Manual for Communication Systems Laboratory (EEE/ECE F311)

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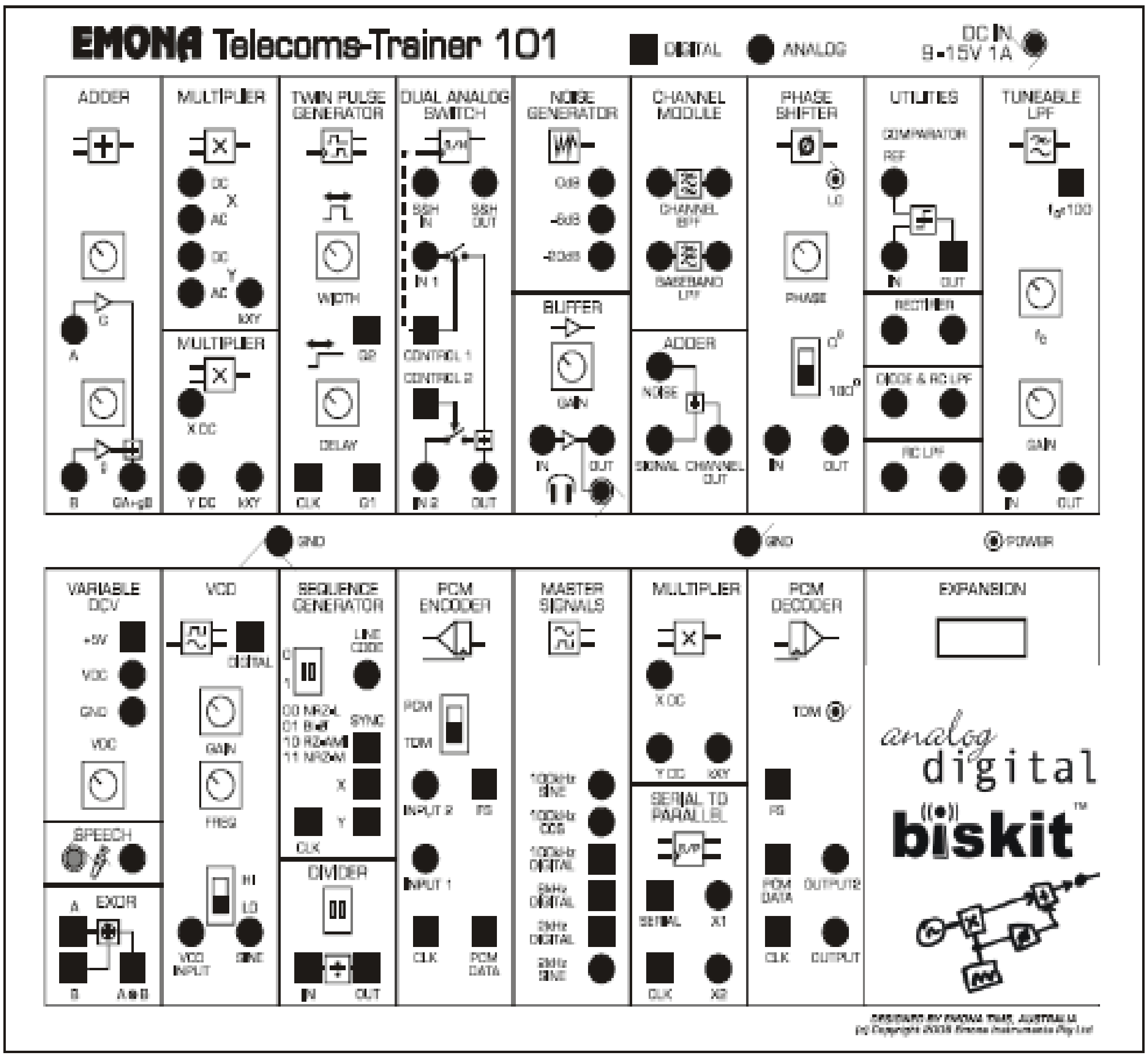
Experiment 5: Angle Modulation and Demodulation

Aim: This experiment is intended to make the student to perform experiments on Frequency Modulation and Demodulations using Emona Telecoms-Trainer 101 kit.

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



A. Frequency Modulation with Square Wave Message Signal

Using the VCO we can generate an FM modulated signal. We will be using the VCO in the **LO** mode around 10 KHz. Make the connections as given in Fig 1.

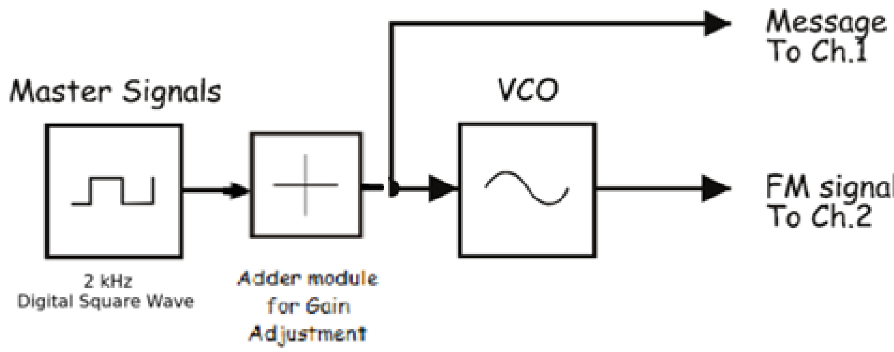


Figure 1: Block Diagram setup for FM Modulation

a. Consider a message signal ***m(t)*** to be a 2 KHz square wave with excursion between (- 1 V and + 1V). You may take the help of adder and Variable DC voltage modules of the Emona kit to adjust the voltages.

b. Set the VCO module's Range control to the LO position. Turn the VCO module's Frequency Adjust control so as to have a nominal frequency of 10 KHz. Turn the VCO module's Gain Adjust control to middle position. ***Do not disturb these settings.***

c. Connect ***m(t)*** to the input of VCO.

d. Display ***m(t)*** in channel 1 and VCO output, the FM signal, in Channel 2 of the DSO. *Stabilize the waveforms on the screen by using trigger feature of DSO.* The trigger can be given from Channel 1. *If you are not able to stabilize the FM signal, do not worry, but the* ***m(t) should be stable.***

e. Adjust the time scale control of DSO, to display just one transition of the ***m(t).***Observe the modulated waveform and the change in frequency at the transition. You may use the RUN/STOP button on the DSO to freeze the modulated signal for proper observation. Do you notice that the frequency of the modulated signal is different in the corresponding HIGH and LOW regions of the Message Signal? (Fig. 5)

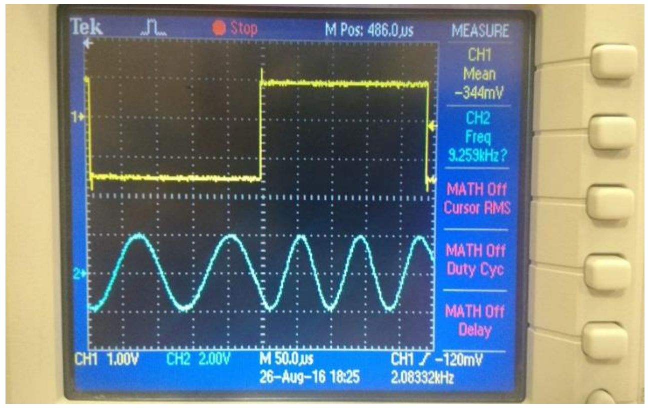


Figure 2: Modulated message signal in time domain

B – Characterization of VCO Module:

Generation of FM signal requires changing the instantaneous frequency of the carrier signal, according to message signal. That is:

$$\omega_i(t) = \omega_c + k_f m(t)$$

Which will result into the standard FM signal described by :

$$\varphi_{\mathrm{FM}}(t) = A \cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha)\, d\alpha\right]$$

One of the ways to change the instantaneous frequency and thus generate and FM signal is to use a Voltage Controlled Oscillator (VCO). As the name suggests, VCO module generates a signal whose frequency can be varied with application of input voltage. For using this module for generating FM signals, we need to know its Voltage Vs Frequency characteristics. To characterize, Make connections as shown in Figure 3.

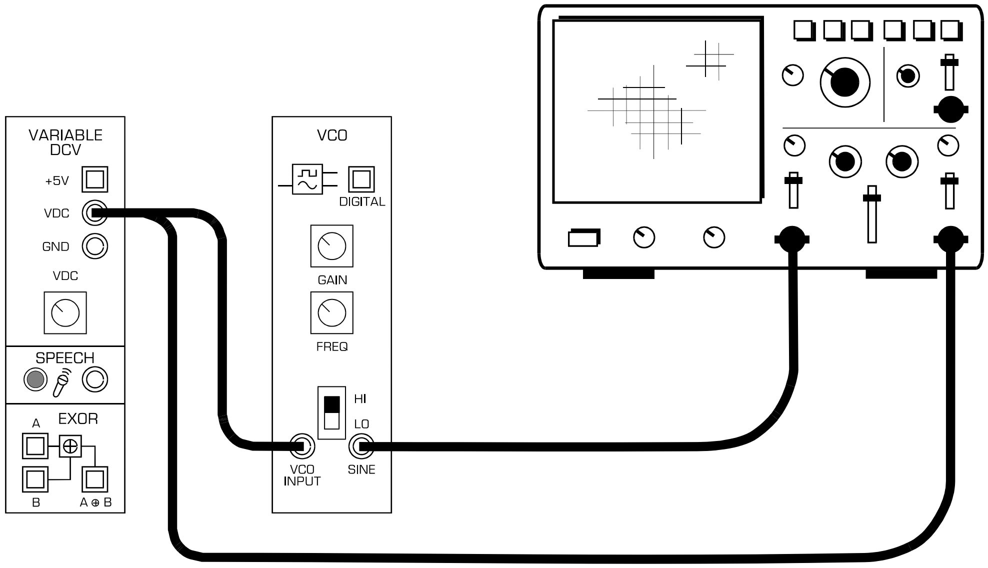


Figure 3: VCO Characterization

You may follow the steps given below:

a) Set the VCO module's Range control to the HI position. Turn the VCO module's Frequency Adjust control so as to have a nominal frequency of 100 KHz. Turn the VCO module's Gain Adjust control to middle position. ***Do not disturb these settings.***

b) Turn the Variable DCV module's VDC control to middle position. Measure the DC voltage and adjust it to 0 Volts. Measure the frequency of the VCO output signal and tabulate in Table 1.

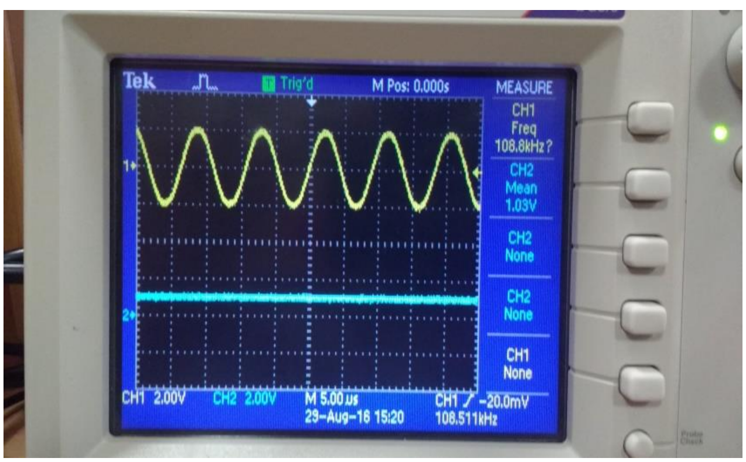


Figure 4: Carrier signal of 108 KHz generated by VCO

a) Turn the VDC control, in steps of 500 mv, in one direction and tabulate the values of voltage and frequency in Table 1. ***Make sure that Channel 2 is in DC Coupling mode***. Change the direction of rotation of the VDC control, in steps of 500 mv, and tabulate the values of voltage and frequency in Table 1.

b) Plot a graph between VCO's input Voltage and Frequency of the VCO output. You may use a graph sheet for plotting this graph. (Refer to Figure 5 for Sample plot) From the plot obtain the slope which is K_f.

MATLAB code:

```
clc;
clear all;
close all;
v=[-2.5 -2 -1.5 -1.0 -0.5 0 0.5 1 1.5 2.0 2.5];
f=[ 79 84 87 91 96 100 104 108 113 117 120];
plot(v,f)
h=polyfit(v,f,1)
slope= h
```

The f values in this plot will be the VCO output.

c) Is the plot linear? Does this have a frequency excursion on both sides of 100 KHz? What is the sensitivity of the VCO, measured as Hz per Volt, around the 0 volts DC (for the current setting of the VCO gain)? Does the sensitivity, measured above, correspond to K_f, used in FM expression?

$$\omega_i(t) = \omega_c + k_f m(t)$$

Sl. No	Vin	VCO Frequency	Frequency sensitivity K_f
1	-2.5 V		
2	-2.0 V		
3	-1.5 V		
4	-1.0 V		
5	-0.5 V		
6	0.0 V		
7	0.5 V		
8	1.0 V		
9	1.5 V		
10	2.0 V		
11	2.5 V		

Table 1: VCO Characterization

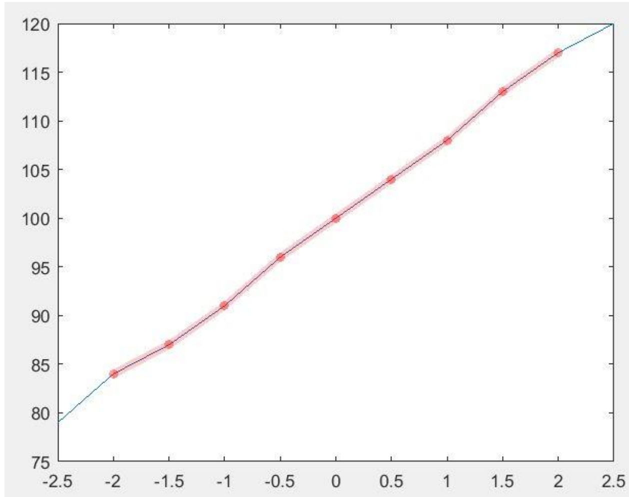


Figure 5: Output Frequency vs VCO voltage plot and linear fit

Remove the VCO characterization Connections. BUT do not disturb the setting of the VCO module's Frequency Adjust control and the Gain Adjust control.

C – Generation of Frequency Modulated Signals – Sine Wave Message Signal:

Although there are many methods of generating Frequency modulated signal, in this experiment we choose to use the VCO method.Student is expected to refer to the text book for other methods of FM signal generation.

a. Consider a message signal ***m(t)*** to be a 2 KHz sine wave with excursion between (-1 V and + 1V). You may take the help of adder and Variable DC (for getting the exact peak values of -1V and 1V while ensuring mean value of 0V) voltage modules of the Emona kit to adjust the voltages. Connect ***m(t)*** to the input of VCO. (Fig.6)

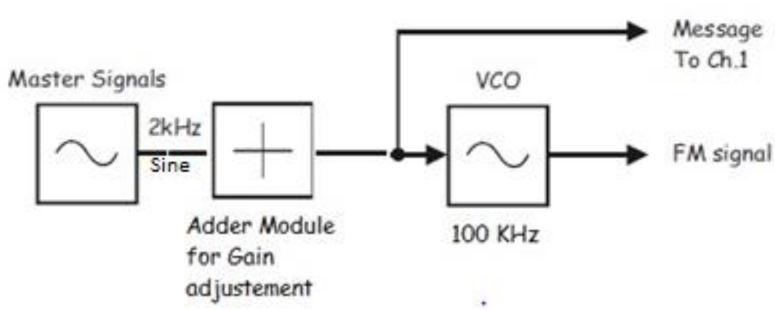


Figure 6: Block Diagram setup for FM Modulation

b. Display ***m(t)*** in Channel 1 and VCO output, FM signal, in Channel 2 of the DSO. *Stabilize the waveforms on the screen by using trigger feature of DSO.*The trigger can be given from

Channel 1. *If you are not able to stabilize the FM signal, do not worry, but the* ***m(t) should be stable.***

c. With sinusoidal message signal, you may not be able to *measure* (Δf). Calculate the theoretical value $\Delta f = K_f * m_p$ where m_p is peak value of message signal.

d. With the chosen ***m(t),*** calculate the expected BW of the resulting FM signal that is obtained theoretically as $BW_{FM} = 2(\Delta f + B_m)$. B_m*(in KHz)* is the essential bandwidth and can be taken as the frequency of m(t). Calculate $\beta = \Delta f / B_m$ for this case and Tabulate in Table 2. These are the theoretical values.

e. From theoretical analysis of FM band width for single tone message signal, we know that the significant spectral components (n) that need to be considered, in arriving at the Bandwidth value, is given by $n = \beta + 1$.

f. Obtain the spectrum of the FM signal on DSO. Use the relation $n = \beta + 1$ to identify the spectral components of the FM spectrum, obtained on DSO. What is the Frequency value of n^{th} spectral component (f_n) ? The bandwidth is then given by $(BW_{FM})' = 2 * (f_n - f_c)$, where f_c is the nominal frequency of the carrier. Tabulate the observations in Table 2.

Figure 7: Frequency Modulated Signal Spectrum

g. How low (relative to the maximum value) is the power in the spectral component corresponding to n? (n_{pow} ***is the power of the n'th spectral component w.r.t max. value).***

h. How do the theoretical and measured Bandwidths compare to each other?

Sl. No.	VCO Gain Position	B_m	Δf	β	BW_{FM}	n	f_n	$(BW_{FM})'$	(n_{pow})
	Middle								

Table 2: Frequency Modulation (Sine wave) Results

i. Try to generate a NBFM signal, by setting the VCO Gain position to LOW side (Turn Anti clock wise) and obtain the spectrum of modulated signal on DSO. Consider only one spectral points on both side, relative to the maximum peak on the spectrum, and designate the frequency at that point as the essential bandwidth $(BW_{FM})'$**.** Tabulate the results in Table 3 and comment on your observations.

j. Try to generate a WBFM signal, by setting the VCO Gain position to HIGH side (Turn clock wise completely) Consider that spectral points whose amplitude is above -30 dB, relative to the maximum peak on the spectrum. Tabulate the results in Table 3 and comment on your observations.

Sl. No.	VCO Gain	B_m	$(BW_{FM})'$
	Low		
	High		

Table 3: Narrow and Wideband Frequency Modulation (Sine wave) Results

D – Demodulation of Frequency Modulated Signal:

There are many methods of demodulating an FM signals: They are *slope detector*, the *Foster-Seeley discriminator,* the *ratio detector*, the *phase-locked loop* (PLL), the *quadrature FM demodulator* and the *zero-crossing detector*. It's possible to implement several of these methods using the Emona Telecoms-Trainer 101 but, for an introduction to the principles of FM demodulation, only the zero-crossing detector is used in this experiment. The zero-crossing detector is a simple yet effective means of recovering the message from FM signals.

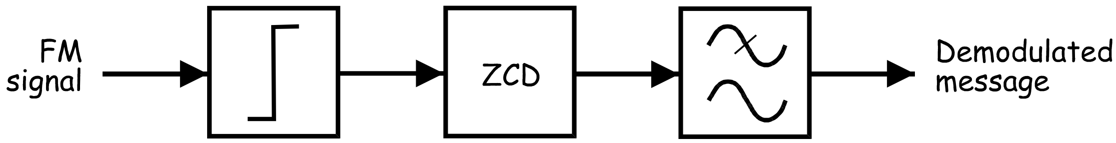


Figure 8: Block diagram for FM Demodulation

The received FM signal is first passed through a comparator to heavily clip it, effectively converting it to a square wave. This allows the signal to be used as a trigger signal for the zero-crossing detector circuit (ZCD). The ZCD generates a pulse with a fixed duration every time the squared-up FM signal crosses zero volts (either on the positive or the negative transition but not both). Given the squared-up FM signal is continuously crossing zero, the ZCD effectively converts the square wave to a rectangular wave with a fixed *mark*time. Make the connections as shown in Figure 9.

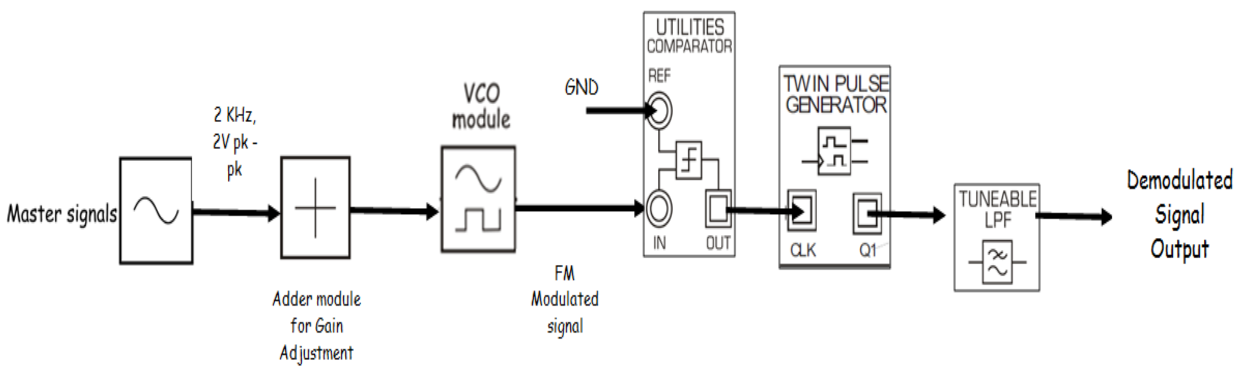


Figure 9: Block diagram for FM demodulation

a) Generate FM signal as in Section B, with ***m(t)*** being a sinusoid and ***carrier of 10 KHz nominal frequency*****.** Let the VCO gain position be in the middle. Use the VCO in **LO** mode.

b) Connect the demodulation circuit as shown in Figure 9.

c) Use the tunable LPF for tuning the output cutoff frequency. Adjust the fc knob until you get a stable demodulated signal. You can use the gain knob to adjust the amplitude.

d) Check the spectral properties of the demodulated output with that of the message signal.

e) Observe the spectrum and compare the demodulated signal frequency with original message frequency.

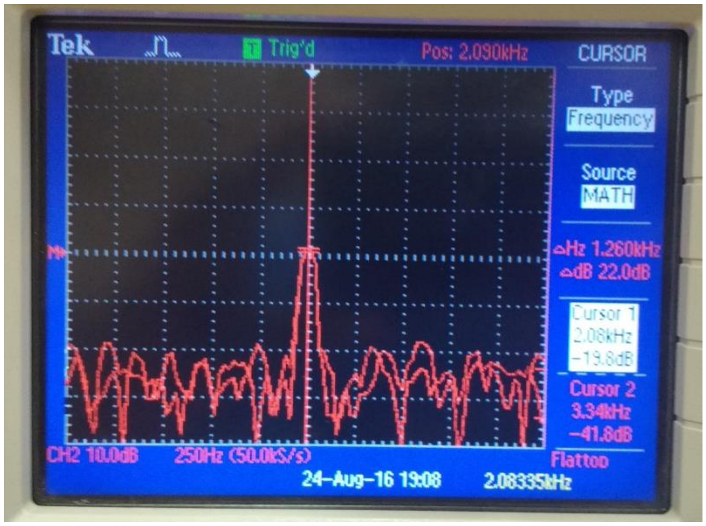


Figure 10: Demodulated signal spectrum

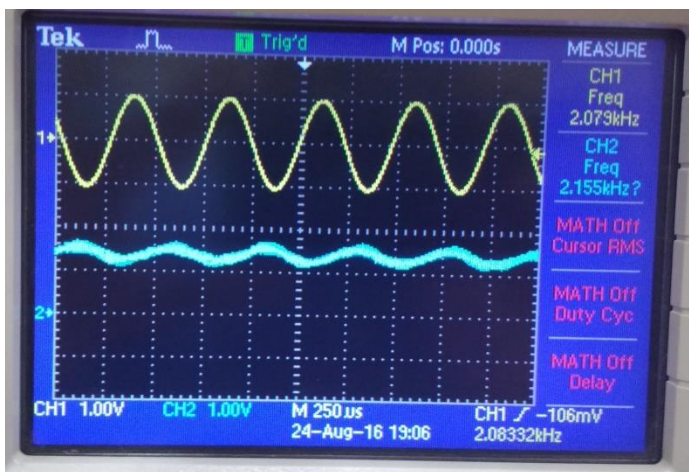


Figure 11: Demodulated message signal in time domain

E –Conclusions:

List out your learning's from the experiments