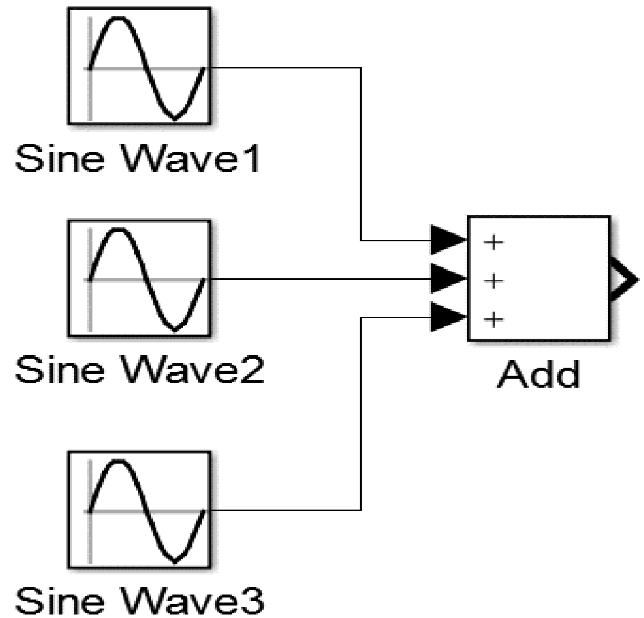
SNR Measurement: Experiment (1/3)

- Parameter setup:
  - **Sine Wave:** Sample per period: 100 | Sample time: 0.0001
  - **Triangular Generator:** Frequency (Hz): 5
  - **Pulse Generator:** Pulse type: Sample based | Period (number of samples): 5000 | Sample time: 0.0001
  - **Random Source:** Source type: Gaussian | Sample time: 0.0001
  - **Digital Filter Design:** Response Type: Lowpass | Design Method: FIR → Window | Filter Order: Specify order → 100 | Options: Scaled Passband, Window → Kaiser | Frequency Specifications: Units → Hz, Fs → 10000, Fc → 100
  - **RMS:** Running RMS

1. Observe the output on **Spectrum (Source)**. What are the power and the bandwidth of the sine wave?
2. Repeat step 1 with a triangular wave generated by **Triangular Generator**.
3. Repeat step 1 with a 50% duty cycle square wave by **Pulse Generator**.
4. 4. Repeat step 1 with a 20% duty cycle square wave by **Pulse Generator**.

SNR Measurement: Experiment (2/3)

5. Repeat step 1 with a sum of 3 sine waves as illustrated:



- Parameter setup:
  - **Sine Wave 1:** Sine type: Sample based | Amplitude: 0.5 | Samples per period: 1000 | Sample time: 0.0001
  - **Sine Wave 2:** Sine type: Sample based | Amplitude: 2 | Samples per period: 500 | Sample time: 0.0001
  - **Sine Wave 3:** Sine type: Sample based | Amplitude: 1.5 | Samples per period: 100 | Sample time: 0.0001

SNR Measurement: experiment (3/3)

6. Observe the outputs on **Scope (Rx)** and **Spectrum (Rx).** Comment on the effect of noise on the signal in the time domain and the frequency domain.

7. Compare the outputs on **Scope (Filtered)** and **Spectrum (Filtered)** with those on **Scope (Rx)** and **Spectrum (Rx),** respectively. Comment on the effect of filtering.

8. Vary **Slider Gain** from small to large. Observe the outputs on **Scope (Filtered)** and **Spectrum (Filtered).** Comment on how the effect of noise varies in accordance with the SNR at the filter output. Repeat for a varied cutoff frequency Fc in **Digital Filter Design**.