

## A.6 - Digital Bandpass Modulation

### A.2.1. Experimental Setup for DSBSC Modulation

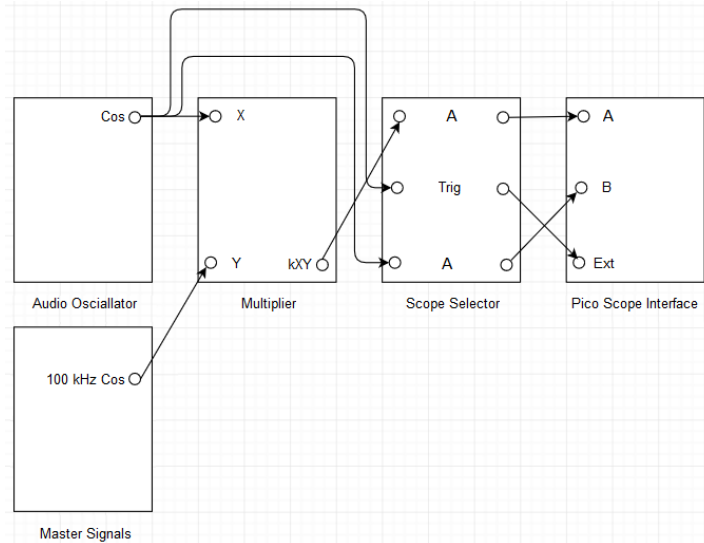


Figure A.2.1: DSBSC modulator setup.

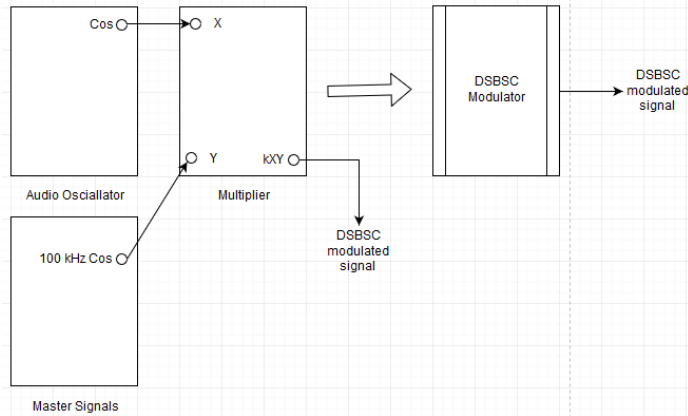
### A.2.2. Laboratory Exercise for DSBSC Modulation

NOTE: Refer A.1 for more information about initial settings and connections of TIMS and Pico Scope interface.

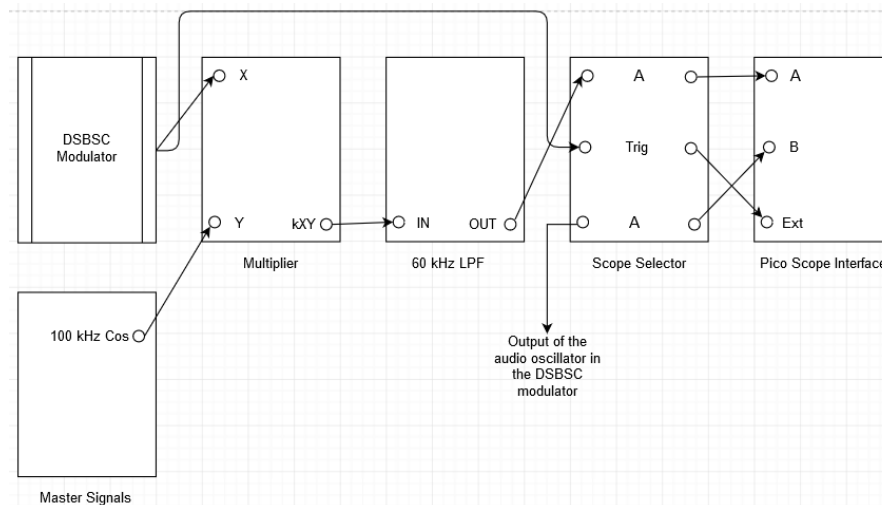
- i. Set an audio oscillator to generate 1 kHz cosine signal. NOTE: This will be used in the modulator setup.
- ii. Make the modulator setup as shown in the Figure A.2.1.
- iii. Toggle the front panel switch of the multiplier to DC.
- iv. Observe that the 1 kHz cosine signal is the message signal and the 100 kHz cosine signal is the carrier signal.
- v. Observe that the external trigger is the message signal because the modulated signal should vary with respect to the message signal.
- vi. Under the scope mode, for channel A and channel B, change the input range to  $\pm 5$  V and select the maximum number of bits as 12. Change the collection time to  $200 \mu\text{s}/\text{div}$  and change the trigger options to auto and ext.
- vii. Add two scope views under the scope mode. Select the second view, right click on it and disable B under channels. Select the third view, right click on it and disable A under channels. I.e., first view has signals from channel A and channel B, second view has signal from channel A and third view has signal from channel B.
- viii. Take a screenshot of output of the multiplier and output of the audio oscillator under the scope mode.

- ix. Under the spectrum mode, for channel A and channel B, change the input range to  $\pm 5$  V. Change the spectrum range to 199.7 kHz and change the trigger options to auto and ext.
- x. Add two spectrum views under the spectrum mode. Select the second view, right click on it and disable B under channels. Select the third view, right click on it and disable A under channels. I.e., first view has signals from channel A and channel B, second view has signal from channel A and third view has signal from channel B.
- xi. In the second view zoom around 90 kHz to 110 kHz. Measure frequency of the modulated signal peaks with cursors.
- xii. Take a screenshot of output of the multiplier and output of the audio oscillator under the spectrum mode.

**A.2.3. Experimental Setup for DSBSC Demodulation**



**Figure A.2.2.a: DSBSC modulator equivalent setup.**



**Figure A.2.2.b: DSBSC demodulator setup.**

#### **A.2.4. Laboratory Exercise for DSBSC Demodulation**

- i.** Retain the modulator setup and make the demodulator setup as shown in the Figure A.2.2.b.
- ii.** Toggle the front panel switch of the multiplier at the demodulator to DC. Turn the knob of the 60 kHz Low Pass Filter (LPF) to minimum.
- iii.** Observe that the external trigger is the modulated signal because the demodulated message signal should vary with respect to the modulated signal.
- iv.** Under the scope mode, for channel A and channel B, change the input range to  $\pm 5$  V and select the maximum number of bits as 12. Change the collection time to 1 ms/div and change the trigger options to auto and ext.
- v.** Add two scope views under the scope mode. Select the second view, right click on it and disable B under channels. Select the third view, right click on it and disable A under channels. I.e., first view has signals from channel A and channel B, second view has signal from channel A and third view has signal from channel B.
- vi.** Adjust the knob of the 60 kHz LPF to obtain the demodulated message signal with minimum phase shift and equal amplitude.
- vii.** Measure frequency of the demodulated message signal and frequency of the message signal under the scope mode.
- viii.** Take a screenshot of output of the 60 kHz LPF and output of the audio oscillator under the scope mode.
- ix.** Under the spectrum mode, for channel A and channel B, change the input range to  $\pm 5$  V. Change the spectrum range to 199.7 kHz and change the trigger options to auto and ext.
- x.** Add two spectrum views under the spectrum mode. Select the second view, right click on it and disable B under channels. Select the third view, right click on it and disable A under channels. I.e., first view has signals from channel A and channel B, second view has signal from channel A and third view has signal from channel B.
- xi.** Measure frequency of the demodulated message signal peak and frequency of the message signal peak under the spectrum mode.
- xii.** In the second view zoom around 0 Hz to 5 kHz. Measure frequency of the demodulated message signal peak with cursor.
- xiii.** Take a screenshot of output of the 60 kHz LPF and output of the audio oscillator under the spectrum mode.

### A.6.1. Experimental Setup for ASK Modulation

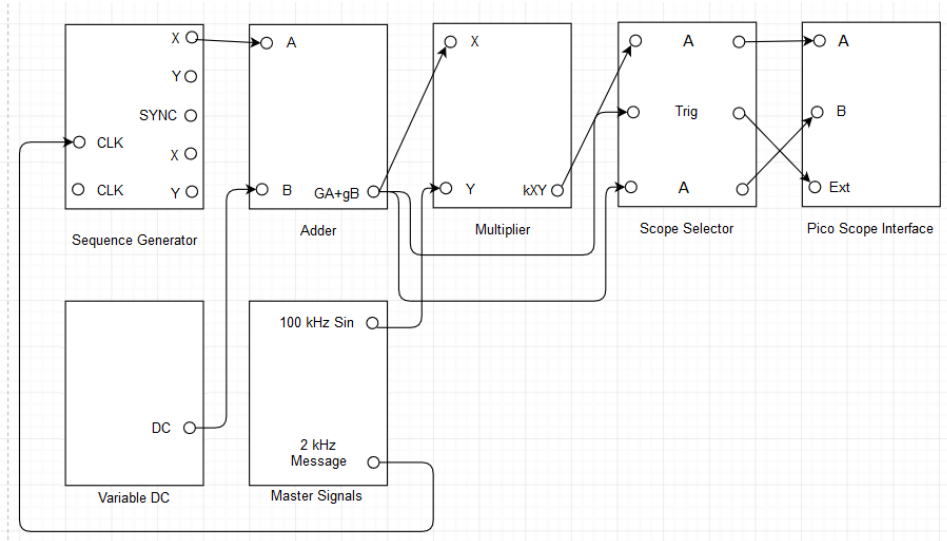


Figure A.6.1: ASK modulator setup.

### A.6.2. Laboratory Exercise for ASK Modulation

- i. Make the modulator setup as shown in the Figure A.6.1.
- ii. Toggle the front panel switch of the multiplier to DC. Turn both the knobs of the adder to maximum and turn the knob of the variable DC to minimum.
- iii. Adjust the knob of the variable DC and the message sequence at the adder to obtain a unipolar message sequence between 0 V and +2 V amplitude.
- iv. Take a screenshot of output of the multiplier and output of the adder under the scope mode.
- v. Unplug the signal from output of the sequence generator to input of the adder. Plug the signal from 8.3 kHz sample TTL clock of the master signals to input of the adder. Repeat step iii and step iv, accordingly.

### A.6.3. Experimental Setup for ASK Demodulation

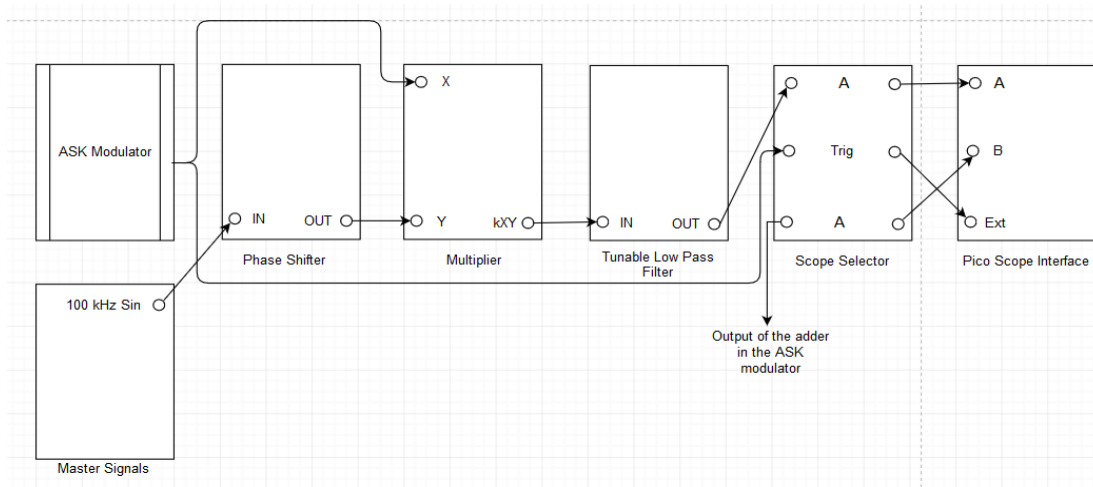


Figure A.6.2: ASK demodulator setup.

#### A.6.4. Laboratory Exercise for ASK Demodulation

- i. Retain the modulator setup and make the demodulator setup as shown in the Figure A.6.2.
- ii. Toggle the front panel switch of the TLPF to wide and toggle the front panel switch of the multiplier at the demodulator to DC. Turn both the knobs of the TLPF to minimum and turn both the knobs of the phase shifter to minimum.
- iii. Adjust both the knobs of the TLPF and both the knobs of the phase shifter to obtain the demodulated message sequence with minimum phase shift and equal amplitude. NOTE: If the demodulated message sequence is inverted with respect to the message sequence then toggle the front panel switch of the phase shifter.
- iv. Take a screenshot of output of the TLPF and output of the adder under the scope mode.
- v. Unplug the signal from 8.3 kHz sample TTL clock of the master signals to input of the adder. Plug the signal from output of the sequence generator to input of the adder. Repeat step **iii** and step **iv**, accordingly.
- vi. Observe that the demodulated message sequence is not similar to the message sequence. What does it signify?

#### A.6.5. Experimental Setup for BPSK Modulation

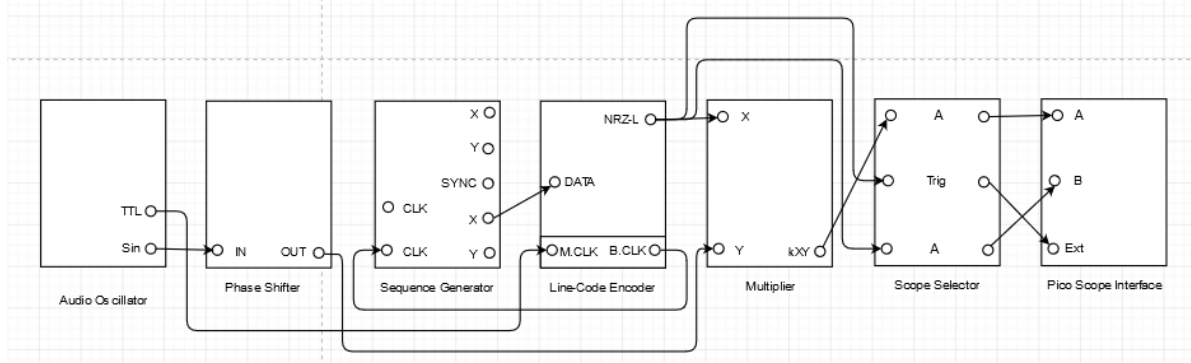


Figure A.6.5: BPSK modulator setup.

#### A.6.6. Laboratory Exercise for BPSK Modulation

NOTE: Refer the user manual to learn about the features of Line Code Encoder (LCE) [2].

- i. Set an audio oscillator to generate 8 kHz sine signal.
- ii. Make the modulator setup as shown in the Figure A.6.5.
- iii. Toggle the on board switch-frequency range of the phase shifter to LO, toggle the front panel switch of the phase shifter down and toggle the front panel switch of the multiplier to DC. Turn both the knobs of the phase shifter to minimum.

- iv. Slowly increase both the knobs of the phase shifter from minimum to maximum to observe the  $180^\circ$  phase difference between the adjacent states.
- v. Turn both the knobs of the phase shifter to minimum.
- vi. Take a screenshot of output of the multiplier and output of the NRZ-L at the LCE under the scope mode.

#### A.6.7. Experimental Setup for BPSK Demodulation

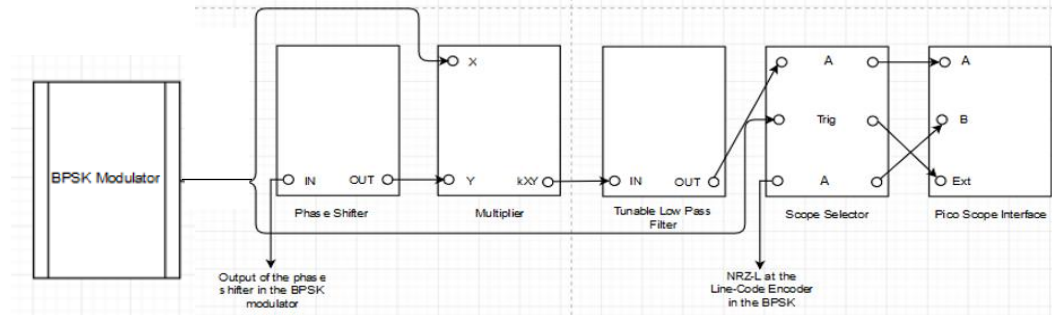


Figure A.6.6: BPSK demodulator setup.

#### A.6.8. Laboratory Exercise for BPSK Demodulation

- i. Retain the modulator setup and make the demodulator setup as shown in the Figure A.6.6.
- ii. Toggle the front panel switch of the multiplier at the demodulator to DC, toggle the front panel switch of the phase shifter at the demodulator down and toggle the front panel switch of the TLPF to wide. Turn both the knobs of the phase shifter at the demodulator to minimum, turn both the knobs of the TLPF to minimum.
- iii. Adjust both the knobs of the TLPF to obtain the demodulated message sequence with minimum phase shift and equal amplitude.
- iv. Take a screenshot of output of the TLPF and output of the NRZ-L at the LCE under the scope mode.