

Manual for Communication Systems Laboratory

(EEE/ECE F311)

Prepared by
Faculty & Laboratory Staff
Dept. EEE



BITS Pilani, Hyderabad

Date: October 2025

Experiment 10: BPSK - Modulation, Demodulation, Constellation Diagrams and Recovery in the Presence of Noise.

Aim: This experiment is intended to make the student to perform experiments on the Bandpass modulations schemes such as Binary Phase shift Keying (BPSK) using Emona Telecoms-Trainer 101 kit.

Equipment Required: Emona Telecom Trainer Kit 101, Oscilloscope, and connecting patch cards, etc.

In BPSK modulation, the binary digit “1” is represented by “0” degree phase of the carrier and binary digit “0” is represented by “180” degree phase of the carrier. This modulation can be accomplished by multiplying the carrier with a pulse of $p(t)$ to transmit digit “1” and multiplying the carrier with a pulse of $-p(t)$ to transmit digit “0”. On Emona kit, one can generate $p(t)$ & $-p(t)$, corresponding to digits “1” & “0”, respectively, by using the NRZ-L output of the sequence generator.

A - Generation and Constellations of NRZ-L Waveform.

1. To generate the NRZ-L waveform, corresponding to pseudorandom digital signal, use the connection diagram of Fig.1. In this experiment we will be using an **8 kHz CLK**. Make sure that you trigger the waveforms, using external trigger, taken from SYNC signal, as shown. Measure the signal voltages, **Vmin & Vmax** in Ch 1 of DSO. What is the bitrate (R_b) of this signal? You will observe the signals similar those in Screenshot 1.

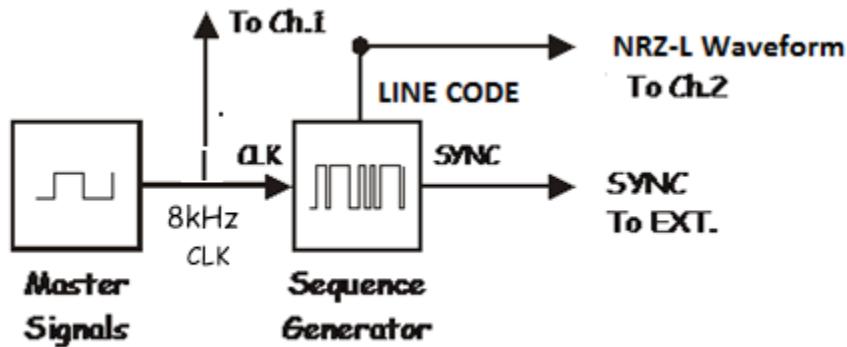
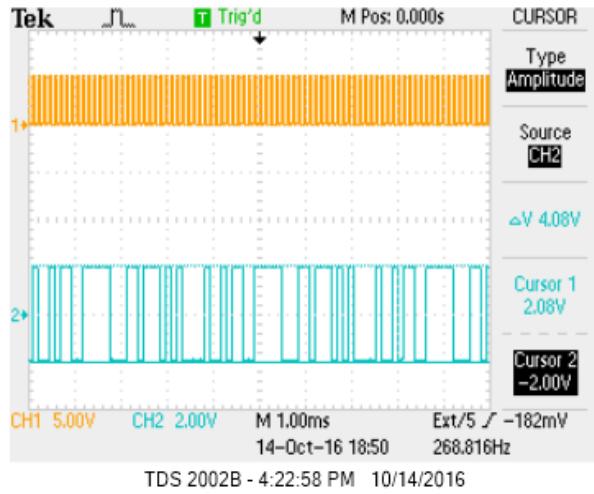
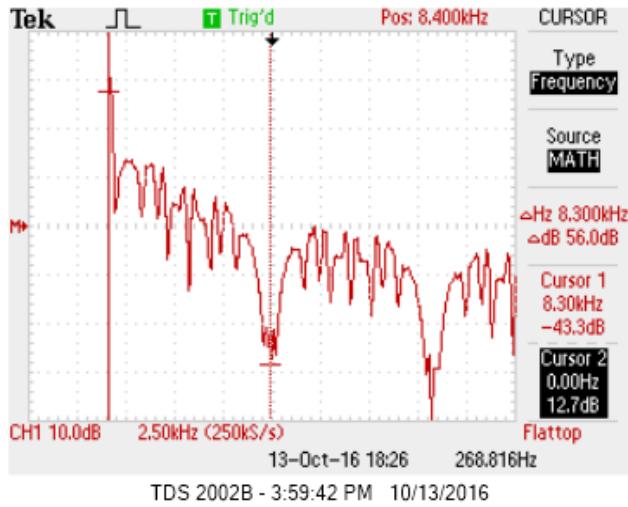


Figure 1: Connection Diagram for Generating NRZ-L Waveform



Screenshot 1: NRZ-L sequence along with CLK signal.

2. To observe the spectrum of the NRZ-L waveform, adjust the time scale of DSO to have at least 3 repetitive bunches of the pseudorandom sequences on the screen. Do not change the time scale settings. Use FFT feature and observe the spectrum of the NRZ-L signal. Use FFT zoom X5 for viewing the spectrum.



Screenshot 2: NRZ-L Spectrum

3. Note the baseband bandwidth (F_b), corresponding to first deep null in the spectrum. How is the first null frequency related to the bit rate (R_b)? (See Screenshot 2.)
4. To observe the constellation diagram of the NRZ-L waveform, use connections as in Figure 2. Select the *Display Mode of the DSO into XY mode*. Also, *the persistence be kept as 1 sec or 5 sec or more*. Adjust the Ch1 & Ch2 scales to have 1V / division. Use the Ch1 & Ch2

position knobs, to view the constellation points, as small dots, on the screen clearly and in the midway of the vertical and horizontal directions of the screen. (Screenshot 3).

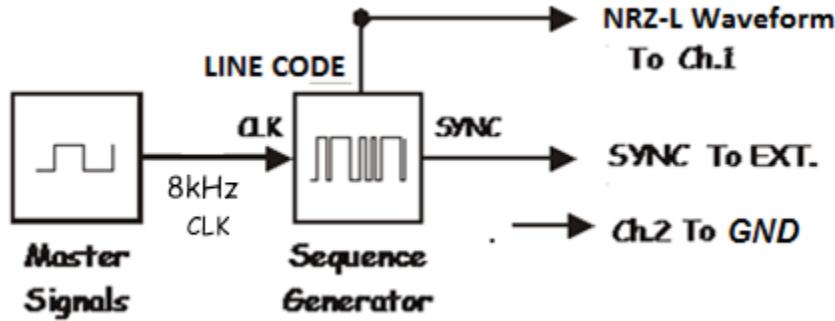
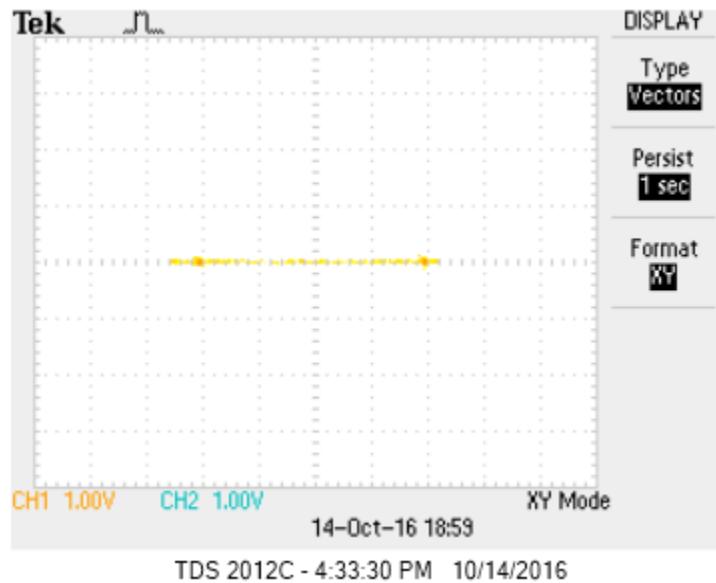


Figure 2: Connection Diagram for Viewing Constellation Diagram of NRZ-L code



Screenshot 3: Constellation diagram of NRZ-L code

5. From the displayed constellation points, measure the separation between constellation points. Do the position and the separation correspond to the **Vmin & Vmax** of the line code that you have generated?
6. Why do you see some fluctuating dots in between the two prominent constellation points?

B – Generation of BPSK Signal

1. To generate BPSK signal with carrier frequency of 100 KHz, use connection diagram of Fig 4. Make sure that the line code settings are for NRZ-L.

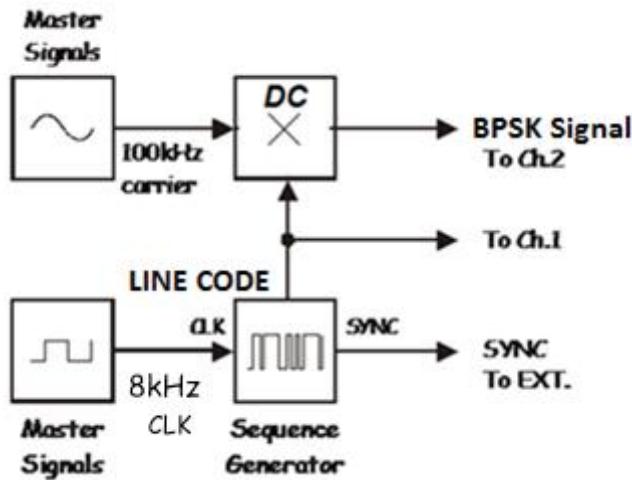
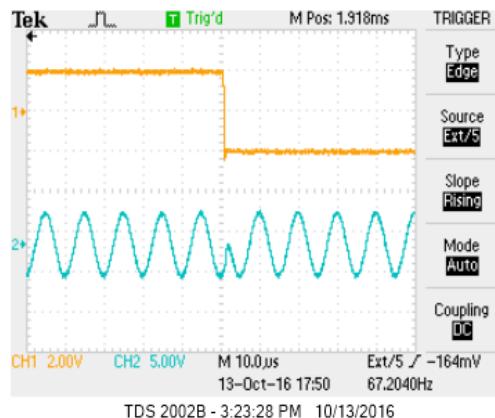


Figure 3: Connection Diagram for Generating BPSK signal.

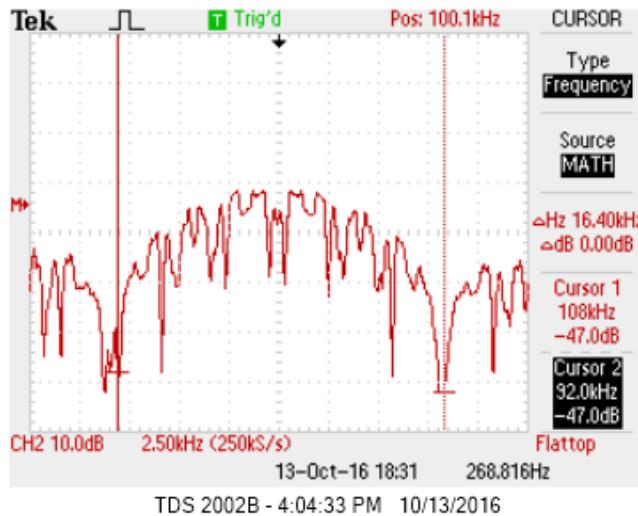
2. Adjust the time scale of the DSO sufficiently to see only a single transition of the channel 1 signal from $-V$ to $+V$. Use the horizontal position knob to bring the transition region to the middle of the screen.
3. Now observe the Binary PSK signal in Channel 2 of DSO. Does the phase of the sinusoid change abruptly at the time instant where there is a transition from $-V$ to $+V$ of the signal in Channel 1? Note that this expected to be the phase shift of 180 degrees at the digital signal transitions from ‘1’ to ‘0’. (See Screenshot 4)



Screenshot 4: Abrupt phase change at the instant of $+V$ to $-V$ transition.

4. To obtain the spectrum of the BPSK signal on DSO, adjust the time scale of DSO so as to have at least 3 repetitive bunches of the BPSK modulated pseudorandom sequences of on the screen. *Do not change the time scale settings*. Use FFT zoom as X5 for viewing the spectrum. Use the horizontal position knob to bring spectrum to the middle of the screen.

5. Measure the power of the spectral component at 100 kHz. Note the frequencies (F_{bl} & F_{bu}), corresponding to first prominent null, on the lower side of the carrier frequency and prominent null on the upper side of the carrier frequency, respectively. Fill in the entries in Table 1 and do the calculations as mentioned. (See Screenshot 5)



Screenshot 5: Spectrum of BPSK signal

Table 1. Bandwidth efficiency of BPSK Modulation

Bit Rate R_b	Power at 100 KHz	F_{bl}	Power at F_{bl}	F_{bu}	Power at F_{bu}	$B_T = F_{bu} - F_{bl}$	BW efficiency = R_b / B_T

C – Channel and Noise effects on BPSK Signal

1. To simulate a channel, we use the channel BPF block of Emona. AWGN noise is taken from the Noise generator block. Use the connection diagram of Fig. 5. It is advised to use the **-20 dB noise** and the gain of the buffer, to control the amplitude of the noise.

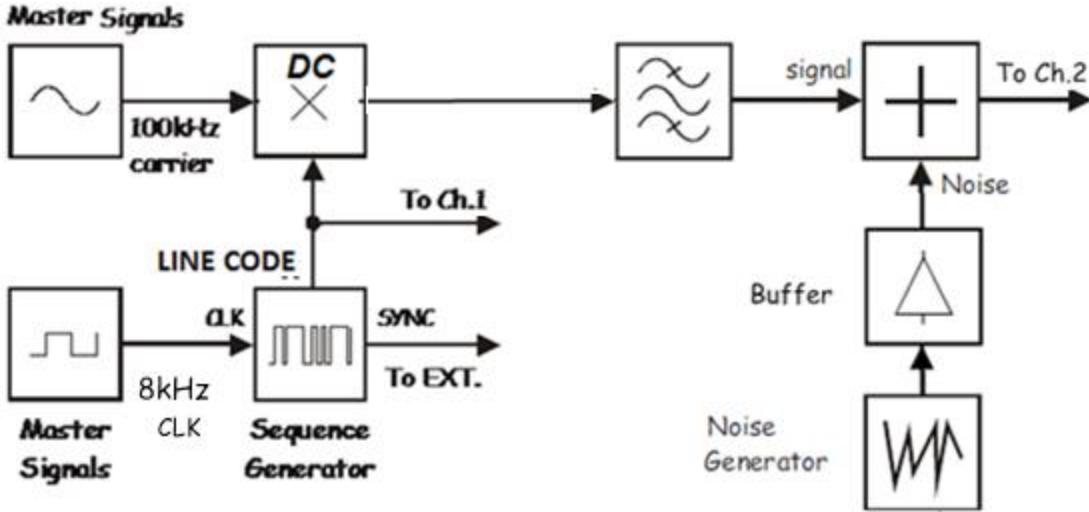
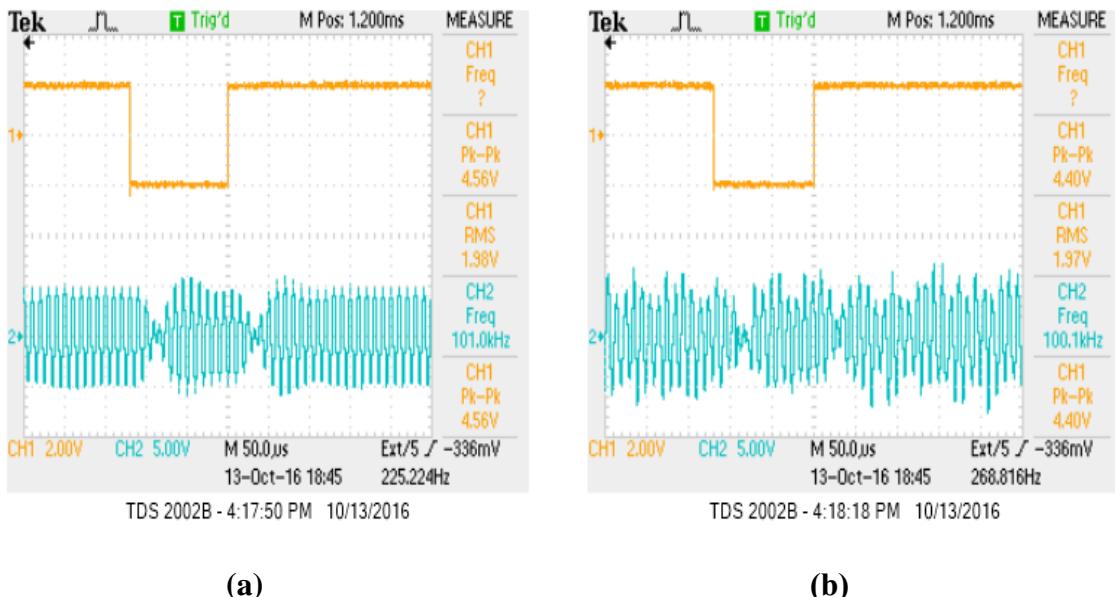


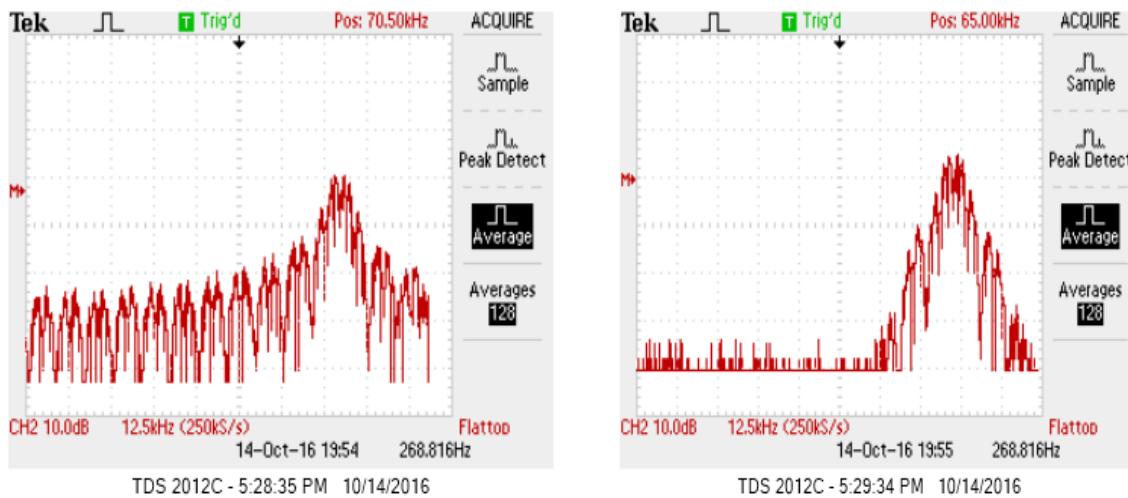
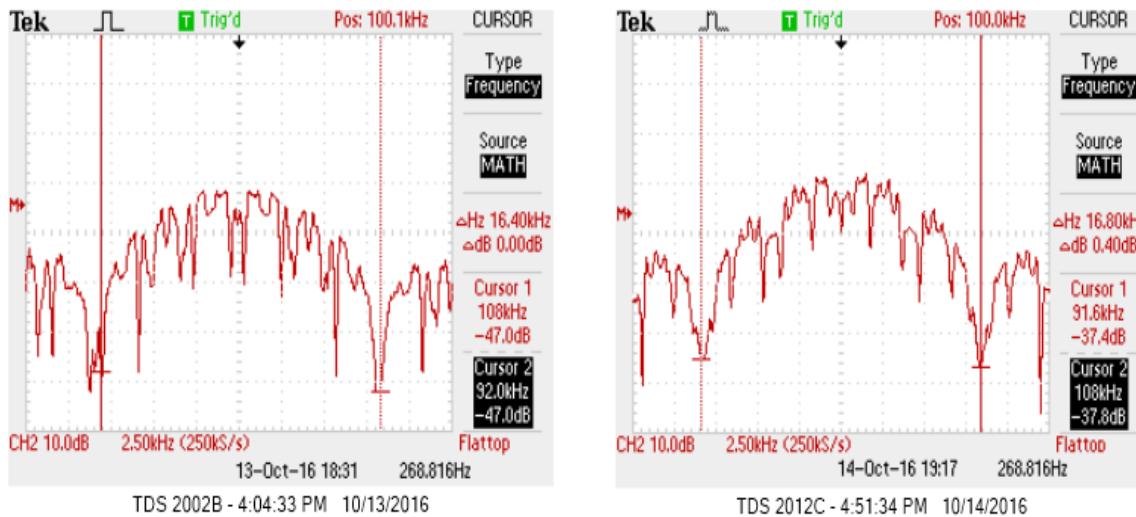
Figure 4: Connection Diagram for Generating Received BPSK signal.

- Observe the Noisy BPSK signal in Ch2, by varying the buffer gain from minimum to maximum.(Try to change the horizontal scale to observe a close view of the BPSK signal)



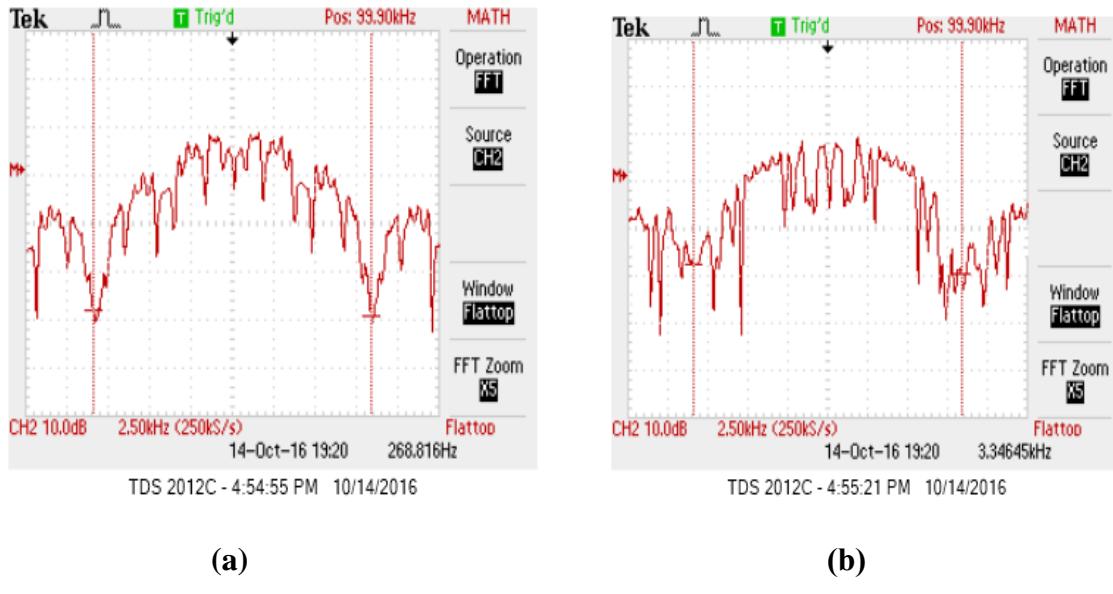
Screenshot 6: Received BPSK signal without noise (a) and with noise (b).

- Obtain the spectra of the BPSK signals, before and after the BPF, on DSO. Before obtaining the spectrum, adjust the time scale of DSO so as to have at least 3 repetitive bunches of the BPSK modulated pseudorandom sequences of on the screen. *Do not change the time scale settings*. Use FFT zoom as X5 for viewing the spectrum. Use the horizontal position knob to bring spectrum to the middle of the screen.



Screenshot 7:

4. Observe the spectrum of the (channel filtered + noise corrupted) BPSK signal. Vary the noise power by changing the buffer gain and observe its effect on the spectrum.



Screenshot 8: Channel + noise corrupted BPSK spectrum with gain knob position being low (a) and high (b).

D – Demodulation and Constellations of Channel and Noise effected BPSK Signal

1. Since the information about the binary digits, in BPSK, is in phase, the BPSK demodulation can be accomplished using coherent demodulator. Use the connection diagram in Fig 6, to demodulate the BPSK signal. Make sure that the Tunable LPF f_c cutoff knob is in maximum position.

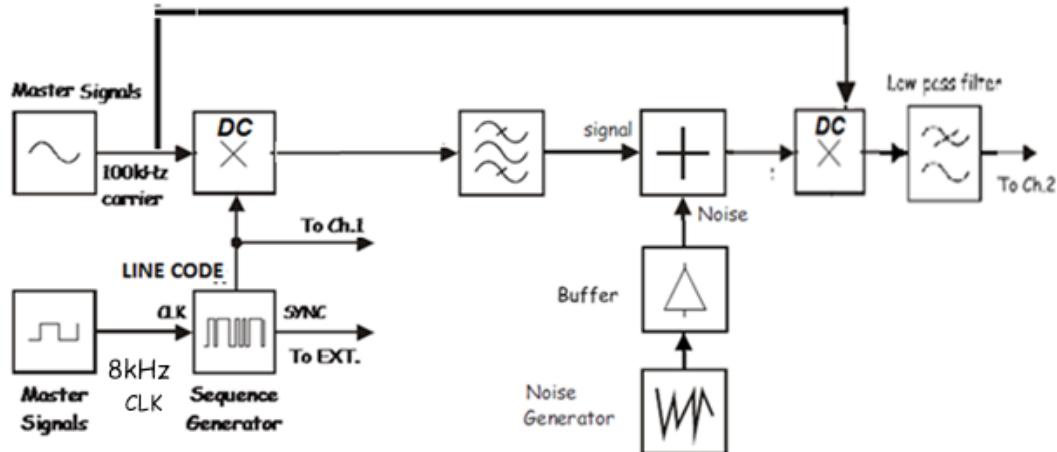
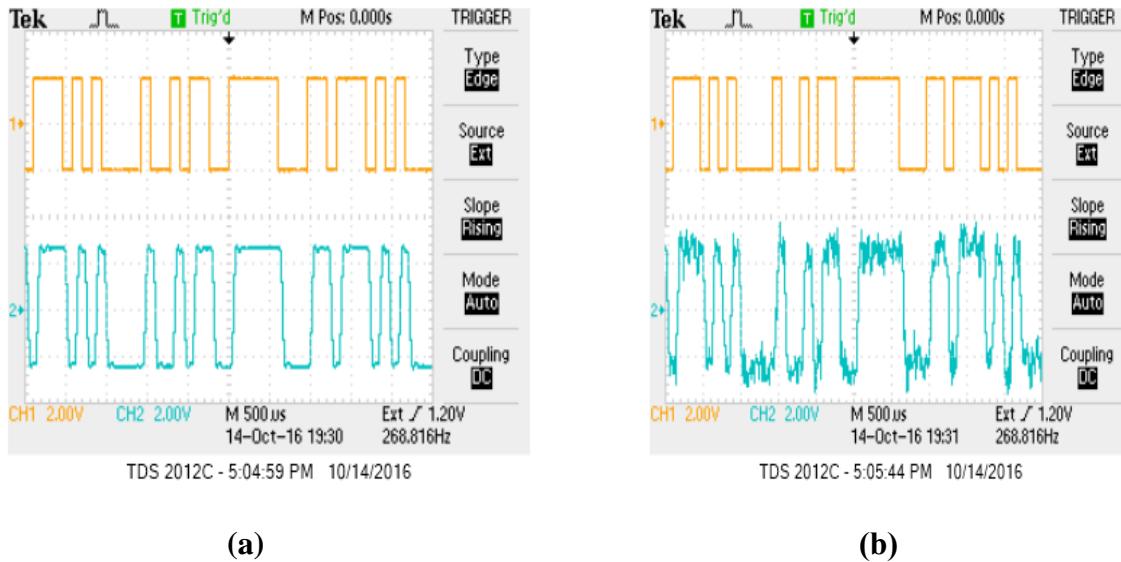


Figure 5: Connection Diagram for Demodulating BPSK signal.

2. Observe the demodulated BPSK signal in Ch2, and compare it with the original signal in Ch1. Vary the buffer gain from minimum to maximum to increase the noise level and see its effect on the demodulated signal.



(a)

(b)

Screenshot 9: Demodulated BPSK signal without noise (a) and with noise (b).

3. To observe the noisy constellations, use connections as per Fig. 7. Adjust the buffer gain to minimum. *Select the Display Mode of the DSO into XY mode. Also, the persistence be kept as 1 sec or 5 sec, or more.* Adjust the Ch1 scale to 1V per division & Ch2 scale to 20 mV / division. Use the position knobs, to view the constellation points on the screen clearly and in the midway of the vertical and horizontal directions of the screen.

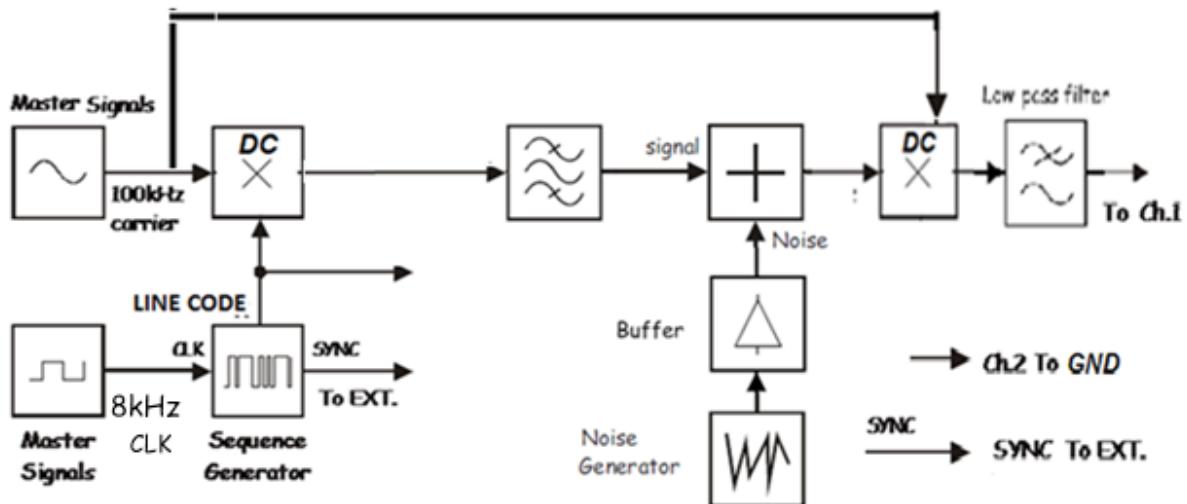
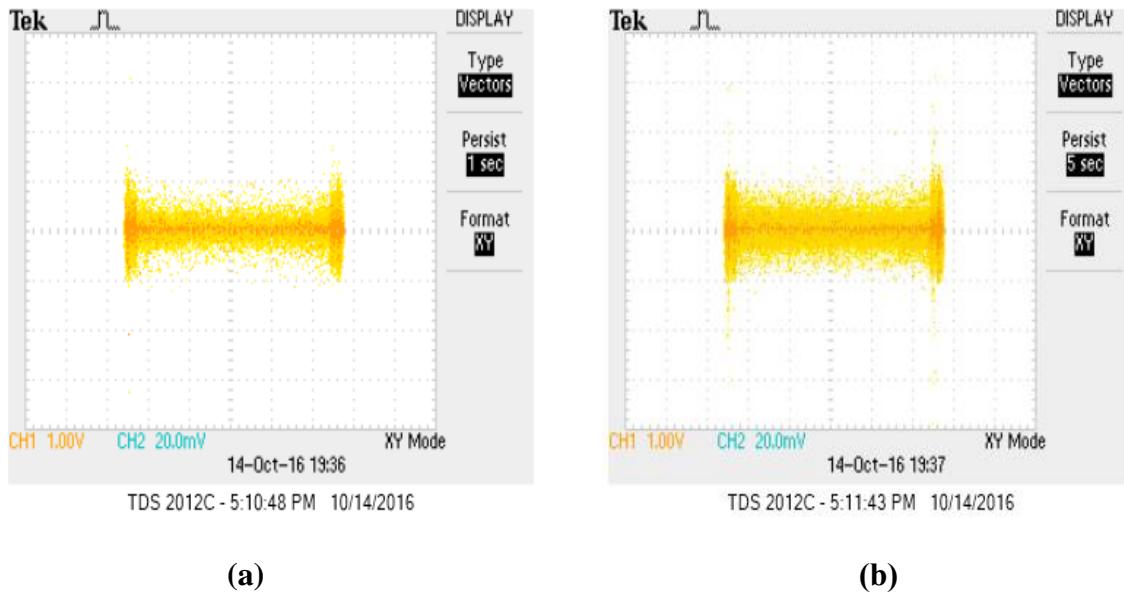


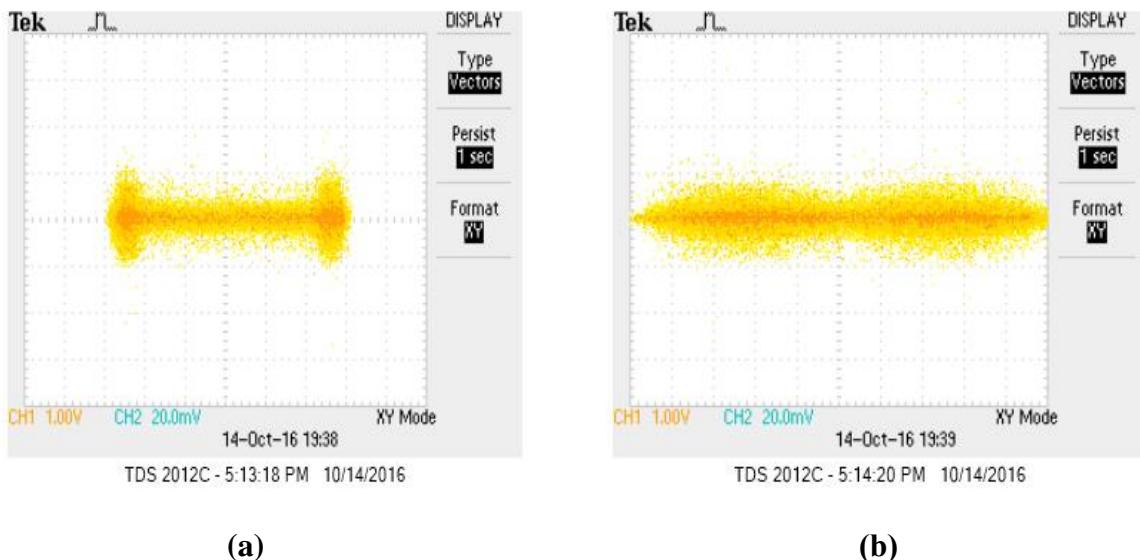
Figure 6: Connection Diagram for observing noisy constellations.

4. With the buffer gain at its minimum, are the constellation points visible distinctly? Try to change the persistence and observe its effect.



Screenshot 10: Constellation diagram of demodulated BPSK signal with 1sec persistence (a) and with 5 sec persistence (b).

5. Vary the buffer gain slowly, from minimum to maximum, and observe the effect of increased noise on the constellations. With maximum gain of the buffer, do these constellation points merge?



Screenshot 11: Constellation diagram of demodulated BPSK signal with low noise (a) and with high noise (b).

E -Recovery of the Bits form Channel and Noise effected BPSK Signal

1. Recovery of the bits from the demodulated BPSK can be accomplished using the connection diagram as in Fig.8. Keep the buffer gain to minimum.

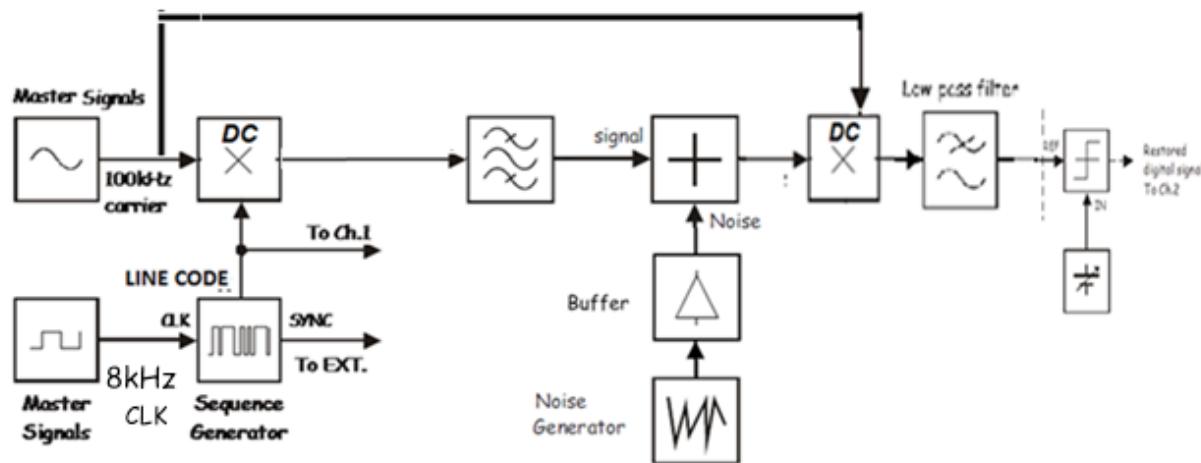
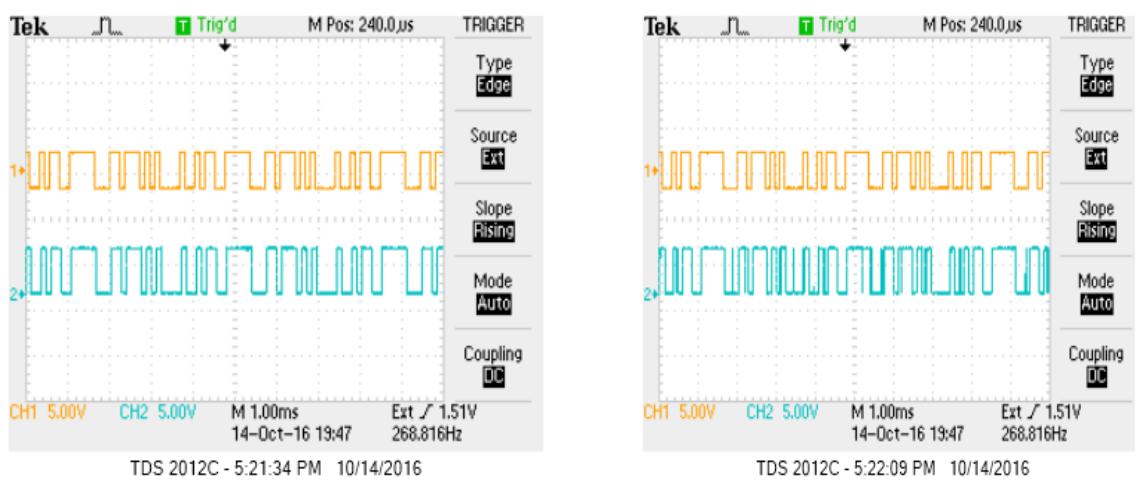


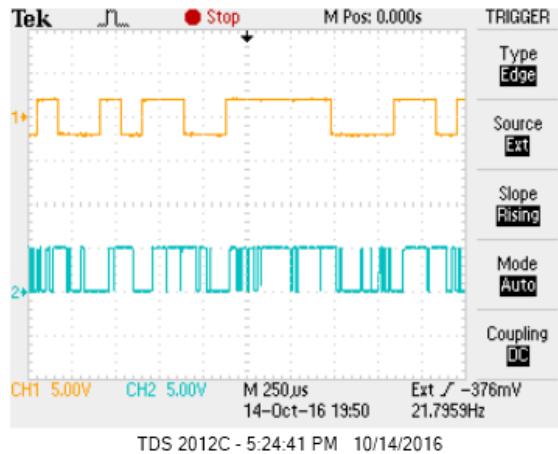
Figure 7 : Connection Diagram for recovering the digits from noisy BPSK signal

2. To recover the original bits, adjust the DC voltage to about 0 volts. This is the threshold we are using to declare the presence of a “1” or “0”, by using comparator.
3. Compare the neatness of the detected bits to the original bits, by comparing the waveforms in Ch1 & Ch2.



Screenshot 12: Recovered signal without noise (a) and with noise (b).

4. Increase the noise level, by varying the buffer gain and observe its effect on the detected bits Vis-a-Vis the original bits.
5. Increase the gain of the buffer to maximum. Do you observe that some of the bits are detected wrongly? You may have to use RUN/STOP feature to see this clearly.



Screenshot 13: Recovered signal with buffer gain in maximum position.

F – Conclusions:-

List out your learnings from the experiments