ECSE 308:
Introduction to
Communication Systems and Networks

L3: Digital Transmission Techniques

Part 1: Baseband digital transmission
Part 2: basic digital modulation schemes: binary ASK, PSK, FSK, and 4-QAM

CEAB Data – Engineering tools

- The following engineering tools are used in this laboratory:
  - MATLAB and SIMULINK
  - Software sequence generator
  - Analog filter design
  - Power spectrum analyzer
  - ASK, PSK, FSK and 4-QAM modulations

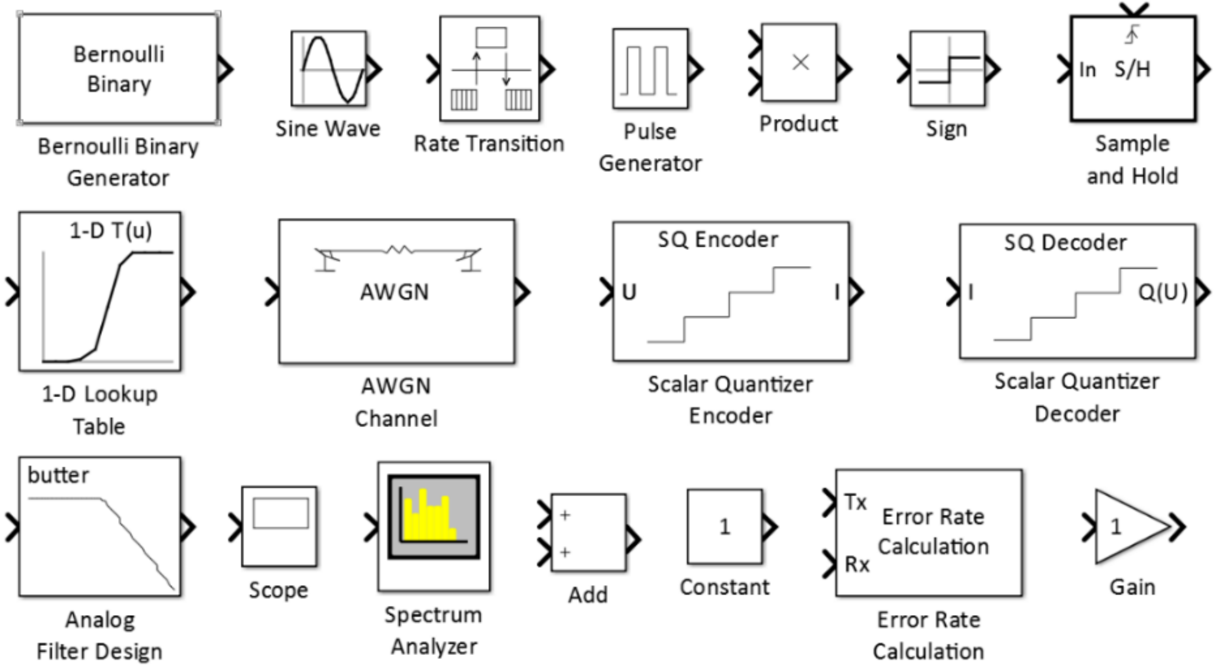
Part 1: Baseband digital transmission

Objectives:

- To understand the basic concepts of
    - Analog-to-digital & digital-to-analog conversions.
    - Baseband digital transmission over AWGN channels.
    - SNR and BER.

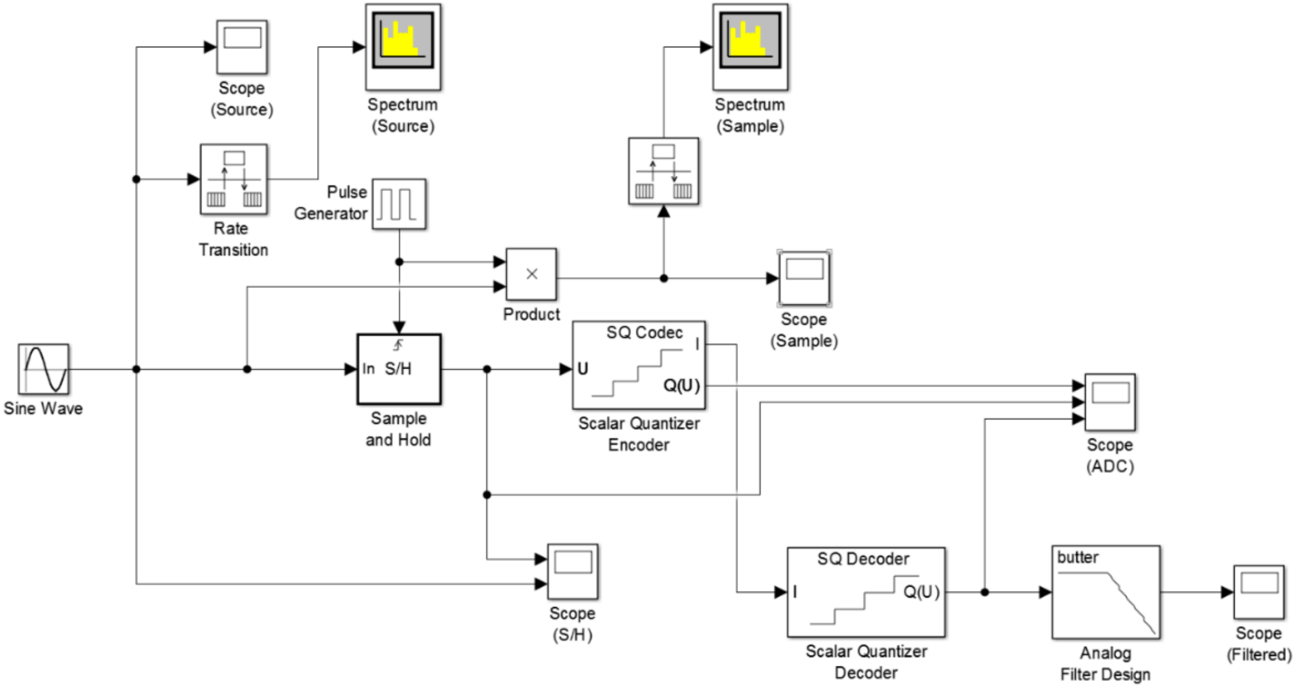
Preparation

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



ADC/DAC System

- Build the ADC/DAC system as illustrated.



ADC/DAC System: Parameter setup

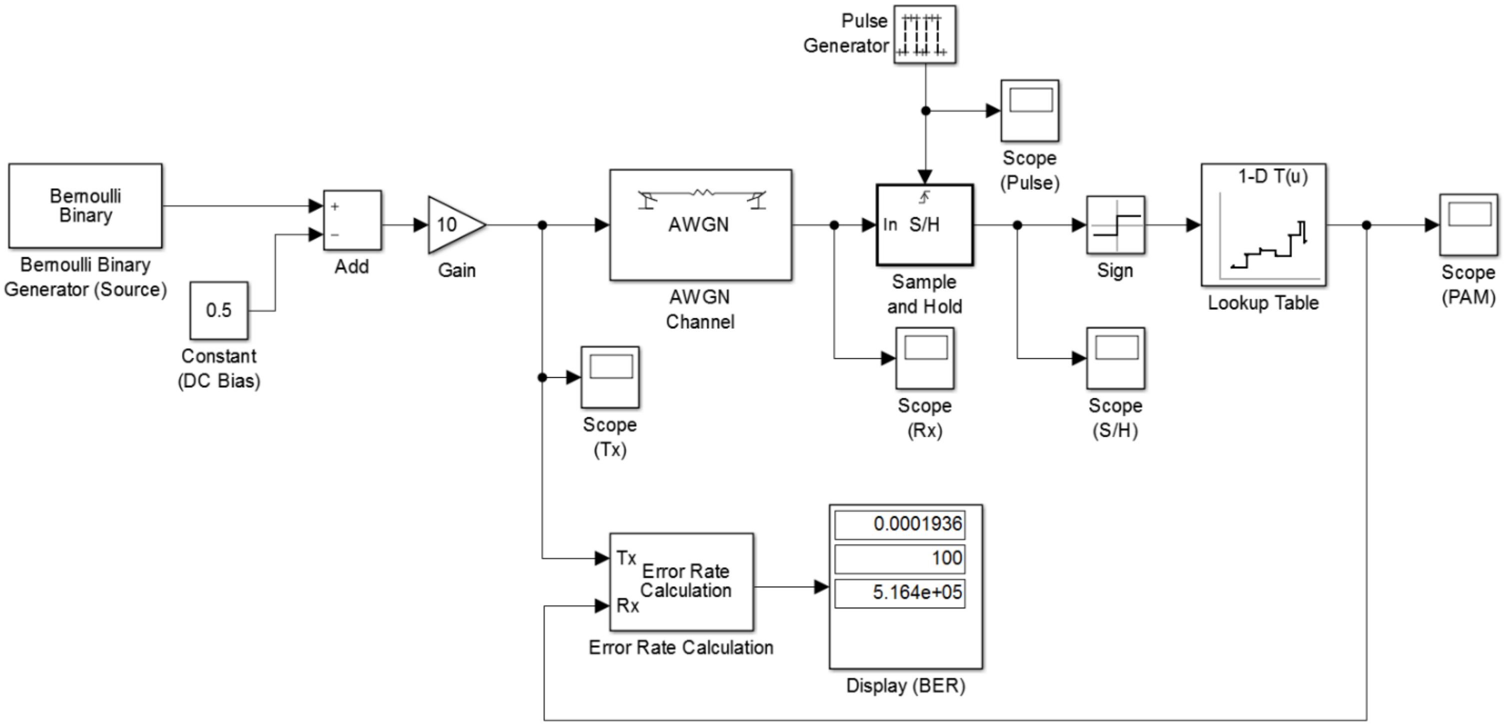
- Parameter setup:
  - **Sine Wave 1: Sine type:** Time based | Amplitude: 2 | Frequency (rad/sec): 500*2*pi
  - **Rate Transition:** Output port sample time: 1e-5
  - **Pulse Generator:** Pulse type: Time based | Amplitude: 1 | Period (secs): 0.001/8 |
  - Pulse Width (% of period): 50
  - **Scalar Quantizer Encoder:** Partitioning: Bounded | Boundary points: -2:0.5:2 | Output codeword | Codebook: [-1.75:0.5:1.75]
  - **Scalar Quantizer Decoder:** Codebook values: [-1.75:0.5:1.75]
  - **Analog Filter Design: Design method:** Butterworth | Filter type: Lowpass | Filter order: 20 | Passband edge frequency (rad/s): 500*2*pi

ADC/DAC System: Experiments

1. Compare the outputs on **Scope (ADC)** and **Scope(S/H)**. Explain how the Scalar Quantizer Encoder converts the analog input to the digital output.
2. Compare the outputs on **Spectrum (Source)** and **Spectrum (Sample)**. Comment on the effect on the spectrum of the source signal when multiplying with a pulse train. Explain why the output of the analog lowpass filter is the recovered source signal.
3. Observe the output on **Scope (ADC)**. Comment on the number of quantization levels and quantization bits utilized. Repeat for the following parameter setup: **Scalar Quantizer Encoder** Boundary points: [-2:2] | Codebook values: [-1.5:1:1.5]; **Scala Quantizer Decoder** Codebook values: [-1.5:1:1.5]. Comment on the performance difference.

Baseband Transmission over AWGN Channel

- Build the baseband AWGN system as illustrated.



Baseband Transmission over AWGN Channel

- Parameter setup:
  - **Bernoulli Binary Generator (Source):** Sample time: 0.001
  - **Constant (DC Bias):** Constant value: 0.5
  - **Gain Gain:** 10
  - **AWGN Channel:** Initial seed: randseed | Mode: Signal to noise ratio (Eb/No) | Number of bits per symbol: 1 | Input signal power, referenced to 1 ohm (watts): 25 | Symbol period (s): 0.001
  - **Pulse Generator:** Pulse type: Sample based | Amplitude: 1 | Period (number ofsamples): 2 | Pulse width (number of samples): 1 | Phase delay (number of samples): 1 | Sample time: 0.5e-3
  - **Lookup Table:** Table data: [-5,-5,5] | Breakpoints specification: Explicit values | Breakpoint 1: [-1,0,1]
  - **Error Rate Calculation:** Receive delay: 1 | Output data: Port

4. Plot the BER-versus-Eb/No curve with Eb/No (dB)= 0, 2, 4, 6, 8, 10. (Change Eb/No and observe the BER, then plot BER-versus-Eb/No using Excel, Matlab, Python, …)

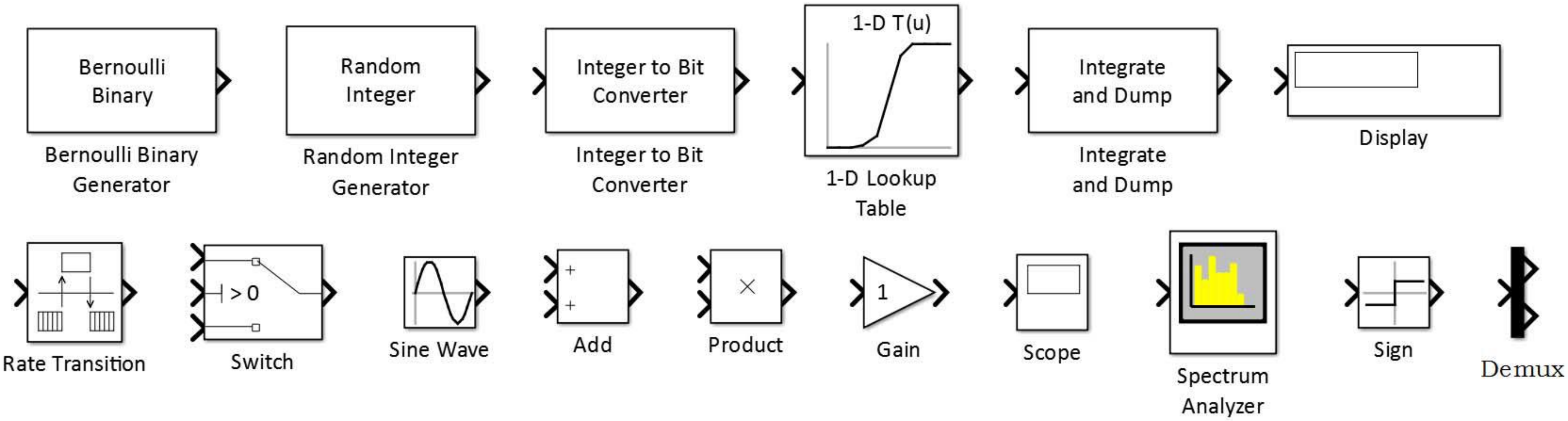
Part 2: basic digital modulation schemes

Objectives:

- To understand the basic concepts of digital modulation schemes: binary PSK, ASK,FSK, and 4QAM, and the modulated signal power spectra

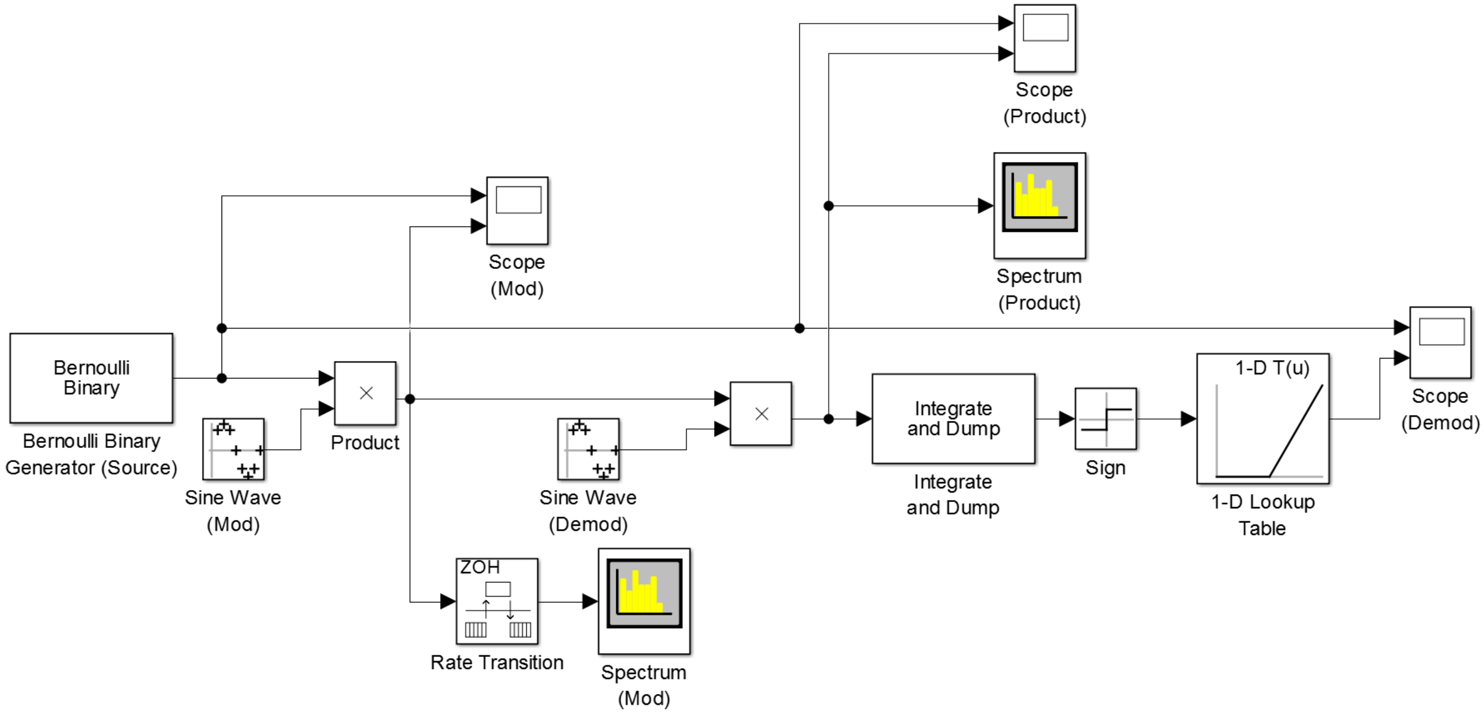
Preparation

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



Binary ASK Modulation

- Build the Binary ASK modulation and demodulation model as illustrated.



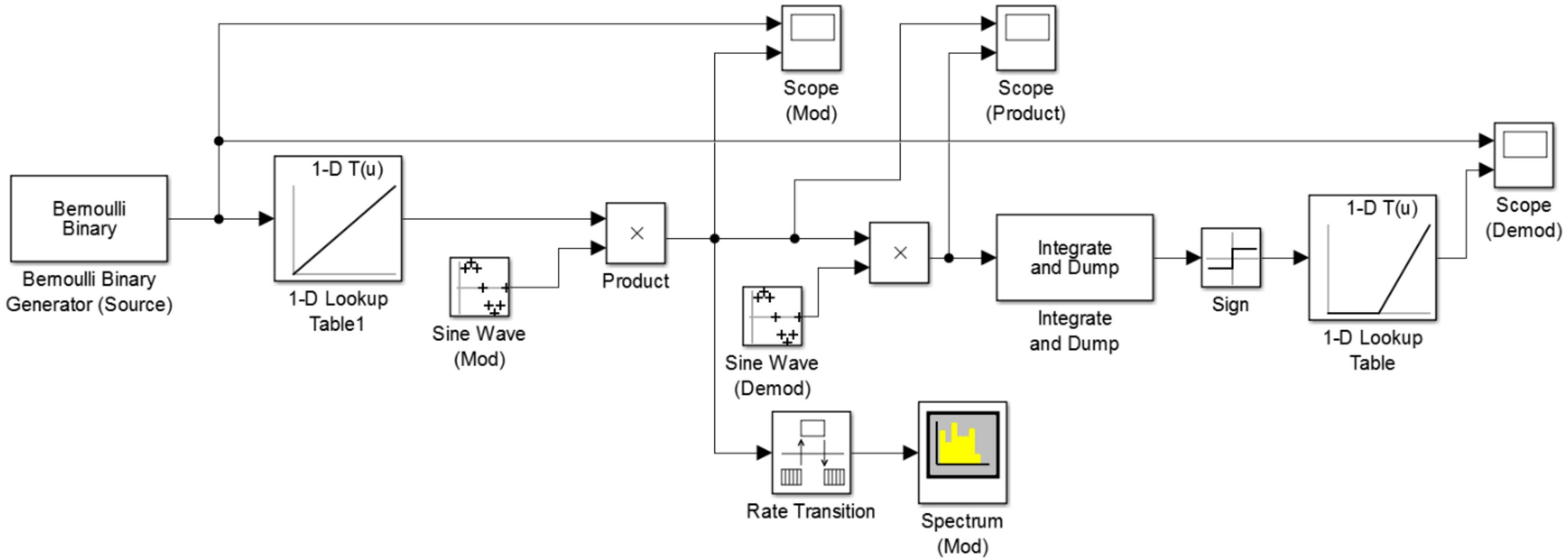
Binary ASK Modulation

- Parameter setup:
  - **Bernoulli Binary Generator (Source):** Probability of zero: 0.5 | Source of initial seed: Parameter | Initial seed: randseed | Sample time: 0.001
  - **Intergrate and Dump:** Imtergration period:8
  - **Sine Wave (Mod):** Sine type: Sample based | Samples per period: 5000 | Sample time: 1e-7
  - **Sine Wave (Demod):** Sine type: Sample based | Samples per period: 5000 | Sample time: 1e-7
  - **Rate Transition:** Output port sample time: 0.5e-4
  - **1-D Lookup Table:** Table data: [0,0,1]| Breakpoints 1: [-1,0,1]

5. Consider binary ASK. Observe the output on Scope (Mod). Describe how the transmitted signal is generated from the binary data streams. Observe the output on scope (demod) and explain the results.

Binary PSK Modulation

- Build the Binary PSK modulation and demodulation model as illustrated.



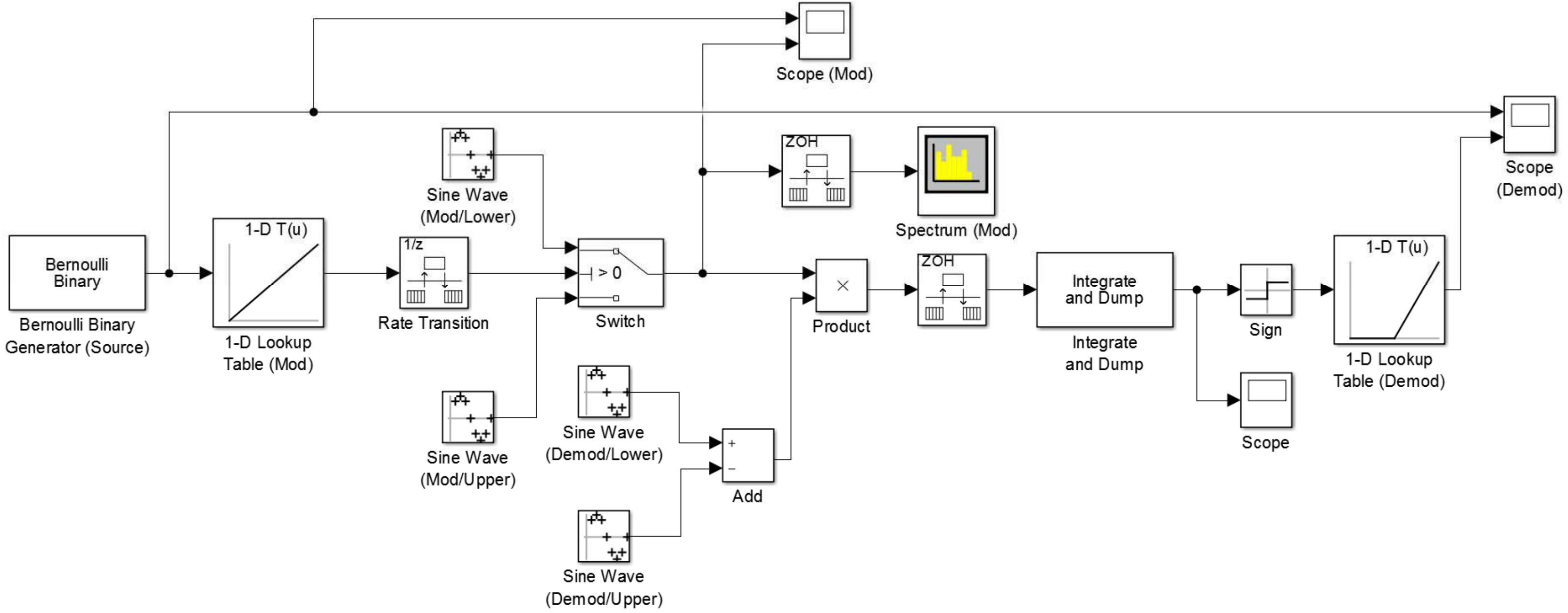
Binary PSK Modulation

- Parameter setup:
  - **Bernoulli Binary Generator (Source):** Probability of zero: 0.5 | Source of initial seed: Parameter | Initial seed: randseed | Sample time: 0.001
  - **1-D Lookup Table1:** Table data: [-1,1]| Breakpoints 1: [0,1]
  - **1-D Lookup Table:** Table data: [0,0,1]| Breakpoints 1: [-1,0,1]
  - **Sine Wave (Mod):** Sine type: Sample based | Samples per period: 5000 | Sample time: 1e-7
  - **Sine Wave (Demod):** Sine type: Sample based | Samples per period: 5000 | Sample time: 1e-7
  - **Rate Transition:** Output port sample time: 0.5e-4

6. Consider binary PSK. Observe the output on Scope (Mod). Describe how the transmitted signal is generated from the binary data streams. Observe the output on scope (demod) and explain the results.

Binary FSK Modulation

- Build the Binary FSK modulation and demodulation model as illustrated.



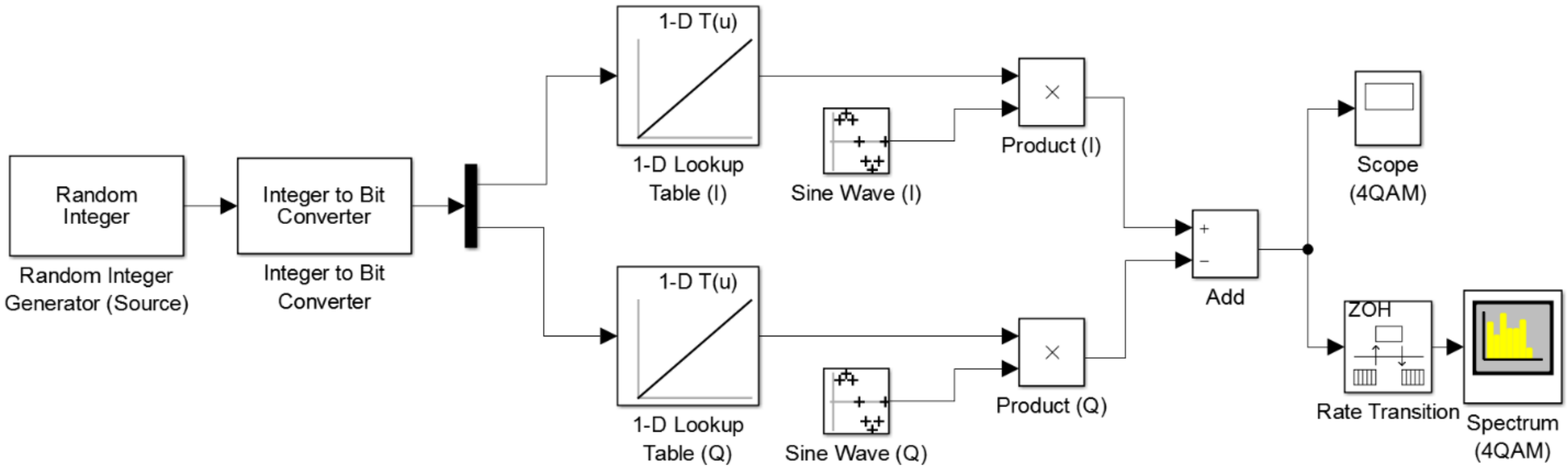
Binary FSK Modulation

- Parameter setup:
  - **Bernoulli Binary Generator (Source):** Probability of zero: 0.5 | Source of initial seed: Parameter | Initial seed: randseed | Sample time: 0.001
  - **1-D Lookup Table1 (Mod):** Table data: [-1,1]| Breakpoints 1: [0,1]
  - **1-D Lookup Table (Demod):** Table data: [0,0,1]| Breakpoints 1: [-1,0,1]
  - **Sine Wave(Mod/Lower):** Sine type: Sample based | Samples per period: 4000 | Sample time: 1e-7
  - **Sine Wave(Mod/Upper):** Sine type: Sample based | Samples per period: 2857 | Sample time: 1e-7
  - **Sine Wave(Demod/Lower):** Sine type: Sample based | Samples per period: 4000 | Sample time: 1e-7
  - **Sine Wave(Demod/Upper):** Sine type: Sample based | Samples per period: 2857 | Sample time: 1e-7
  - **Switch:** Threshold: 0
  - **Rate Transition:** Output port sample time: 0.5e-4

7. Consider binary FSK. Observe the output on Scope (Mod). Describe how the transmitted signal is generated from the binary data streams. Observe the output on scope (demod) and explain the results.
8. Specify the carrier frequencies used for modulation and the corresponding frequency separation.

4-QAM Modulation

- Build the 4-QAM modulation and demodulation model as illustrated.



4-QAM Modulation

- Parameter setup:
  - **Random Integer Generator (Source):** Set size: 4 | Sample time: 0.001
  - **Integer to Bit Converter:** Number of bits per integer(M): 2
  - **1-D Lookup Table (I):** Table data: [-sqrt(0.5),sqrt(0.5)] | Breakpoints 1: [0,1]
  - **Sine Wave (I): Sine type:** Sample based | Samples per period: 5000 | Number of offset samples: 1250 | Sample time: 1e-7
  - **1-D Lookup Table (Q):** Table data: [-sqrt(0.5),sqrt(0.5)] | Breakpoints 1: [0,1]
  - **Sine Wave (Q): Sine type:** Sample based | Samples per period: 5000 | Number of offset samples: 0 | Sample time: 1e-7
  - Rate Transition: Output port sample time: 0.5e-4

9. Consider 4-QAM. Observe the output on Scope (Mod). Describe how the transmitted signal is generated from the binary data streams.
10. Explain how 4-QAM can be implemented from binary PSK. Explain how the power spectrum of 4-QAM is related to that of binary PSK.