Department of Electronics & Communication Engineering

LAB MANUAL

SUBJECT: SIGNAL SYSTEM AND COMMUNICATION LABORATORY [ECE223]

B.Tech Year – 2^{nd}, Semester - 4^{th}

(Branch: ECE)

VERSION: 01^{st} JANUARY 2020

The LNM Institute of Information Technology, Jaipur, Rajasthan-302031

The LNM Institute of Information Technology
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Digital Communication Laboratory

Semester - EVEN

List of Experiments:

Experiment No.: 01

1 AIM

1. To generate periodic rectangular signals of varying duty cycles (10%, 30%, 50%, and 75%).
2. Observe the Fourier domain representation of the above generated periodic signals.
3. Observe the change in spectrum of the signals when passed through an integrator/low-pass R-C filter.

2 Pre Lab (To be done before coming to Lab)

1. Write the Fourier series representation for four periodic rectangular signals having frequency 1KHz, Amplitude 4.45V and duty cycles 10%, 30%, 50%, and 75%, respectively.
2. Calculate the first four Fourier series coefficients of the Fourier series generated in the above step.

3 Apparatus Used

1. 555 Timer IC
2. DC power supply +5 volts
3. Resistors
4. Digital signal oscilloscope
5. Capacitors
6. Connecting wires
7. Breadboard

4 Theory

4.1 Fourier Series

We know that continuous time periodic signals[1] are represented by the Fourier series. The Fourier series of a signal $x(t)$ with fundamental time period T and fundamental frequency $\omega_0 = \frac{2\pi}{T}$ is given by following expression:

$$x(t) = \sum_{k=-\infty}^{\infty} X(k) e^{jk\omega_0 t} \tag{1}$$

where the series coefficients are

$$X(k) = \frac{1}{T} \int_T x(t) e^{-jk\omega_0 t} dt. \tag{2}$$

A sinusoid of frequency $k\omega_0$ is called the k^{th} harmonic of the sinusoid of fundamental frequency ω_0. Signal $x(t)$ with period T and amplitude 4.45V is shown in the Figure 1.

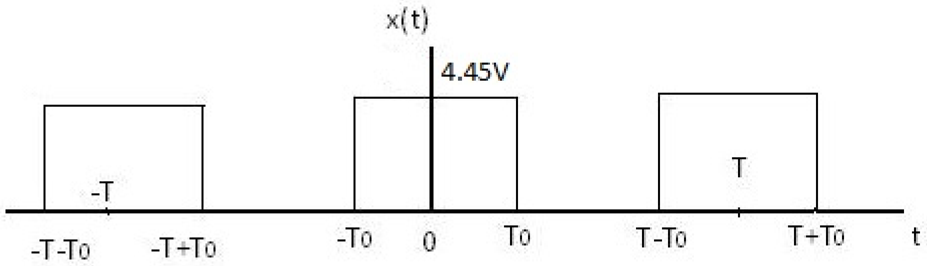


Figure 1: Rectangular signal with half duty cycle

[1] Satisfying Dirichlet's conditions

4.2 Figure/Connection Diagram

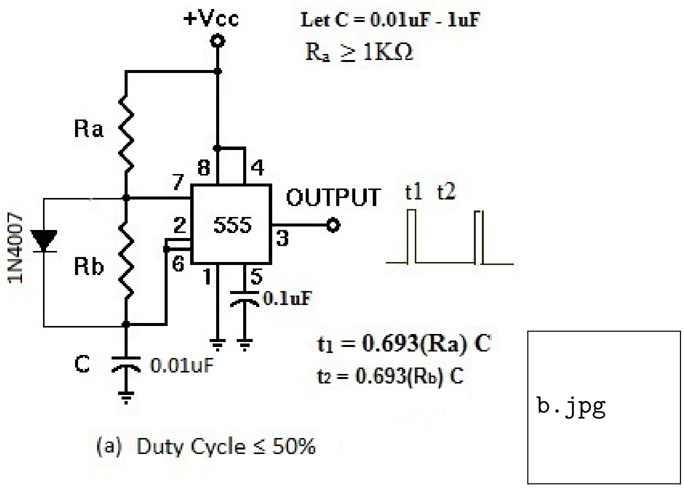


Figure 2: 555 Timer IC in Astable mode

We will use 555 timer IC to generate periodic rectangular signal. For this we connect 555 in astable mode as shown in Figure 2.

4.3 Circuit operation

4.3.1 For duty cycle $\leq 50\%$

In astable mode, the 555 timer puts out a continuous stream of rectangular pulses having a specified duty cycle ($\leq 50\%$) with desired time period. Resistor R_a is connected between $+Vcc$ and the discharge pin (pin 7). Resistor R_b is connected between the discharge pin (pin7) and the trigger (pin 2) along with the threshold pin (pin 6). The capacitor C charges through the path with R_a and the diode and discharges only through R_b. There are two discharge paths available: i) through R_b, ii) through diode. However, diode being in the reverse biased condition offers high impedance and hence the discharge path chosen is R_b. It is because pin 7 has a low impedance to ground during output low intervals of the cycle, therefore provides a path for discharge to the capacitor during off time. The charge and discharge times are given by $t_1 = 0.693(R_a)C$ and $t_2 = 0.693(R_b)C$ respectively. The total time period is

$$T = t_1 + t_2 = 0.693(R_a + R_b)C \tag{3}$$

and hence the frequency

$$f = \frac{1}{T} = \frac{1.44}{(R_a + R_b)C}. \tag{4}$$

If we change the resistance R_b the duty cycle and frequency of the rectangular wave changes.

4.3.2 For duty cycle $\geq 50\%$

In astable mode, the 555 timer puts out a continuous stream of rectangular pulses having a specified duty cycle ($\geq 50\%$) with desired time period. Resistor R_a is connected between $+Vcc$ and the discharge pin (pin 7). Resistor R_b is connected between the discharge pin (pin7) and the trigger (pin 2) along with the threshold pin (pin 6). The capacitor C charges through R_a and R_b ,and discharges only through R_b. It is because pin 7 has a low impedance to ground during output low intervals of the cycle, therefore provides a path for discharge to the capacitor during off time. The charge and discharge times are given by $t_1 = 0.693(R_a + R_b)C$ and $t_2 = 0.693(R_b)C$ respectively. The total time period is

$$T = t_1 + t_2 = 0.693(R_a + 2R_b)C \tag{5}$$

S. No.	D (Duty Cycle)	R_a	R_b	Ton	Toff	D1(Observed D)	B.W.	Fourier series coefficients			
								a_0	a_1	a_2	a_3
1	10%										
2	30%										
3	50%										
4	75%										

and hence the frequency

$$f = \frac{1}{T} = \frac{1.44}{(R_a + 2R_b)C}. \tag{6}$$

If we change the resistance R_b the duty cycle and frequency of the rectangular wave changes.

5 Procedure

1. Generate a periodic rectangular signal $x(t)$, of frequency 1KHz, using 555 timer.
2. Change the duty cycle by changing R_a and R_b, while keeping the frequency same (i.e. 1 KHz).
3. Trace the time domain wave forms and their respective spectrums.
4. Prepare a Table 1 for various values of R_a and R_b. Observe the on and off time period, frequency, duty cycle, bandwidth and the Fourier series coefficients. Compare these values with the theoretical values.
5. Pass $x(t)$ through a RC network and see the effect of integration (charging, discharging) on the shape of the output signal $y(t)$. Also observe the spectral change.

6 Analysis of Results

Calculations/Display/plot/typical graph Write/Plot Your Own.

7 Conclusions

Write Your Own.

8 Precautions

1. Check the connections before switching on the kit.
2. Connections should be done properly.
3. Observation should be taken properly.

Experiment No.: 02

1 AIM

1. To verify the linearity property of Fourier series/transform.
2. Add two sinusoidal signals and eliminate the higher frequeny component using second order low pass Butterworth filter.
3. To shift the phase of a sinusoindal signal by $\frac{\pi}{2}$ and understand the difference between phase shift and time delay.

2 Apparatus Used

1. Opamp-741 IC
2. DC power supply ± 12 volts
3. Resistors
4. Breadboard
5. Capacitors
6. Connecting wires
7. Digital signal oscilloscope
8. Function Generator

3 Figure/Connection Diagram

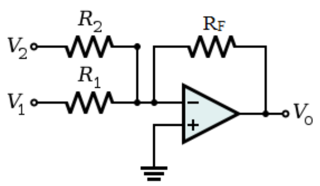


Figure 1: Summing amplifier

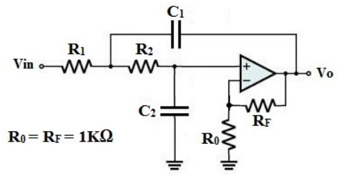


Figure 2: Second order low pass Butterworth filter

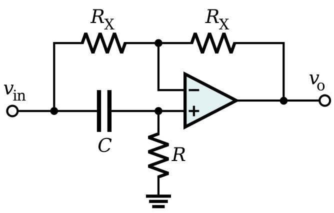


Figure 3: All pass filter and Phase shift between input and output

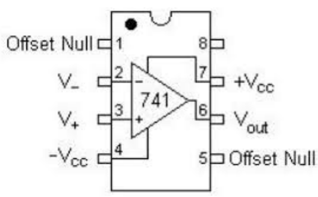


Figure 4: Operational Amplifier IC741 Pin Diagram

4 Theory

4.1 Linearity property

Additivity of the Fourier transform means that addition in one domain corresponds to addition in the other domain. As the two time domain signals add to produce the third time domain signal, the two corresponding spectra add to produce the third spectrum. Frequency spectra are added in rectangular notation by adding the real parts to the real parts and the imaginary parts to the imaginary parts. Think of this in terms of cosine and sine waves. All the cosine waves add (the real parts) and all the sine waves add (the imaginary parts) with no interaction between the two. The linearity property states that

$$x(t) = x_1(t) + x_2(t) \Leftrightarrow X(jw) = X_1(jw) + X_2(jw) \tag{1}$$

4.2 Phase shifter

The result of time shifting the signal $x(t)$ by t_0 corresponds to the multiplication of $X(jw)$ by e^{-jwt_0}. Hence, a shift in time leaves the magnitude spectrum unchanged and introduces a phase shift that is a linear function of frequency. The slope of this linear phase shift is equal to the time delay. Time-shifting a complex sinusoid results in a complex sinusoid of the same frequency and magnitude, with the phase shifted by the product of the time shift and the sinusoid's frequency.

$$x(t - t_0) \Leftrightarrow e^{-jwt_0} X(jw) \tag{2}$$

4.3 Circuit operation

1. Summing Amplifier: There are several ways to understand the operation of the inverting summing amplifier circuit. One simple method is an application of the Superposition theorem. In this case, we consider the effects of each input signal one at a time with all other sources being set to 0. We know from our discussion of the basic inverting amplifier that the (-) input terminal is a virtual ground point. That is, unless the amplifier's output is saturated, the voltage on the (-) input will be within a few microvolts of ground potential. Thus, when we replace all but one source with a short (i.e., set them to 0 volts), the associated input resistors essentially have a ground connection on both ends. In other words, one end of each resistor is connected to ground through the temporary short that we inserted across the battery as part of the application of the Superposition theorem. The inverting amplifier with two inputs V_1 and V_2 depending on the relationship between the feedback resister R_F and the input resistors R_1 and R_2 produces V_o. The circuit can be used as summing amplifier.The circuit function can be verified by examing the expression for the output voltage.

$$V_o = -(\frac{R_F}{R_1} V_1 + \frac{R_F}{R_2} V_2) \tag{3}$$

2. Second order low pass Butterworth filter: The key characterstic of the Butterworth filter is that it has a flat passband as well as stopband. A first order low pass filter can be converted into a second order type by using an additional RC network. The gain of the second order filters is set by R_1 and R_F, while the high cut off frequency f_H is determined by R_1, C_1, R_2 and C_2.

$$f_H = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}} \tag{4}$$

For a second order low pass Butterworth response, the voltage gain magnitude equation is

$$\left|\frac{V_o}{V_{in}}\right| = \frac{A_F}{\sqrt{1 + (\frac{f}{f_H})^4}} \tag{5}$$

where $A_F = 1 + \frac{R_F}{R_0}$ and f is the frequency of the input signal.

3. Phase shifter: A phase shifter passes all frequency components of the input signal without attenuation, while providing predictable phase shifts for different frequencies of the input signal. When signals are transmitted over transmission lines, such as telephone wires, they undergo change in phase. To compensate for these phase changes, phase shifters are required. The phase shifters are also called delay equalizers or phase correctors. The tranfer function is given by

$$\frac{V_0}{V_{in}} = \frac{1 - j2\pi f RC}{1 + j2\pi f RC} \tag{6}$$

The phase shift between $V_0(t)$ and $V_{in}(t)$ is a function of input frequency f. The phase angle is given by

$$\phi = -2\tan^{-1}(\frac{2\pi f RC}{1}) \tag{7}$$

5 Procedure

1. Generate two sinosoids of amplitude $3V_{pp}$ and frequency 1 KHz and 10 KHz respectively from function generator. Give these two waveforms to adder circuit described in figure 1. Observe Time domain and Frequency domain representation of adder output.Vary amplitudes (V_1 & $V_2 \leq 6V$) of sinosoids and see the effect in frequency domain. Validate the magnitude level of both sinosoids by measuring magnitude in frequency domain. Is it coming same? If not why?

Table 1: Summing Amplifier

S. No.	Time Domain			Frequency Domain		
	V_1 (in Volts)	V_2 (in Volts)	V_0 (in Volts)	V_1 (in dBV)	V_2 (in dBV)	V_0 (in dBV)
1.						
2.						

2. Give the output of adder to a 2^{nd} order active low pass filter circuit of $-3db$ cut-off frequency 2 KHz. Observe the output in both domain. Measure the magnitude of both frequencies and validate it. How will you validate it?

3. Generate a sinosoid of amplitude $3V_{pp}$ with frequency $f = 1KHz$. Give this sinosoid to phase shifter circuit. Using the formulae for Phase shift given in section 2.2 calculate the value of R and C so that phase shift is equal to $\frac{\pi}{2}$. Now, Observe time shift between input and output of phase shifter and calculate respective phase shift by using these data.

Table 2: Phase Shifter

S. No.	Phase	Frequency	R	C	Time Period (T)	Time Shift Δt	Observed $\phi = \frac{\Delta t}{T} * 360^0$
1.	$\frac{\pi}{2}$	1KHz					

6 Observation

Write/ Plot Your Own With Observation Table (If Required).

7 Analysis of Results

Calculations/Display/plot/typical graph Write/Plot Your Own.

8 Conclusions

Write Your Own.

Precautions

(a) Check the connections before switching on the kit.
(b) Connections should be done properly.
(c) Observation should be taken properly.

Experiment No.: 03

1 AIM

(a) To study a switching modulator for generating conventional AM waves. ($\mu = 0.3$, 0.5 and 1)

(b) Analyze the effect of modulation index on modulation efficiency.

(c) Design an envelope detector to demodulated the AM wave.

2 Apparatus Used

1. Function Generator
2. Digital signal oscilloscope
3. Opamp-741 IC & PN diode
4. Breadboard & Connecting wires
5. Resistors & Capacitors
6. DC power supply

3 Theory

Multiplication of a signal by a square pulse train is in reality a switching operation. It involves switching the signal $m(t)$ on and off periodically and can be accomplished by simple nonlinear (switching) device like a diode. Based on the nature of cancellation of carrier and/or message at the output of the switch, it is called a singly balanced or doubly balanced switching modulator. Bandpass filter is used to ensure that only the desired AM wave is produced at the output centered at the carrier frequency.

3.1 Switching Modulator for AM Generation

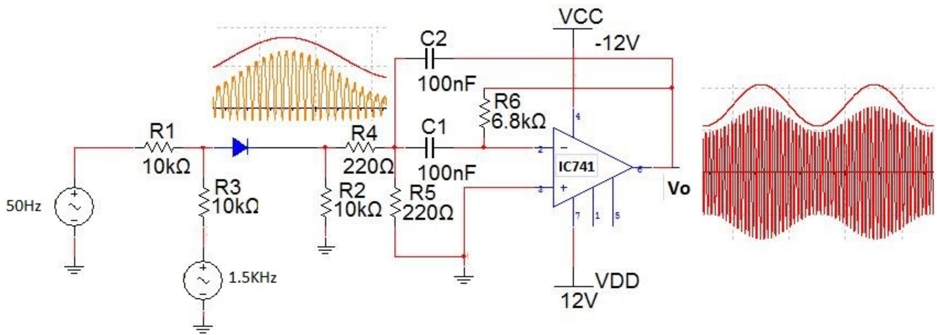


Figure 1: Amplitude modulation

3.2 Envelope Detector

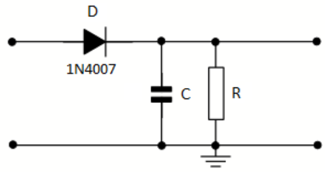


Figure 2: Envelope Detector

4 Procedure

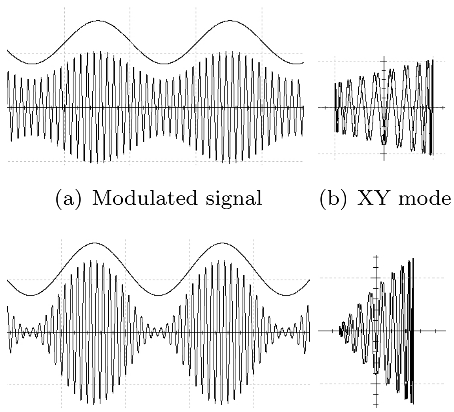
1. For the band pass filter prescribed in the Figure. find the band-width and the cut-off frequencies, both experimentally and by using the expressions.

$$f_{mid} = \frac{1}{2\pi C_1}\sqrt{\frac{R_4 + R_5}{R_4 R_5 R_6}} \tag{1}$$

$$Bandwidth = \frac{1}{\pi R_6 C_2} \tag{2}$$

2. Set up a unipolar sampler on bread board as suggested in the circuit diagram, Figure 1. Set the modulating signal to a sinusoid of frequency f_m = 50Hz. Set the frequency of the Sine wave to about 1.5KHz. Pass the output of the sampler through band pass filter. Sketch the AM output waveform neatly.

3. Vary the modulating signal amplitude and note the waveform for different modulation index. Modulation index $\mu = \frac{m_p}{A} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$, where m_p is the peak value of modulating signal and A is the carrier amplitude, V_{max} and V_{min} are maximum and minimum values of the envelope. (Also observe the over modulation case)



(a) Modulated signal (b) XY mode

(c) Modulated signal (d) XY mode

Figure 3: Amplitude Modulation with $\mu = 0.3$ and $\mu = 1$

4. On DSO observe the modulating signal and modulated signal in time domain. Utilize XY mode of DSO to see the trapezoidal pattern as shown in the Figure 3. Analyze various cases of modulation and effect of modulation index on trapezoidal pattern. This pattern provides an idea about the input-output linearity of the modulator.

5. Calculate the efficiency of the modulation in each case. Use DSO to calculate the carrier power and the message signal power. Compare your results with the theoretical values. Efficiency is defined as $\eta\% = \frac{P_s}{P_s + P_c} \times 100$, where P_s is the side-band power and P_c is the carrier power.

6. For the envelope detector, find the values of R and C and demodulate the AM signal.

7. The Ouput from this detector will contain a high-frequency component also, how would you reduce it?

5 Observation

6 Analysis of Results

Calculations/Display/plot/typical graph Write/Plot Your Own.

Table 3: AM Modulator

S. No.	m_p	A	$\mu_{th.}$	$\eta_{th.}$	V_{max}	V_{min}	$\mu_{pr.}$	P_c	Total Side Band Power	$\eta_{pr.}$
1.			0.3							
2.			0.5							
3.			1							

7 Conclusions

Write Your Own.

Precautions

1. Check the connections before switching on the kit.
2. Connections should be done properly.
3. Observation should be taken properly.

Experiment No.: 04

1 AIM

1. To implement a Double Side Band - Suppressed Carrier (DSB-SC) modulator using a sampler (switch) and a band-pass filter.

2. To recover the modulating signal with help of an coherent detector.

2 Apparatus Used

1. Function Generator
2. Digital signal oscilloscope
3. Opamp-741 IC & PN diode
4. Breadboard & Connecting wires
5. Resistors & Capacitors
6. DC power supply

3 Theory

Switching Modulator

Multiplication of a signal by a square pulse train is in reality a switching operation. It involves switching the signal $m(t)$ on and off periodically and can be accomplished by simple nonlinear (switching) device like a diode. Based on the nature of cancellation of carrier and/or message at the output of the switch, it is called a doubly balanced switching modulator. Band pass filter is used to ensure that only the desired AM wave is produced at the output centered at the carrier frequency.

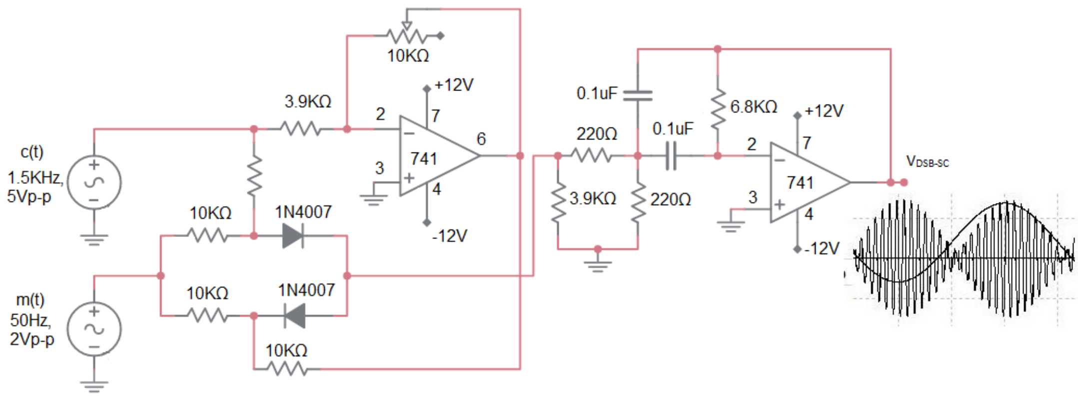


Figure 1: DSB-SC Modulator

4 Procedure

1. For the Band Pass Filter prescribed in the Figure 1. Find the band-width and the cut-off frequencies, both experimentally and by using the expressions.

$$f_{mid} = \frac{1}{2\pi C_1}\sqrt{\frac{R_7 + R_8}{R_7 R_8 R_9}} \tag{1}$$

$$Bandwidth = \frac{1}{\pi R_9 C_2} \tag{2}$$

2. Set up the bipolar sampler as per the circuit diagram shown in Figure 1. Set the modulating signal and Carrier signal to a sinusoid of frequency $f_m = $ 50Hz and 1.5KHz.

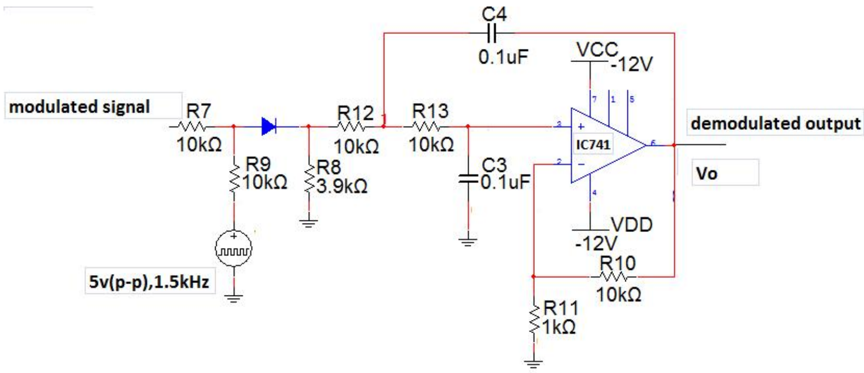


Figure 2: Coherent Demodulator

3. Now apply the modulating signal, observe the sampled signal and pass the output of the sampler through Band pass filter. We take FFT of the band pass filter and see the carrier power suppressed or not, when carrier power not suppressed we vary the variable resistance and suppressed the carrier. Then sketch the output waveform neatly.
4. On DSO observe the modulating signal and modulated signal in time domain. Utilize XY mode of DSO to see the trapezoidal pattern and check the linearity of the modulator.
5. You recover the modulating signal with help of an coherent detector in given in Figure 2. (Explain)

5 Observation

Write/ Plot Your Own With Observation Table (If Required).

6 Analysis of Results

Calculations/Display/plot/typical graph Write/Plot Your Own.

7 Conclusions

Write Your Own.

Precautions

1. Check the connections before switching on the kit.
2. Connections should be done properly.
3. Observation should be taken properly.

Experiment No.: 05

1 AIM

1. To study the characteristics of Phase Locked Loop, identify Lock and Capture range.
2. To generate frequency modulated signal (using varactor diodes in the oscillator circuit).

2 List of components and equipments

1. Varactor diodes
2. 565 PLL IC
3. Digital signal oscilloscope
4. Opamp-741 IC
5. DC power supply
6. Function Generator
7. Resistors
8. Connecting wires
9. Breadboard
10. Capacitors

3 Theory

3.1 Connection Diagram of Frequency Modulation and Demodulation

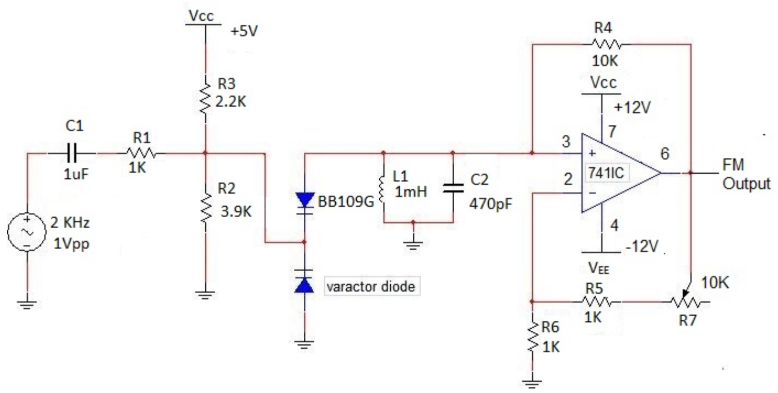


Figure 1: Frequency modulator using Varactor Diodes in the oscillator

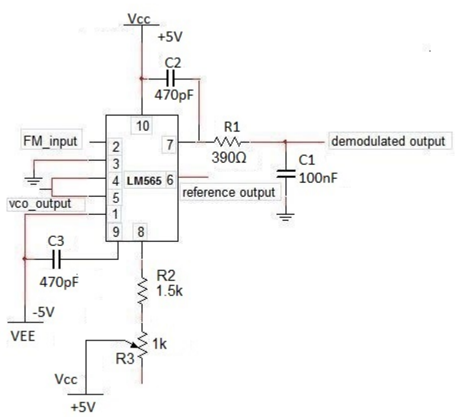


Figure 2: Phase Locked Loop as FM demodulator

4 Procedure

4.1 Generation of FM using varactor diodes

1. The capacitance of varactor diode in $Figure1$ is given by 100/sqrt(V),where V is the amount of reverse bias voltage across p-n junction.Increasing the reverse bias voltage applied across the diode decreases the capacitance,the depletion region becomes wider.When an ac voltage is applied across the diode,the capacitance varies with the change in amplitude.

2. Generate a modulating signal of an amplitude $1V_{pp}$ with a fundamental frequency $f_m = 2KHz$ and apply as input to FM modulator as shown in $Figure1$.

3. Caluculate the oscillating frequency from the $Figure1$ using the expression

$$\frac{1}{2\pi\sqrt{LC}} \tag{1}$$

4. Observe the frequency modulated wave and note down the frequencies corresponding to the positive peak and negative peak of the modulating signal.

4.2 Study of PLL characterstics

1. Connect the circuit as shown in $Figure2$.Now adjust the potentiometer R_3 to get the free running of $200kHz$ which is given by

$$f_0 = \frac{0.3}{(R_2 + R_3)C_3} \tag{2}$$

2. Give sine wave of $1V_{pp}$ of $200kHz$ as input to $pin2$.Connect input signal at $channel1$ of DSO and VCO output at $channel2$ of DSO.When PLL is in frequency-lock with input, input signal and output signal of VCO will not move with respect to each other(why?).Now decrease the frequency of input signal very slowly(why?) and keep on observing both signals on DSO.At some frequency both signals will start moving with respect to each other ,this is lower lock frequency at which PLL looses it's frequency lock.Now PLL is out of lock,keep on increasing input frequency.At some frequency PLL will retain it's lock,this is lower capture frequency.In the same way,caluculate upper lock and capture frequency.Difference between lower and upper lock and capture frequency is defined respectively as lock range and capture range,which is given by

$$f_L = \pm\frac{8f_o}{V_c} \tag{3}$$

where $V_c = V_{cc} - (-V_{cc})$

$$f_c = \pm\frac{1}{2\pi}\sqrt{\frac{2\pi \times f_L}{3.6 \times 10^3 \times C_2}} \tag{4}$$

3. Study the Voltage - frequency(V-F) characteristics,by changing f_i from $50kHz$ to $400kHz$ (following the same procedure given in Exercises:2.2) and observe the DC output at $pin7$.Draw the V-F curve.

5 Observation

Write/ Plot Your Own With Observation Table (If Required).

6 Analysis of Results

Calculations/Display/plot/typical graph Write/Plot Your Own.

7 Conclusions

Write Your Own.

Precautions

1. Check the connections before switching on the kit.
2. Connections should be done properly.
3. Observation should be taken properly.