

REMOTE LAB SYSTEM FOR FM DEMODULATION

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ABSTRACT

This paper presents analysis of FM demodulation process on Remote laboratory system. This remote access system as options of changing the frequency, modulation index of the input signal and many circuit parameters to analyze the performance of the FM demodulation using Phase Locked Loop circuit with the help of PLL IC 565. User has the option to observe the response of the circuit using Analog Discovery module a National Instruments product. The variation of different parameters of the circuit is enable using Arduino ATMEGA-2560, and python script is used to develop the graphical user interface. The user can analyze performance parameters like Voltage Controlled Oscillator, lock & capture range, loop filter time constant and modulation index for proper demodulation.

Keywords: Phase Locked loop, Voltage Controlled Oscillator, Frequency Demodulation, Analog Discovery.

1. Introduction

In the current Engineering Education most of the concepts are circuit based so students get limited time to conduct lab experiments they will be satisfied if they get output. Students won't get much time to explore different parametric variations of the circuit, as they have to complete the entire process of doing connections, debugging the same to get the output in the allotted lab time. As the students make lots of mistakes in the connections and signal amplitude and frequency settings and hence left-out with less time for performance analysis.

Remote laboratory is the concept of conducting experiments using the internet and accessing it remotely from anywhere at any time. In this project, the laboratory experiment setup is done at the laboratory and access is provided to the student. Student can use this facility from anywhere through internet. Remote laboratory offers, the user can conduct analog electronic experiments. The user can remotely modify the configuration and conduct the experiment with the available parameters after selection of the experiment.

The user will have complete access to the experiment setup and can perform the experiment with all possible variations in the input and measurement settings. As in [1], [2] and [3] the project aims to provide remote-access

to laboratories in various disciplines of science and engineering for students at all levels from undergraduate to research.

“It also aims to develop a comprehensive learning management system where students can use different learning tools including additional web resources, video-readings, animated demonstrations and self-assessment. There is also a component in which expensive equipment and resources are shared, otherwise available only to a limited number of users due to time constraints and geographical distance ‘Seven IIT’s (Delhi, Bombay, Kanpur, Kharagpur, Madras, Roorkee and Guwahati), IIT Hyderabad, Amrita University, Dayalbagh University, NIT Karnataka, and College of Engineering Pune are the institutions involved in the project’. As in [2] This laboratory offers a good understanding and learning opportunity for various designs including VLSI for users in this laboratory there are different studies covering the following aspects:

- Schematic design and simulation Software interface
- Web base spice technology simulation
- Digital circuit design using Verilog.

This virtual lab user can learn layout design rules and check the design rules of their designs.

In this paper we are discussing about FM demodulation here the circuit is implemented in a PCB. PCB is interfaced with Arduino ATMEGA- 2560 ,Python script and Analog Discovery Kit .

First step is to load the Arduino code into Arduino ATMEGA-2560 after loading run the PYTHON script and select and conduct the FM Demodulation experiment and perform different variations on the same circuit. Results will be observed in the waveform tool. Results of simulation are shown using waveform tool.

The methodology of performing experiments should be similar to that of the conventional lab, so that the student can work easily. Established remote laboratory system needs theoretical clarity, specifications, design equations, values of components and expected readings ideal & typical values. In PLL we can easily detect the capture and lock ranges of the VCO frequency .after measuring capture and lock range apply message and carrier frequency which is equal to that of free running frequency and observe the FM demodulation output by switching different values of resistors and capacitors.

2. Methodology

Remote Lab System

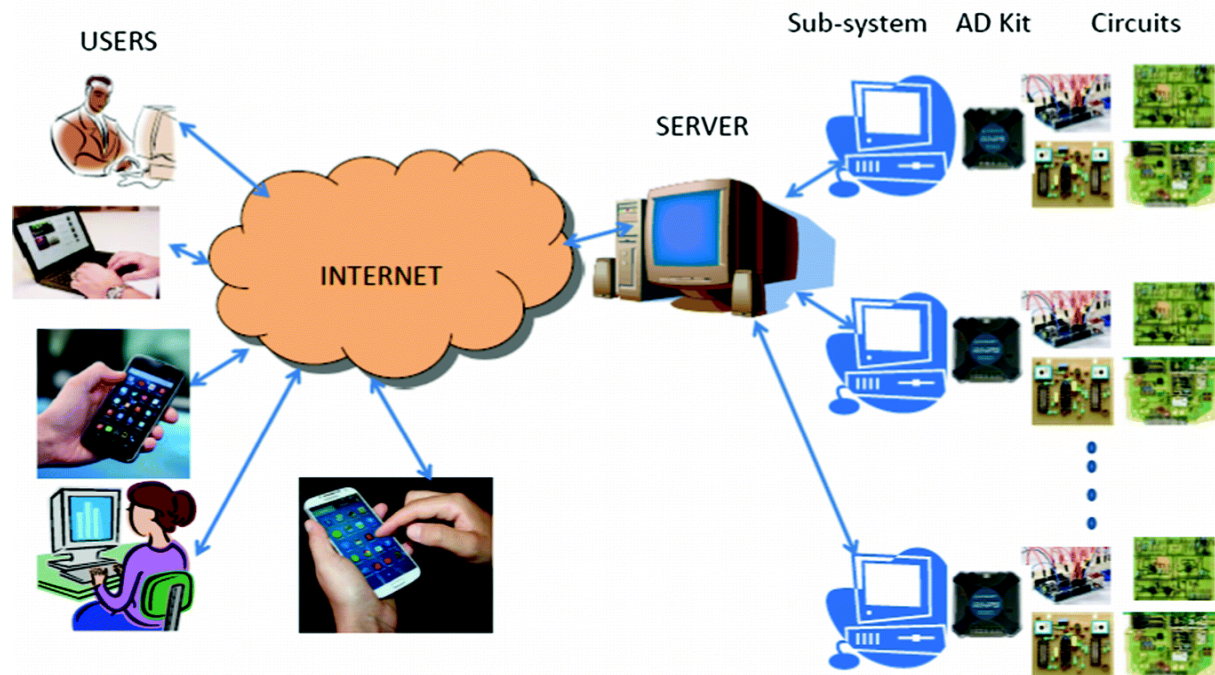


Figure 1: Block Diagram of Remote Lab System.

This Remote Lab system Fig 1 consists of printed circuit board (PCB), Analog Discovery Kit, Arduino ATMEGA2560.

PCB is interfaced with Arduino ATMEGA-2560 with Arduino code ,python script and AD-Kit all are connected to a server .using “TEAM-VIEWER” app where team viewer is installed in both the system their is a user ID and password for the particular system .The server consists of a remote lab setup where access is provided to the user. User can access the remote laboratory any where any time through internet.

Remote laboratory program is established to provide faculties and students with access to "Experiential Learning" .Experiments can be accessed via the internet via a laptop or smart phone .The requirement of this remote lab setup is there is no need any special software at the end of the user. The benefits of using Remote laboratory are that users can conduct experiments from anywhere at any time and get the circuit output and performance analysis. User can perform the experiments at the desired speed and repeat the experiments until they grasp the concepts. Through varying main circuit components as shown in Table 1, users can perform the experiments together with peers for better learning. As well as Bode analysis, the user can perform time response. The circuits are analyzed by measuring desired parameters of the relevant waveform or plots.

3. FM Demodulation Design and Analysis

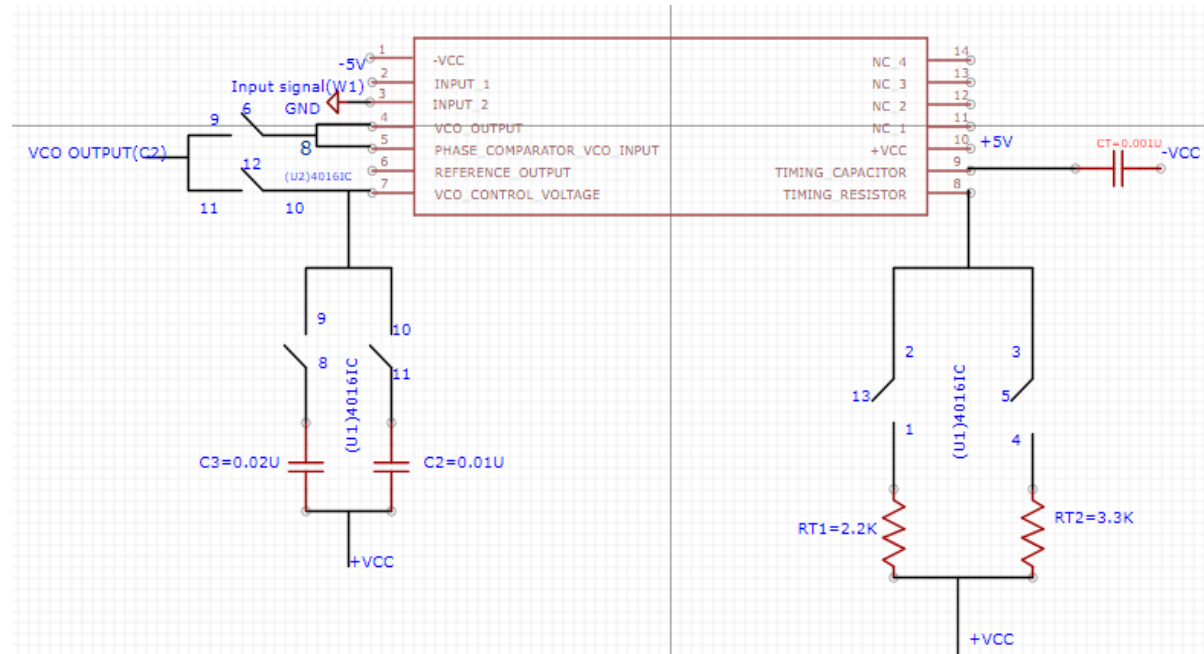


Figure 2 : FM Demodulation Circuit.

Fig 2 shows the FM demodulation circuit where u1 and u2 are used as switches. The circuit is working at 5V.

1.Measure the output (VCO) without giving the FM signal and measure the VCO frequency at pin 4.

$$\text{i.e., } f_0 = \frac{0.3}{R_T C_T} \dots \dots \dots (1)$$

Where , $2k \leq R_T \leq 20k$, $100pF \leq C_T \leq 0.1\mu F$.

2. Apply only carrier signal to lock the PLL to VCO frequency.

3. Give the carrier frequency which is equal to that of that of the free –running frequency of VCO to capture the and lock the signal.

4. View the frequency response and measure the lock range. After setting the lock range apply FM input.

5. Give FM signal to the phase detector input the VCO i.e (f_0) tries to track the FM signal but in the process of tracking the error voltage is coming that itself is the message signal and Vary the modulation index , message signal frequency, carrier frequency and observe the Demodulation output at pin no.7 and take the reading for all the combinations.

Table 1: Different variation of FM Demodulation Circuit.

SI No.	RT1=2.2kHz	RT2=3.3kHz	C2=0.01 μ F	C3=0.02 μ F	VCO OUTPUT	FM DEMODULATION OUTPUT
1	1	0	1	0	1	0
2	0	1	1	0	1	0
3	1	1	1	0	1	0
4	1	0	0	1	1	0
5	0	1	0	1	1	0
6	1	1	0	1	1	0
7	1	0	1	0	0	1
8	0	1	1	0	0	1
9	1	1	1	0	0	1
10	1	0	0	1	0	1
11	0	1	0	1	0	1
12	1	1	0	1	0	1

Table 1 shows the different variation of FM Demodulation circuit by switching different value of resistor and capacitor. Above table shows the twelve combinations and observe the VCO output for different value of resistor and capacitor and also measure the capture range . Repeat the same procedure for FM Demodulation.

3.1 VCO and PLL

The VCO is in-built frequency in LM565 IC but it is set with an external resistor and capacitor.

3.1.1 PLL Block Diagram

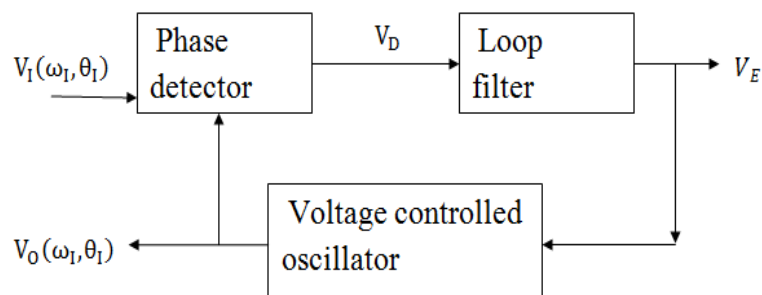


Figure 3 : Block Diagram of Phase Lock Loop.

Fig 3 shows the block diagram of Phase Lock Loop it consists of phase detector, loop filter, and voltage controlled oscillator.



Where, V_D = difference between input and reference voltage

V_E = Error voltage

V_I = Input voltage

V_O = Reference voltage

ω_I = Input angular frequency

θ_I = Input phase response

ω_O = Output angular frequency

θ_O = Output Phase response

1.VCO: Free operating frequency ω_O depends on the V_E DC voltage.

2.PHASE DETECTOR: The output voltage V_D proportional to the phase difference in the input signal V_I and VCO signal V_O .

3.LOOP FILTER: A low pass filter is used for eliminating the V_D noise.

PLL is a circuit used to track variation in input signal phase and frequency. For this reason a reference signal within the PLL is produced. Meaning there is a function in the PLL to track the input signal frequency and phase variance by looking at the frequency and phase of the reference signal. The LM565 IC is a PLL with a stable highly linear (VCO) voltage controlled oscillator and a double balanced phase detector.

3.1.2 LOCKING OF PLL

- As there is no difference between V_I and V_O the phase detector output $V_D=0V$.
- The V_D output is filtered using loop filter (LPF) and the output voltage (V_E) called error voltage is applied to VCO.
- Error voltage $V_E=0$ represents no difference in phase of V_I and V_O
- When V_E is 0V, VCO output free running frequency will not be modified.

$$\omega_O(t) = \omega_0 + K_O V_E(t)$$

Where, K_O = sensitivity of VCO.

- Suppose if there is any variations in the input signal frequency or phase with respect to reference signal, phase detector detects it and gives a proportional output voltage V_D .

$$\text{i.e, } V_d(s) = K_d \theta_d(s), \quad \theta_d(s) = \theta_i(s) - \theta_o(s)$$

- This phase detector output filtered in a LPF and its output (DC voltage) V_E named as error voltage will be used to vary the free running frequency of the VCO such that the error voltage is reduced to 0V.
- Error voltage produced is a measure of deviation in the phase of the input with the reference signal
- Suppose if there is any deviation (+ / -) in the frequency or phase of the input signal with VCO signal V_O will not be zero, hence the error signal V_E will be used to adjust ω_O till the V_O synchronizes with V_I ,

that is “until for every one input cycle there is one and only one VCO cycle “the condition is called PLL is locked i.e $\omega_0 = \omega_1$ exactly. VCO frequency is given by , $f_0 = \frac{0.3}{R_T C_T}$

Where $2k \leq R_T \leq 20k$

$$100\text{pF} \leq C_T \leq 0.1\mu\text{F}$$

- If there is a continues variation in the frequency and phase of the input signal with VCO signal, then V_E will be represent the pattern of variation of frequency or phase .

3.1.3 WORKING OF PLL

- Phase detector is realized using a balanced mixer ,its output consists of sum and difference frequencies $\omega_0 \pm \omega_1$.when the loop is locked, the sum is twice of ω_1 and the difference is zero, the LPF suppresses the sum as it is twice of ω_1 ,but passes the dc component, which thus keeps the loop locked.
- If the PLL is not locked and the difference frequency falls above the cutoff frequency of the filter ,it will be suppressed along with the sum frequency, leaving the PLL unlocked. However ,if ω_0 is sufficiently close ω_1 such that the difference frequency is close to the filter band edge, then this part is passed tending to drive ω_0 towards ω_1 hence the PLL is locked.

3.1.4 CAPTURE AND LOCK RANGE

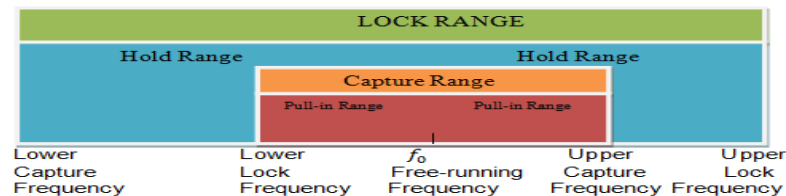


Figure 4 : Capture and Lock Range.

- When the input is at lower capture frequency VCO is not capture and not locked. When we increase the input frequency if it is close enough to the VCO frequency PLL has capture that input signal it has generated a error signal and the VCO frequency is lock to the incoming frequency as shown in table(2) and Fig 4.
- The capture range is the frequency range $\pm\omega_c$ centered around ω_0 over which the loop can acquire lock.
- The range is affected by filter characteristics and gives an indication how close the ω_1 must be to ω_0 to acquire lock.
- The lock range is the frequency range $\pm\omega_L$ centered around ω_0 over the loop can track the input once the lock has been established.
- This range is affected by operating range of phase detector and the VCO.
- The capture range is never greater than lock range.

Table 2: Capture and Lock range example.

V_I (kHz)	VCO (kHz)	Condition
79	100	NC-NL
80	100	NC-NL
89	100	NC-NL
90	90	C-L
100	100	C-L
110	110	C-L
111	111	C-L
120	100	NC-NL
121	100	NC-NL
130	100	NC-NL
NC - NL : Not Captured hence Not Locked	C - L : Capture hence Locked	C - L : 90kHz-111kHz

Table 2 shows the capture and lock range example. Assume that VCO is oscillate at 100kHz which is decided by the resistor and capacitor. Assume input frequency is 60kHz it is too far away from the 100kHz hence it is not capture and not locked. The capture and lock frequency range is shown in Fig 4. At 90kHz is close enough to 100kHz the PLL capture that input signal it has generated a error signal the VCO frequency is also change to 90kHz now it is captured and locked as shown in Fig 7.

3.4 PLL BLOCK DIAGRAM V/S LM565 IC

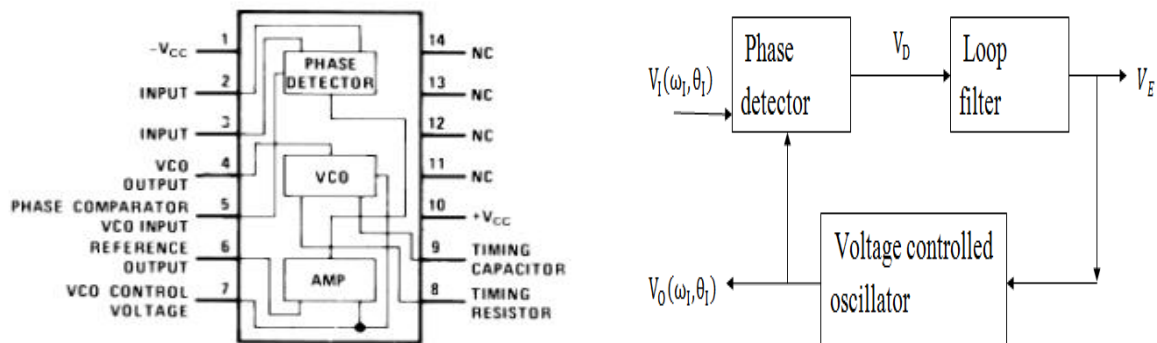


Figure 5 : PLL Block Diagram v/s LM565 IC

- We have a phase detector in both diagrams i.e VCO output (pin4) to the phase detector input (pin2).
- Loop filter : connecting a capacitor to pin 7 and internal resistor is acting like resistive part of loop filter.

3 FM DEMODULATION RESULTS AND DISCUSSION



Figure 6 : Remote Lab Window

Fig 6 shows the first window of our remote lab with our institute logo .user should click on the click here for start . After that second window will open as shown in Fig 7.

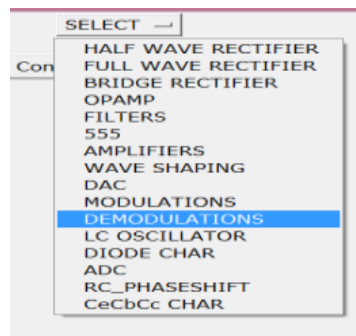


Figure 7: Option for Different Experiment Selection.

Fig 7 shows the second window of our remote lab. That shows the option for different experiment selection here this paper deals with the FM Demodulation experiment. User should click on the Demodulation option .

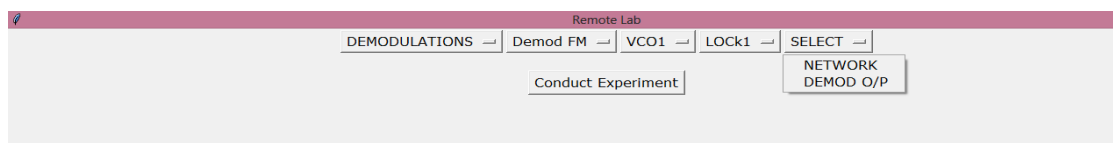


Figure 8 : Option for Different Variation .

Fig 8 shows the different combinations of FM Demodulation circuit. Here in FM Demodulation circuit we included twelve combination by varying resistor, capacitor, VCO output and FM Demodulation output as shown in Table 1. Here we have option of VCO1, VCO2. Again in VCO1 itself we have option of Lock1, Lock2, Lock3. Again in Lock1 we have option of VCO/Network output, FM Demodulation output. Suppose user select VCO1, Lock1, Network option means Table 1 first combination be selected. Again in Lock1 FM Demodulation output means Table 1 seventh combination be selected like that it continues for VCO2, Lock1, Lock2, Lock3 .

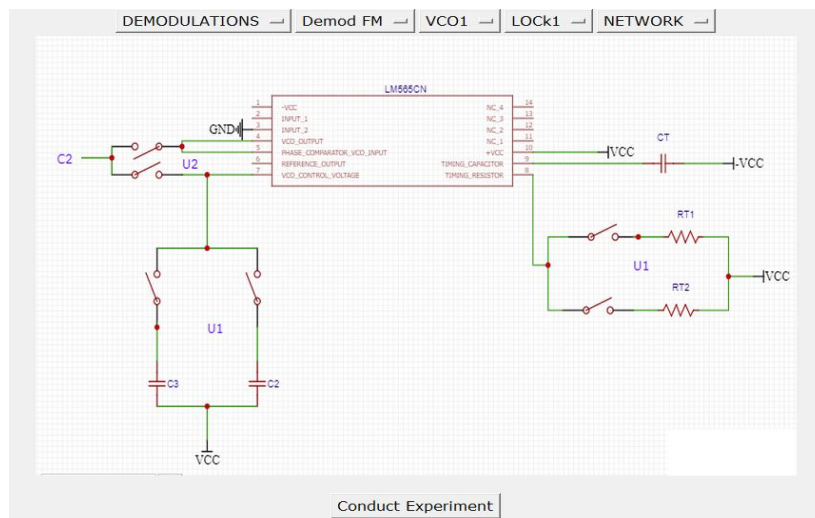


Figure 9 : Option for Condition of Experiment.

Fig 9 shows the option for conduct experiment. Here user should click on the conduct experiment at that time that particular combination is in the Arduino code that is interfaced with the Arduino and python script after that the output will be observe in the waveform tool as shown in Fig 10 and Fig 11.

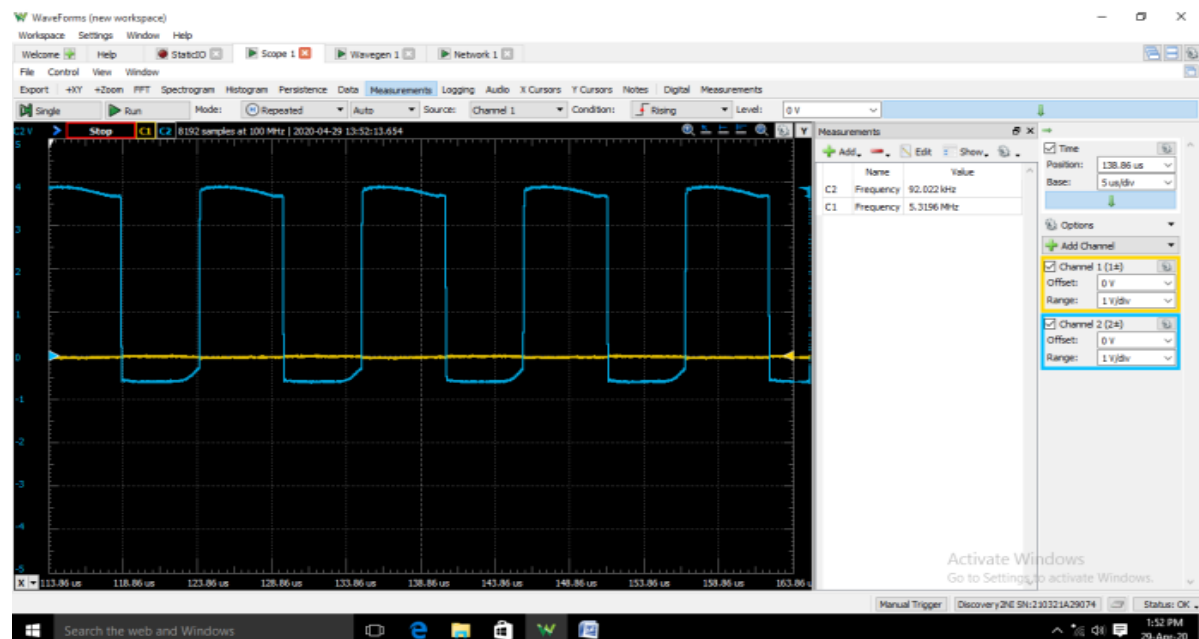


Figure 10 : VCO Output.

Fig 10 shows the Voltage Controlled Oscillator output. That is from Table 1 second combination output means RT2, C2 is on and using “equation(1)” Theoretical frequency = 90kHz and Practical frequency = 92kHz.

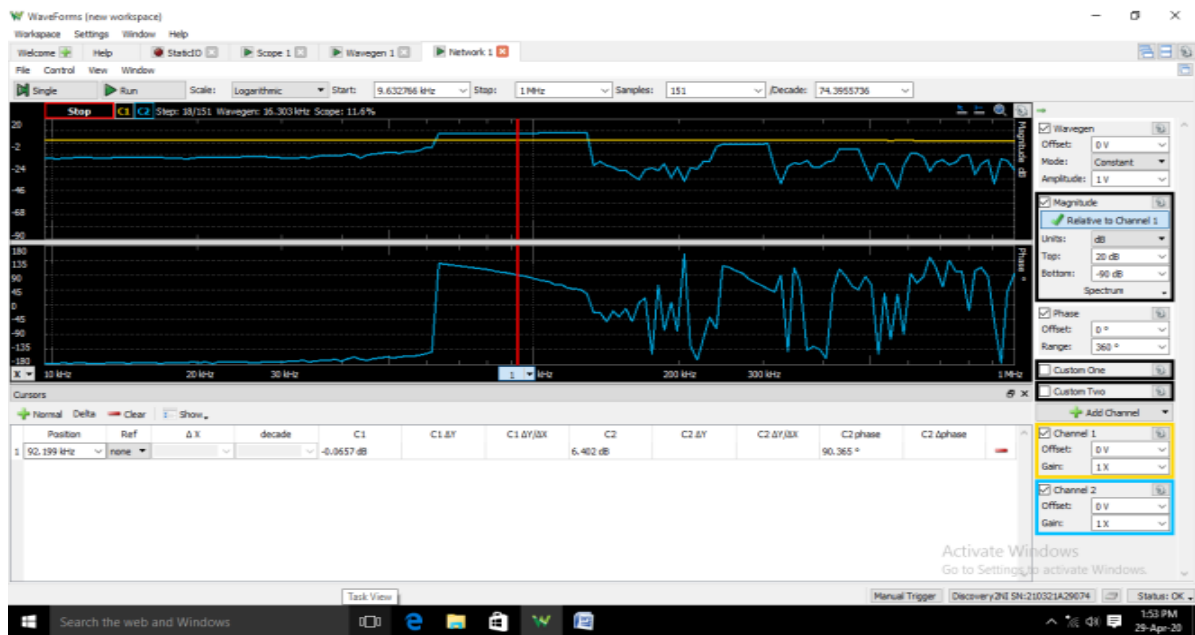


Figure 11 : PLL Lock Range

Fig 11 shows the Phase Lock Loop Lock range. At 90 degree phase we got the VCO frequency i.e 92kHz. And the Capture – LOCK range = 60kHz - 110kHz .

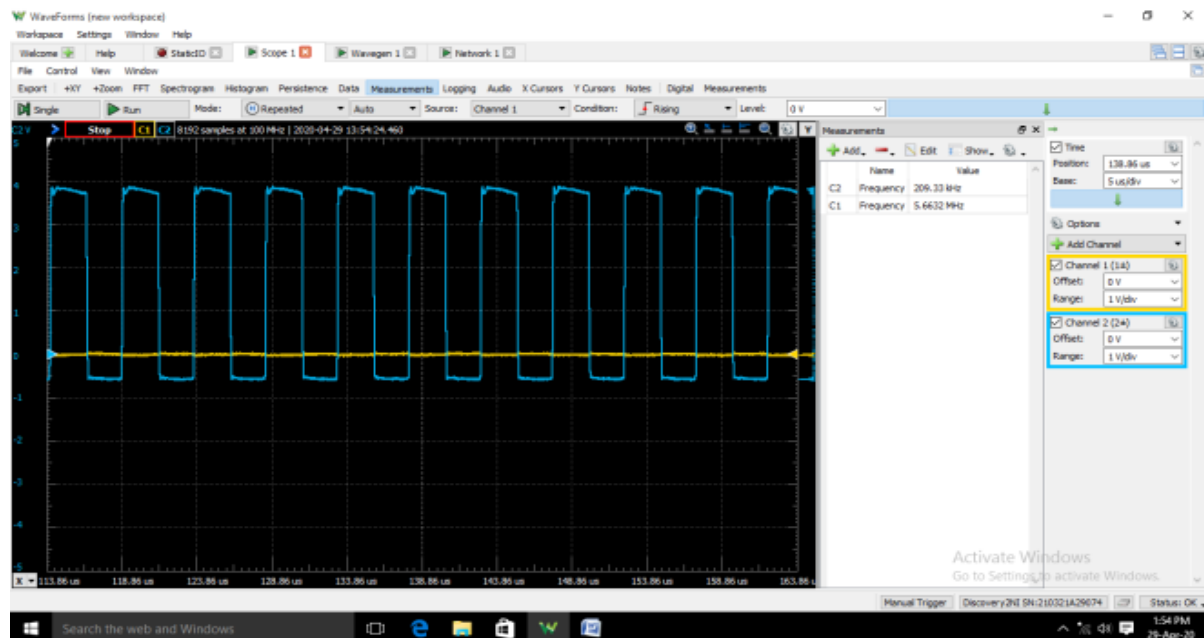


Figure 12 : VCO Output.

Fig 12 shows the Voltage Controlled Oscillator output. That is from Table 1 second combination output means RT1, RT2,C2 is on using “equation(1)” Theoretical frequency = 227kHz and Practical frequency = 209kHz .

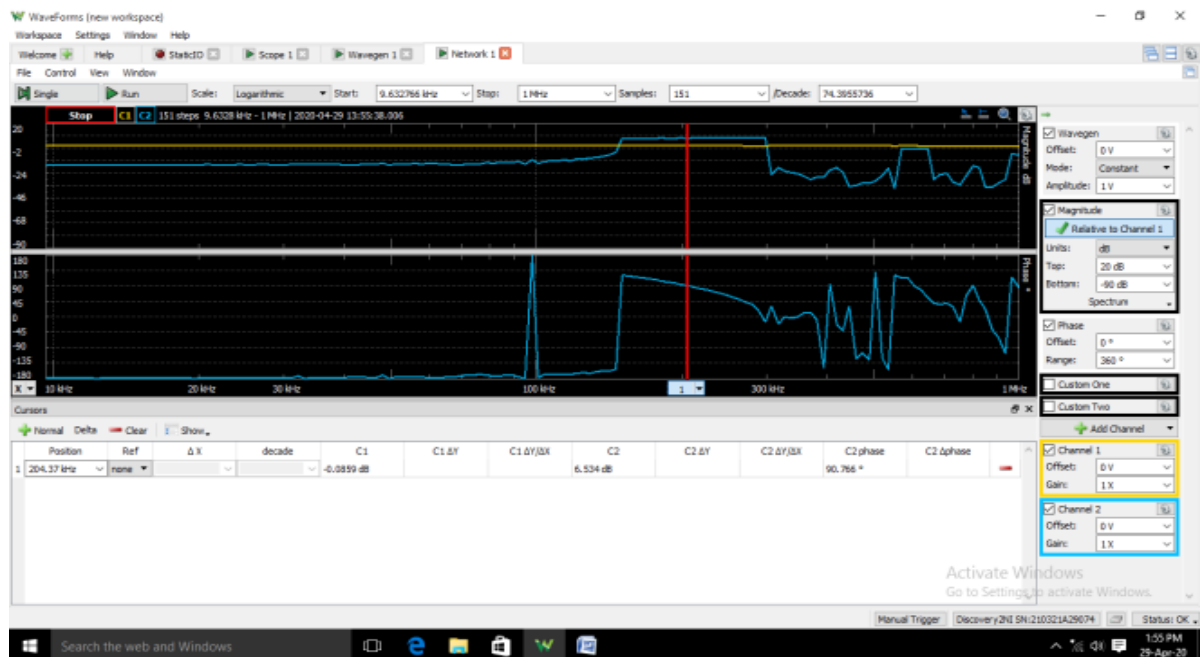


Figure 13 : PLL Lock Range.

Fig 13 shows the Phase Lock Loop Lock range. At 90 degree phase we got the VCO frequency i.e 209kHz. And the Capture – LOCK range = 120 kHz - 300kHz .

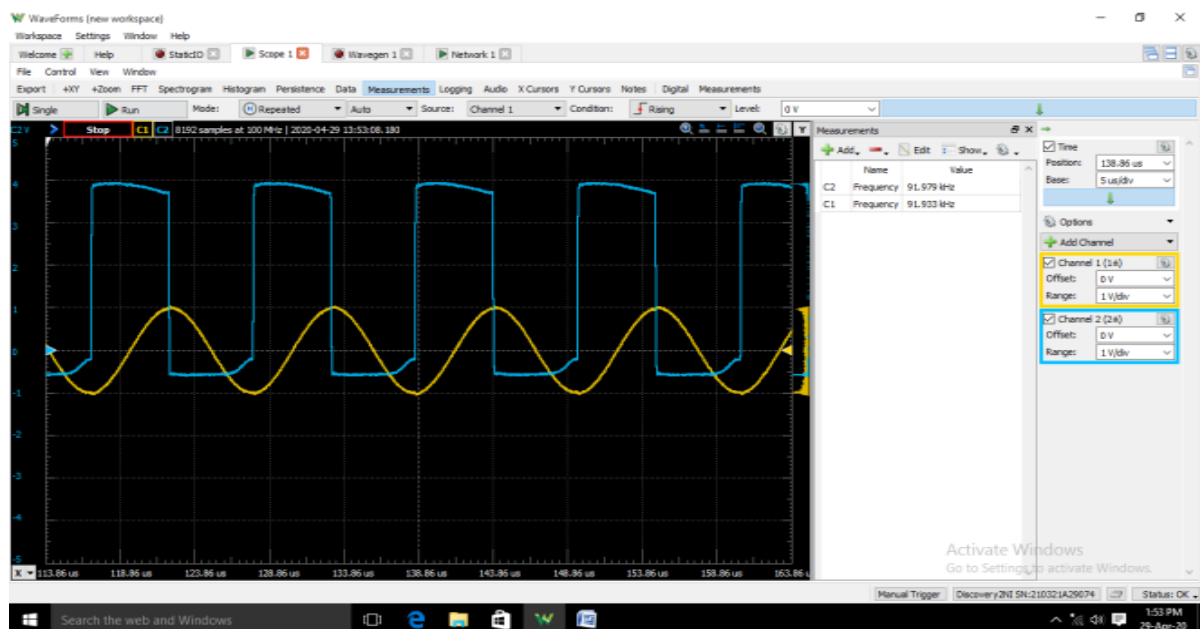


Figure 14 : Output of VCO Frequency with the Input Carrier Frequency.

Fig 14 shows the output of VCO along with the carrier frequency . Give the carrier frequency which is equal to that of that of the free –running frequency i.e VCO to Capture and Lock the signal and view the frequency response and measure the Lock range as shown in Fig 11.

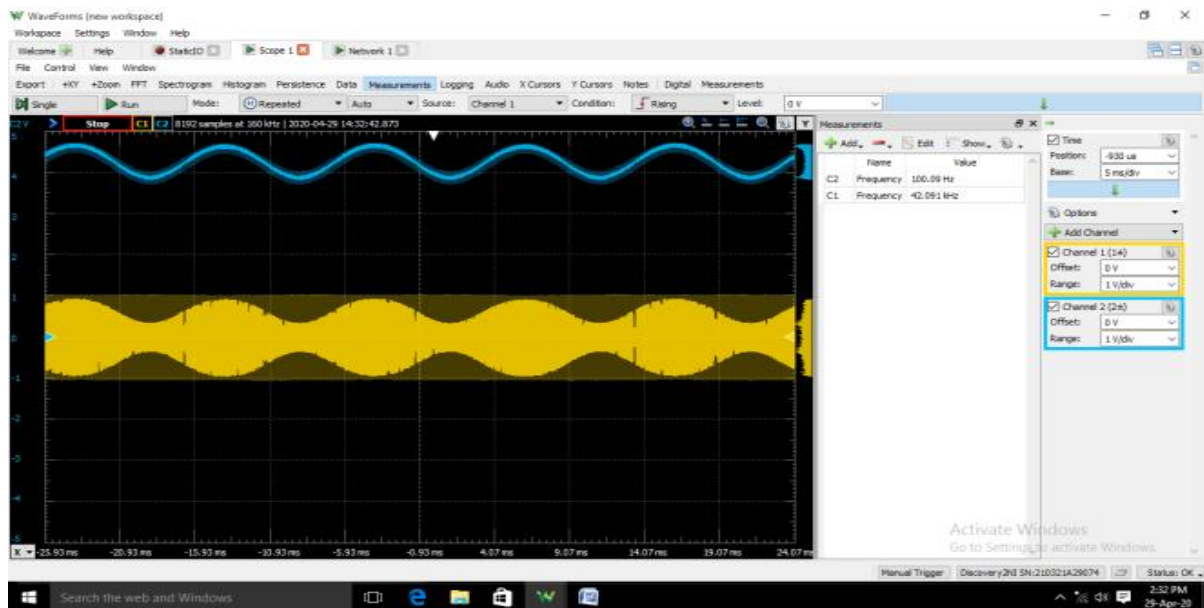


Figure 15 : FM Demodulation Output.

Fig 15 shows the FM demodulation output. Give FM signal to the phase detector input the VCO i.e (f_0) tries to track the FM signal but in the process of tracking the error voltage is coming that itself is the message signal and Vary the modulation index, message signal frequency, carrier frequency and observe the Demodulation output at pin No.7 and take the reading for all combinations.

4 CONCLUSION

In this paper, the development of remotely controllable FM Demodulation circuit and their different variations along with Lock range have been discussed and also the Analysis of PLL is explained in detail. The user can understand the effect of adding a different resistor and capacitor on to the circuit by observing the bode response.

This Remote lab is built to support students / faculty with all practical information at anytime, anywhere, anyone so that learning can be more effective. User may access the experiments remotely 24x7, perform investigations to examine the circuit's behavior. But continuous power supply is needed for the master PC and PCB and also the circuit needs a daily maintenance.

User may perform experiments multiple times to understand the behavior of the circuit. And also helpful for making readings quickly. It is a forum for learning, thus teaching the theoretical concepts.

Further improvement of this remote laboratory is "Making a test-bench to check whether the component is working well or not, Creating a web sites, Interactive Virtual lab creation".

5 ACKNOWLEDGMENT

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