LIC LAB REPORT

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PSG COLLEGE OF TECNOLOGY

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COIMBATORE-641 004

ABSTRACT:

The report discloses the design of the basic aspects of Adder subtractor and average,Instrumentation amplifier,Universal filter, VCO ,Study of PLL.The theory behind on each circuit is also well explained in the report below.This report gives detailed explanation on each circuit using multisim simulations.

LIST OF CONTENTS:

EXP:1 ADDER,SUBTRACTOR,AVERAGER

1.1.Aim:

To design and simulate adder,subtractor,and averager circuit using multisim.

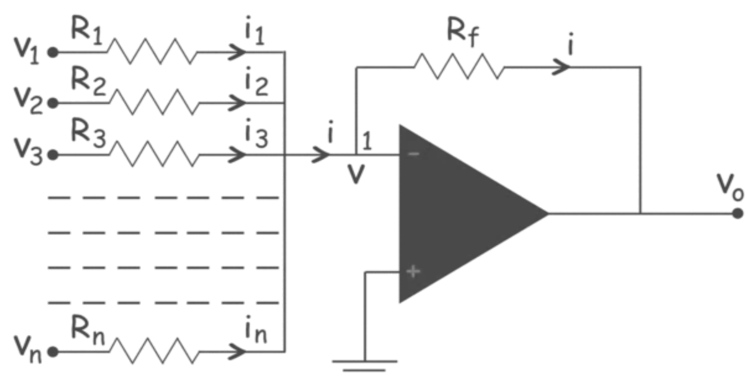
1.2. Materials required:

Component	Range	Quantity
IC741		1
Resistors	1kΩ	5
Power source		3
Multimeter		1

1.3. Theory:

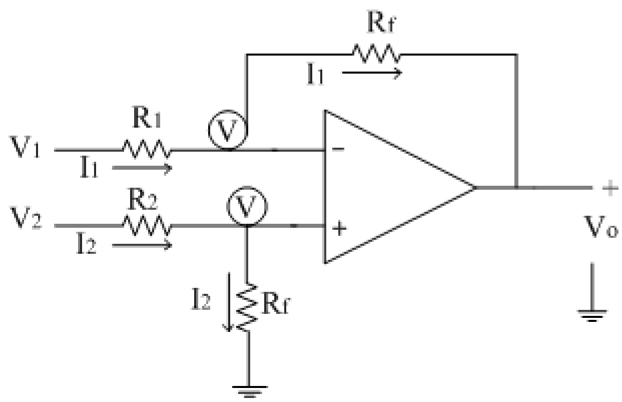
- **Adder(summing amplifier):**

Summing amplifier is basically an op amp circuit that can combine numbers of input signal to a single output that is the weighted sum of the applied inputs.The summing Amplifier is one variation of inverting amplifier. This simple inverting amplifier can easily be modified to summing amplifier, if we connect several input terminals in parallel to the existing input terminals as shown below.



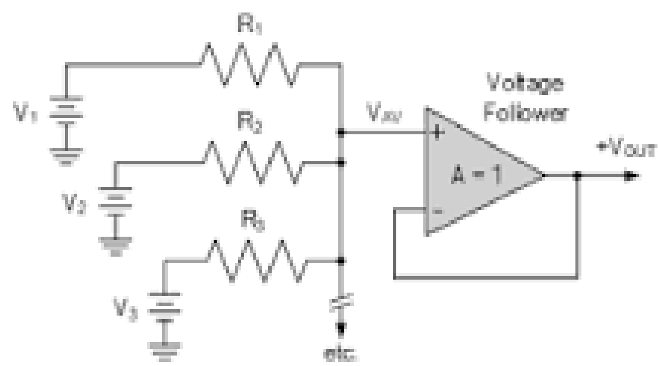
- **Subtractor:**

The subtraction of the two input voltages is possible with the help of subtractor. The subtractor using op-amp is shown in figure below. It is also called as difference amplifier.The voltage output from the differential op-amp A3 acting as a subtractor, is simply the difference between its two inputs (V2 – V1) and which is amplified by the gain of A3 which may be one, unity, (assuming that R3 = R4).



- **Averager:**

If we take three equal resistors and connect one end of each to a common point, then apply three input voltages (one to each of the resistors' free ends), the voltage seen at the common point will be the mathematical average of the three.



1.4. Design steps:

Adder:

Here, n numbers of input terminal are connected in parallel. Here, in the circuit, the non-inverting terminal of the op amp is grounded, hence potential at that terminal is zero. As the op amp is considered as ideal op amp, the potential of the inverting terminal is also zero. So, the electric potential at node 1, is also zero. From the circuit, it is also clear that the current i is the sum of currents of input terminals.

Therefore,

$$i = i_1 + i_2 + i_3 + \cdots\cdots + i_n$$
$$\Rightarrow i = \frac{v_1 - 0}{R_1} + \frac{v_2 - 0}{R_2} + \frac{v_3 - 0}{R_3} + \cdots\cdots\cdots + \frac{v_n - 0}{R_n}$$
$$\Rightarrow i = \frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} + \cdots\cdots\cdots + \frac{v_n}{R_n} \cdots\cdots\cdots\cdots (i)$$

Now, in the case of ideal op amp the current at the inverting and non-inverting terminal are zero. So, as per Kirchhoff Current Law, the entire input current passes through the feedback path of resistance R_f. That means,

$$i = \frac{0 - v_0}{R_f} = -\frac{v_0}{R_f} \cdots\cdots\cdots (ii)$$

From, equation (i) and (ii), we get,

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} + \cdots\cdots\cdots + \frac{v_n}{R_n} = -\frac{v_0}{R_f}$$
$$\Rightarrow v_0 = -(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3 + \cdots\cdots\cdots + \frac{R_f}{R_n}v_n)$$

Subtractor:

Let the current flowing through resistance R1 and R2 are I1 and I2 respectively. Since input current to the op-amp is zero, the two currents flows through the resistance Rf as shown in circuit diagram above. The current I2 is given as

$$I_2 = \left[\frac{V_2 - V}{R_2}\right] = \left[\frac{V - 0}{R_f}\right]$$

From the above equation voltage 'V' can be calculated as

$$\frac{V_2}{R_2} - \frac{V}{R_2} = \frac{V}{R_f}$$

$$\therefore \quad \frac{V_2}{R_2} = \frac{V}{R_2} + \frac{V}{R_f}$$

$$\therefore \quad \frac{V_2}{R_2} = V\left[\frac{R_2 + R_f}{R_2 R_f}\right]$$

The current I1 is given as

$$I_1 = \frac{V_1 - V}{R_1} = \frac{V - V_o}{R_f}$$

Simplify the equation,

$$\frac{V_1}{R_1} - \frac{V}{R_1} = \frac{V}{R_f} - \frac{V_o}{R_f}$$

$$\frac{V_o}{R_f} = \frac{V}{R_f} + \frac{V}{R_1} - \frac{V_1}{R_1}$$

$$\frac{V_o}{R_f} = V\left[\frac{R_f + R_1}{R_f R_1}\right] - \frac{V_1}{R_1}$$

Substituting the voltage 'V' from the equation we get, Substituting the voltage 'V' from the equation we get,

$$\frac{V_o}{R_f} = V_2\left(\frac{R_f}{R_f+R_2}\right)\left[\frac{R_f+R_1}{R_fR_1}\right] - \frac{V_1}{R_1}$$

$$V_o = V_2\left(\frac{R_f}{R_f+R_2}\right)\left[\frac{R_f+R_1}{R_1}\right] - \frac{R_fV_1}{R_1}$$

If R1=R2

$$V_o = \frac{R_f}{R_1}[V_2 - V_1]$$

If R1=R2=Rf

$$V_o = [V_2 - V_1]$$

Averager circuit:

$$V_{OUT} = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2}}$$

If $R_1 = R_2 = R$, then:

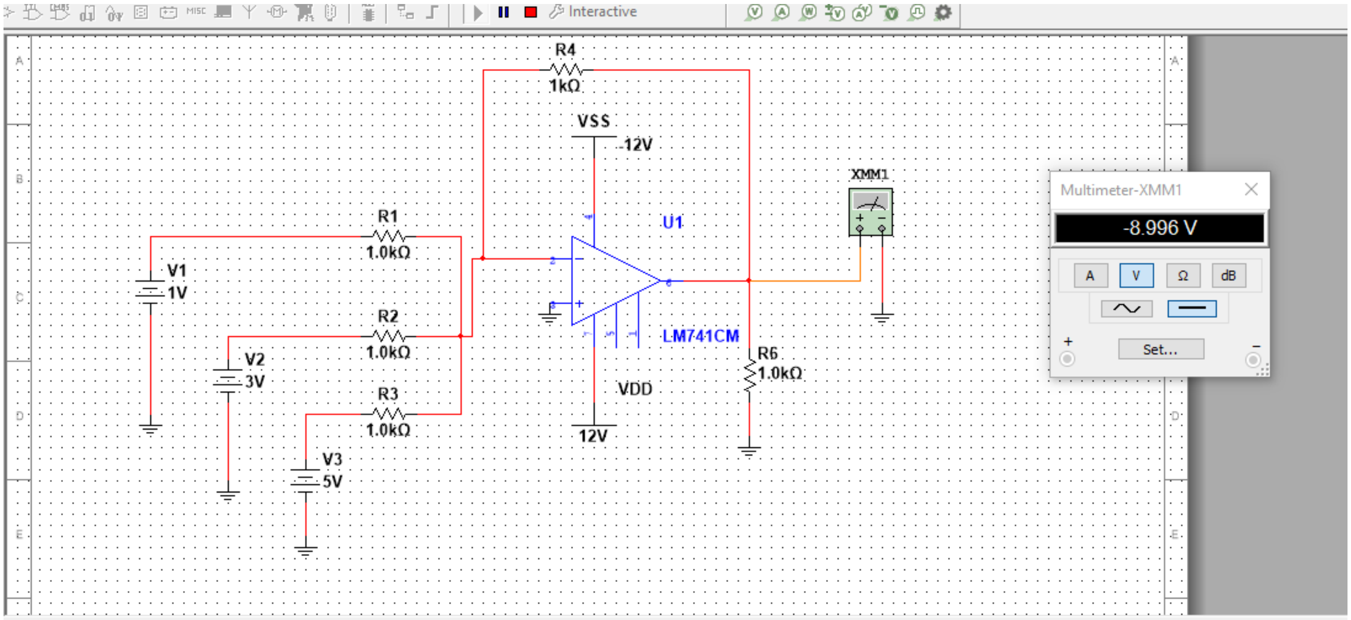
$$V_{OUT} = \frac{\frac{V_1}{R} + \frac{V_2}{R}}{\frac{1}{R} + \frac{1}{R}} = \frac{\frac{V_1 + V_2}{R}}{\frac{2}{R}}$$

$$\therefore\ V_{OUT} = \frac{\frac{V_1 + V_2}{\cancel{R}}}{\frac{2}{\cancel{R}}} = \frac{V_1 + V_2}{2}$$

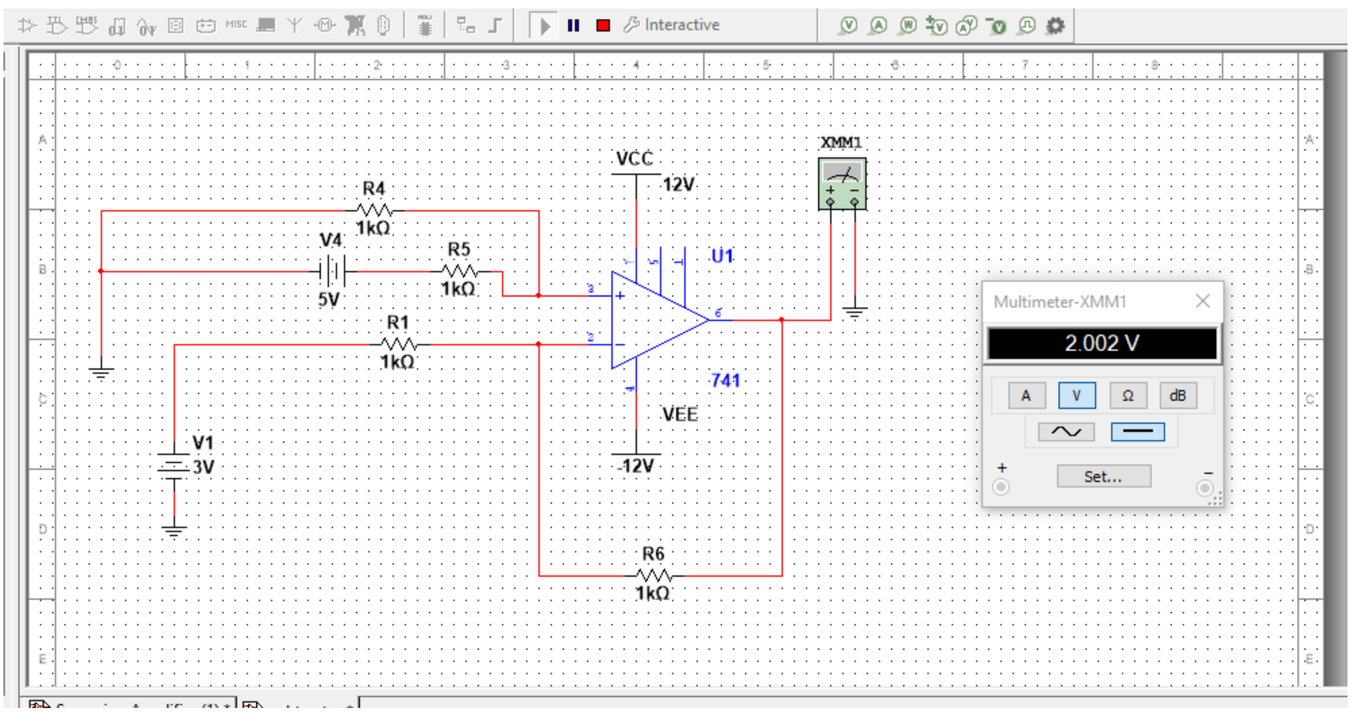
1.5. Results:

Simulations:

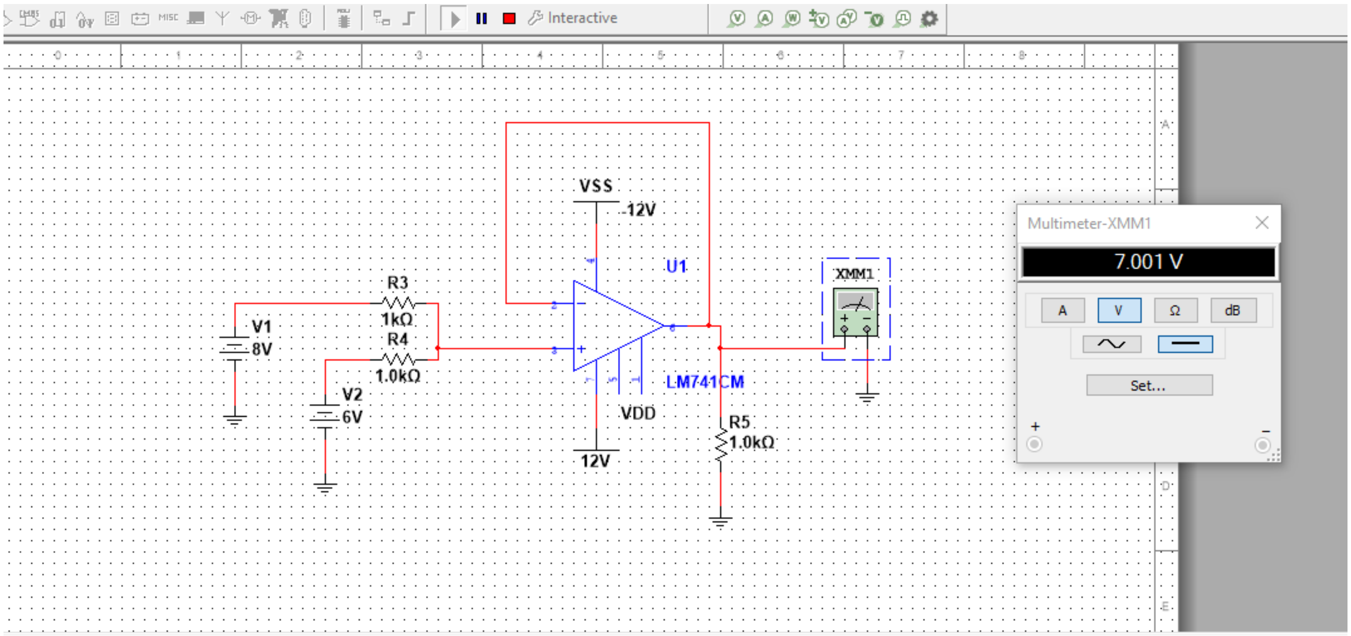
Adder:



Subtractor:



Averager:



1.6. Applications:

- An op-amp based adder produces an output equal to the sum of the input voltages applied at its inverting terminal. It is also called as a summing amplifier, since the output is an amplified one. In the above circuit, the non-inverting input terminal of the op-amp is connected to ground.
- An op-amp based subtractor produces an output equal to the difference of the input voltages applied at its inverting and non-inverting terminals. It is also called as a difference amplifier, since the output is an amplified one.
- An average is used to perform addition as well as division by finding the average

EXP:2 INSTRUMENTATION AMPLIFIER

2.1. Aim:

To design and simulate instrumentation amplifier using multisim.

2.2. Materials required:

Components	range	Quantity
Ic741		3
Power source		2
resistors	1kΩ	7
multimeter		1

2.3. Theory:

An instrumentation amplifier (sometimes shorthanded as in-amp or InAmp) is a type of differential amplifier that has been outfitted with input buffer amplifiers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment. Additional characteristics include very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedances. Instrumentation amplifiers are used where great accuracy and stability of the circuit both short- and long-term are required.

Although the instrumentation amplifier is usually shown schematically identical to a standard operational amplifier (op-amp), the electronic instrumentation amplifier is almost always internally composed of 3 op-amps. These are arranged so that there is one op-amp to buffer each input (+, −), and one to produce the desired output with adequate impedance matching for the function.The most commonly used instrumentation amplifier circuit is shown in the figure. The gain of the circuit

$$A_v = \frac{V_{\text{out}}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{\text{gain}}}\right)\frac{R_3}{R_2}.$$

I

2.4. Design steps:

$$\frac{V_{01} - V_1}{R_2} = \frac{V_1 - V_2}{R_1} \quad .....(7)$$

Or, $\frac{V_{01}}{R_2} = \frac{V_1}{R_1} + \frac{V_1}{R_2} - \frac{V_2}{R_1}$

Or, $V_{01} = \frac{R_2}{R_1} \times V_1 + V_1 - \frac{R_2}{R_1} \times V_2$

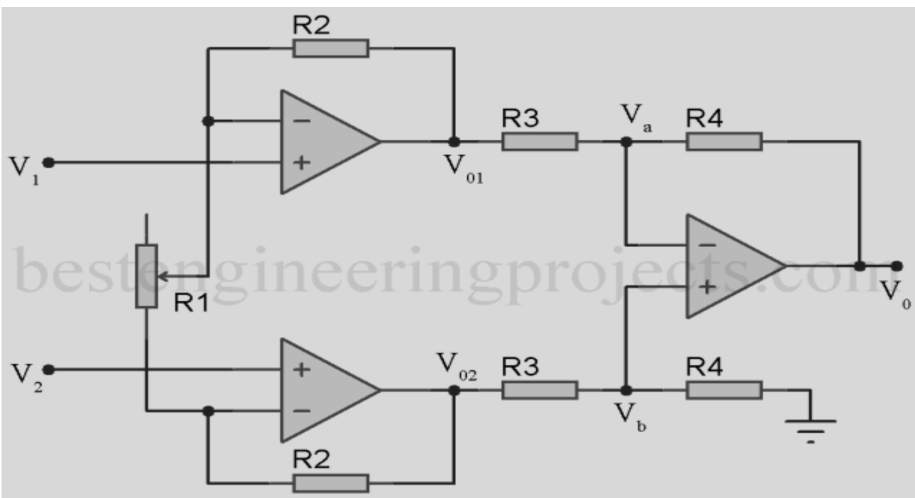
Or, $V_{01} = V_1 + \frac{R_2}{R_1} \times [V_1 - V_2]$ .....(8)

Similarly,

$$\frac{V_2 - V_{02}}{R_2} = \frac{V_1 - V_2}{R_1} - \frac{V_{02}}{R_2} = \frac{V_1}{R_1} - \frac{V_2}{R_2} - \frac{V_2}{R_1} \frac{V_{02}}{R_2} = \frac{V_2}{R_2} + \frac{V_2}{R_1} - \frac{V_1}{R_1}$$

$$V_{02} = V_2 + \frac{R_2}{R_1} \times V_2 - \frac{R_2}{R_1} \times V_1$$

$$V_{02} = V_2 + \frac{R_2}{R_1} \times [V_2 - V_1]$$ ......(9)



Now, for equation 2 and 4,

$$V_{01} - V_{02} = V_1 + \frac{R_2}{R_1} \times [V_1 - V_2] - V_2 - \frac{R_2}{R_1} \times [V_2 - V_1]$$

$$= V_1 - V_2 + \frac{R_2}{R_1} \times V_1 - \frac{R_2}{R_1} \times V_2 - \frac{R_2}{R_1} \times V_2 + \frac{R_2}{R_1} \times V_1 V_1 - V_2 + 2 \times \frac{R_2}{R_1} \times V_1 - 2 \times \frac{R_2}{R_1} \times V_2$$

$$V_1 - V_2 + 2 \times \frac{R_2}{R_1} \times [V_1 - V_2]$$

$$V_{01} - V_{02} = (V_1 - V_2) \times [1 + 2 \times \frac{R_2}{R_1}]$$ ....(10)

Now applying KCL at node V_a, one can write

$$\frac{V_a - V_{01}}{R_3} + \frac{V_a - V_o}{R_4} = 0 \, \frac{V_a}{R_3} + \frac{V_a}{R_4} - \frac{V_{01}}{R_3} - \frac{V_0}{R_4} = 0 \, \frac{V_0}{R_4} = \frac{V_a}{R_3} + \frac{V_a}{R_4} - \frac{V_{01}}{R_3} \, \frac{V_a}{R_3} + \frac{V_a}{R_4} = \frac{V_0}{R_4} + \frac{V_{01}}{R_3}$$
$$V_a \times (\frac{R_3 + R_4}{R_3 R_4}) = \frac{V_0}{R_4} + \frac{V_{01}}{R_3}$$
$$V_a = [\frac{R - 3}{R_3 + R_4} \times V_0 + \frac{R_4}{R_3 + R_4} \times V_{01}] \quad ......(11)$$

Similarly, applying kcl at node V_b,

$$\frac{V_b - V_{02}}{R_3} + \frac{V_b}{R_4} = \frac{V_b}{R_3} + \frac{V_b}{R_4} - \frac{V_{02}}{R_3} = 0 \, V_b \times (\frac{R_3 + R_4}{R_3 R_4}) = \frac{V_{02}}{R_3}$$
$$V_b = \frac{R_4}{R_3 + R_4} \times V_{02} \quad ......(12)$$

For perfect balance, V_a must be equal to V_b. Thus, one can write as

$V_a = V_b$

$$\frac{R_3}{R_3 + R_4} \times V_0 + \frac{R_4}{R_3 + R_4} \times V_{01} = \frac{R_4}{R_3 + R_4} \times V_{02}$$
$$\frac{R_3}{R_3 + R_4} \times V_0 = \frac{R_4}{R_3 + R_4} \times V_{02} - \frac{R_4}{R_3 + R_4} \times V_{01} \, \frac{R_3}{R_3 + R_4} \times V_0 = \frac{R_4}{R_3 + R_4} \times [V_{02} - V_{01}]$$
$$V_0 = \frac{R_4}{R_3} \times [V_{02} - V_{01}]$$
$$V_0 = -\frac{R_4}{R_3} \times [V_{01} - V_{02}] \quad ....(13)$$

From equation 12 and 13 we can write

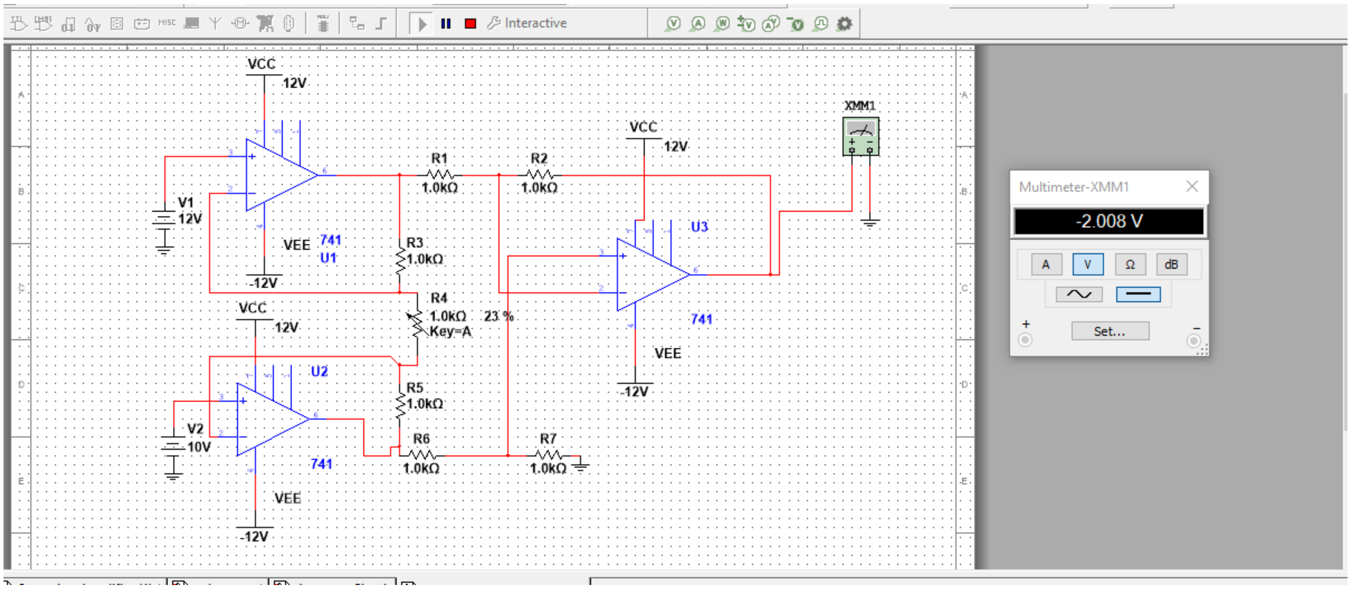
$$V_0 = -\frac{R_4}{R_3} \times [V_1 - V_2] \times [1 + 2 \times \frac{R_2}{R_1}]$$
$$V_0 = \frac{R_4}{R_3} \times [V_2 - V_1] \times [1 + 2 \times \frac{R_2}{R_1}] \quad ......(14)$$

This gain can be expressed as

$$A_v = \frac{V_0}{(V_2 - V_1)}$$
$$A_v = \frac{R_4}{R_3}[1 + 2 \times \frac{R_2}{R_1}]$$

2.5. Results:

Simulation:



2.6. Applications:

The applications of Instrumentation Amplifier are:

- They are used extensively in Bio-medical applications like ECG's and EEG's.
- Instrumentation Amplifiers are used where long-term stability is essential like Industrial applications that includes automation.
- Instrumentation amplifiers are incorporated with pressure transducers in Weighing Systems to monitor various physical quantities such as weight, force, pressure, displacement and torque.
- They are used in Gaming industry.
- Instrumentation Amplifiers are also used in hand held batteries.

EXP:3 UNIVERSAL FILTER

3.1. Aim:

To design and simulate the Universal Filter and to obtain the frequency response curve of the same.

3.2. Materials required:

COMPONENTS:	RANGE:	QUANTITY:
IC	741	3
Resistors	1kΩ,10kΩ,16kΩ,19kΩ	1,2,2,1
Capacitor	10nF	2
Breadboard	-	1
Connecting wires, probes	-	As required

3.3. Theory:

The state variable filter / universal filter is a type of multiple-feedback filter circuit that can produce all three filter responses, Low Pass, High Pass and Band Pass simultaneously from the same single active filter design. State variable filters or universal filter use three (or more) operational amplifier circuits (the active element) cascaded together to produce the individual filter outputs but if required an additional summing amplifier canalso be added to produce a fourth *Notch filter* output response as well.

One of the main advantages of a universal filter design is that all three of the filters main parameters, Gain (A), corner frequency, f_C and the filters Q can be adjusted or set independently without affecting the filters performance.

Although the filter provides low pass (LP), high pass (HP) and band pass (BP) outputs the main application of this type of filter circuit is as a state variable band pass filter design with the center frequency set by the two RC integers.

While we have seen before that a band pass filters characteristics can be obtained by simply cascading together a low pass filter with a high pass filter, state variable band pass filters have the advantage that they can be tuned to be highly selective (high Q) offering high gains at the center frequency point.

Working:

With a constant input voltage, V_{IN} the output from the summing amplifier produces a high pass response which also becomes the input of the first RC Integrator. The output from this integrator produces a band pass response which becomes the input of the second RC Integrator producing a low pass response atits output. As a result, separate transfer functions for each individual output withrespect to the input voltage can be found.The Filters Corner Frequency, $ƒC$

If we make both the integrators input resistors and feedback capacitors thesame, then the state variable filters corner frequency can be easily tuned withoutaffective its overall Q.

3.4. Design steps:

Input to the 2nd Op – amp,

$$V_{BP} = -\frac{1}{2\pi f_C RC} V_{HP}$$

Op – amp A2 transfer function:

$$\frac{V_{OUT}}{V_{IN}} = \frac{V_{BP}}{V_{HP}} = -\frac{1}{2\pi f_C RC} V_{HP}$$

Op – amp A3 Transfer Function:

$$\frac{V_{OUT}}{V_{IN}} = \frac{V_{LP}}{V_{BP}} = -\frac{1}{2\pi f_C RC}$$

Therefore the transfer function between V_{HP} and V_{LP} is given as,

$$\frac{V_{LP}}{V_{HP}} = -\frac{1}{2\pi f_C RC} \times -\frac{1}{2\pi f_C RC} = \frac{1}{((2\pi f_C RC))^2}$$

The State Variable Transfer function,

$$\frac{V_{OUT}}{V_{IN}} = \frac{V_{LP}}{V_{IN}} = \frac{\frac{R_2(R_3+R_4)}{R_3(R_1+R_2)} \times \frac{1}{RC}}{\frac{R_3}{R_4} + \frac{R_1(R_3+R_4)}{R_4(R_1+R_2)} \cdot \frac{1}{2\pi fRC} \cdot \left(\frac{1}{2\pi fRC}\right)^2}$$

The normalised 2nd order transfer function,

$$\frac{V_{OUT}}{V_{IN}} = \frac{A_0\left(\frac{f}{f_0}\right)}{\left[1 + 2\delta\frac{f}{f_0} + \left(\frac{f}{f_0}\right)^2\right]}$$

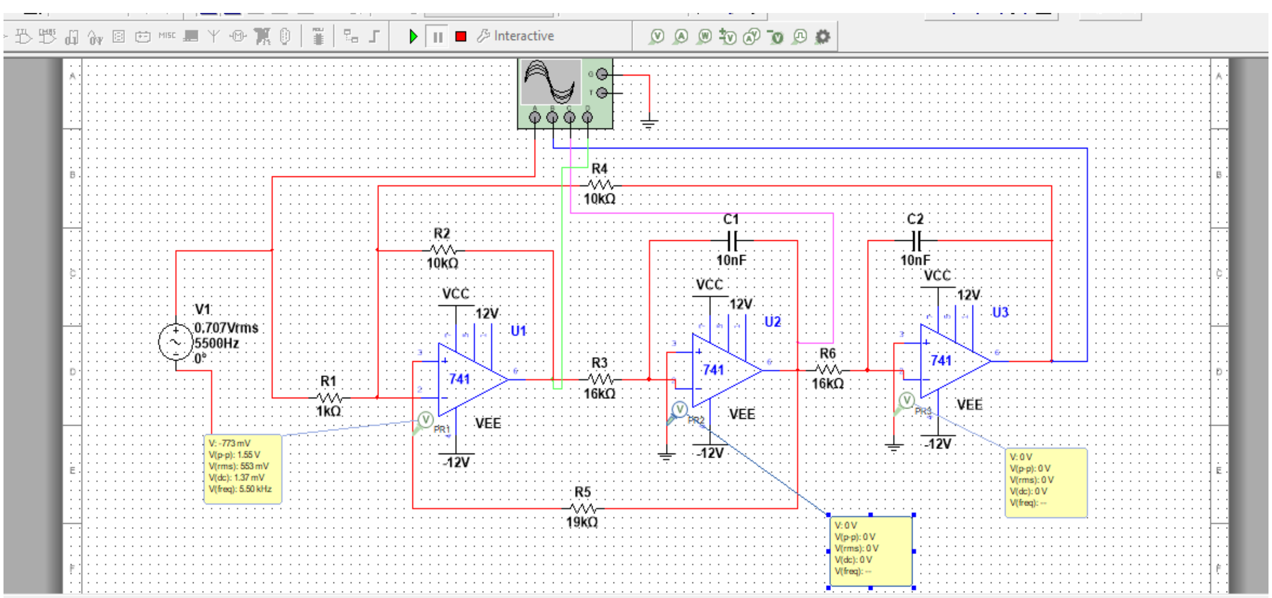
The state variable filter corner frequency,

$$f_C = \sqrt{\frac{R_3}{R_4(2\pi RC)^2}}$$

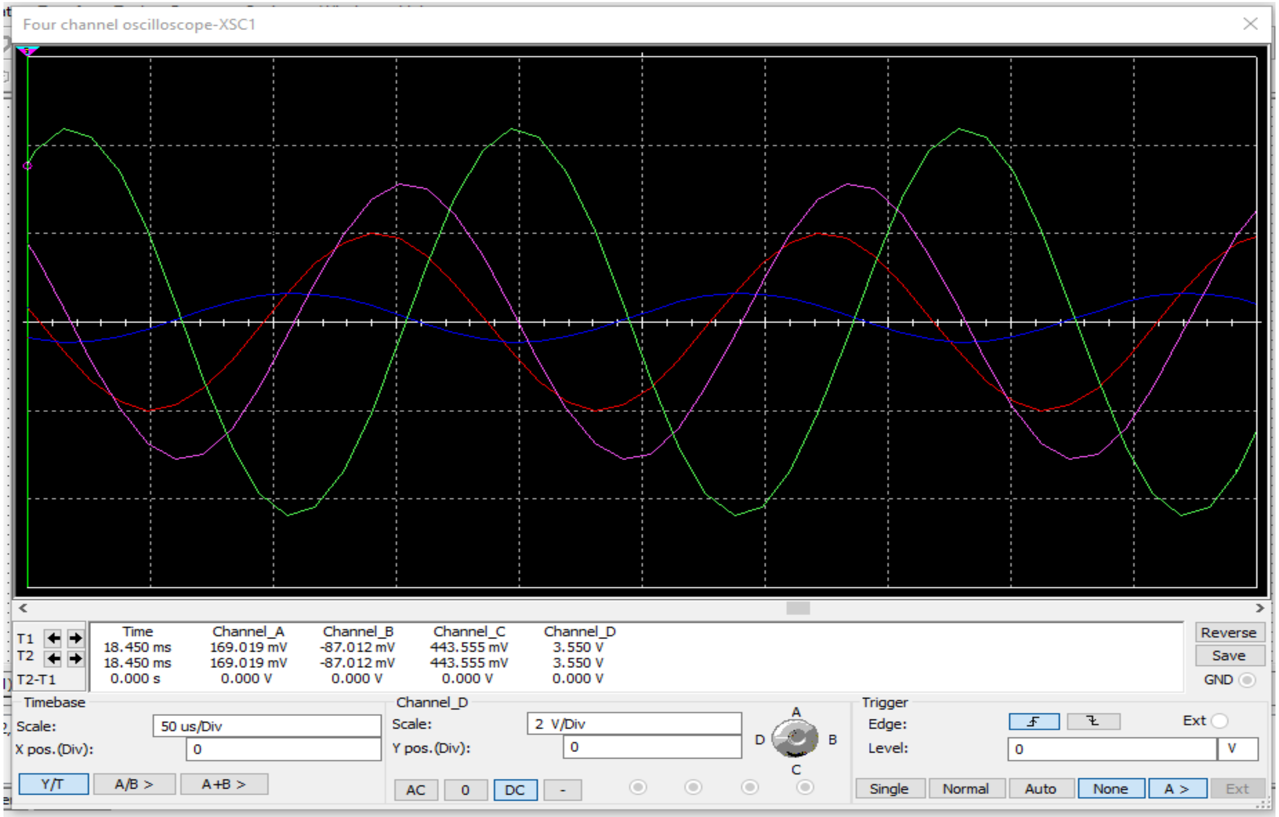
If R_3 and R_4 equal then,

$$f_{C(HP)} = f_{C(BP)} = f_{C(LP)} = \frac{1}{2\pi RC}$$

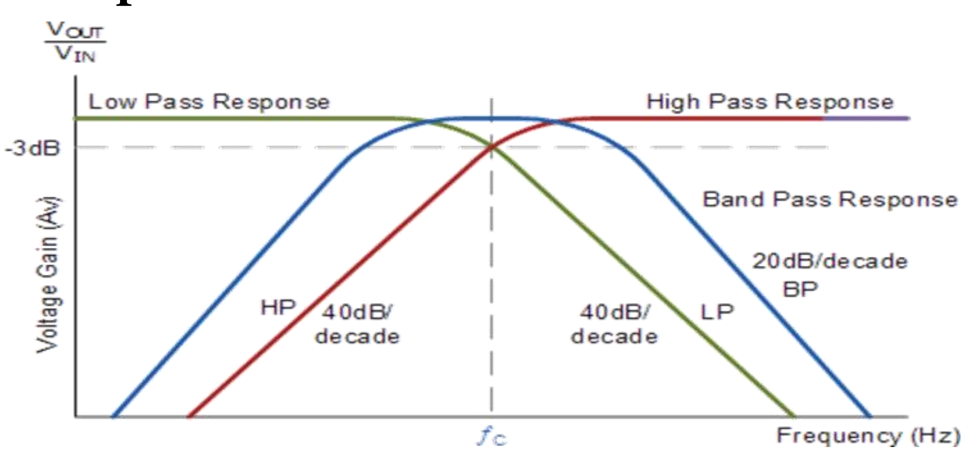
3.5. Results:



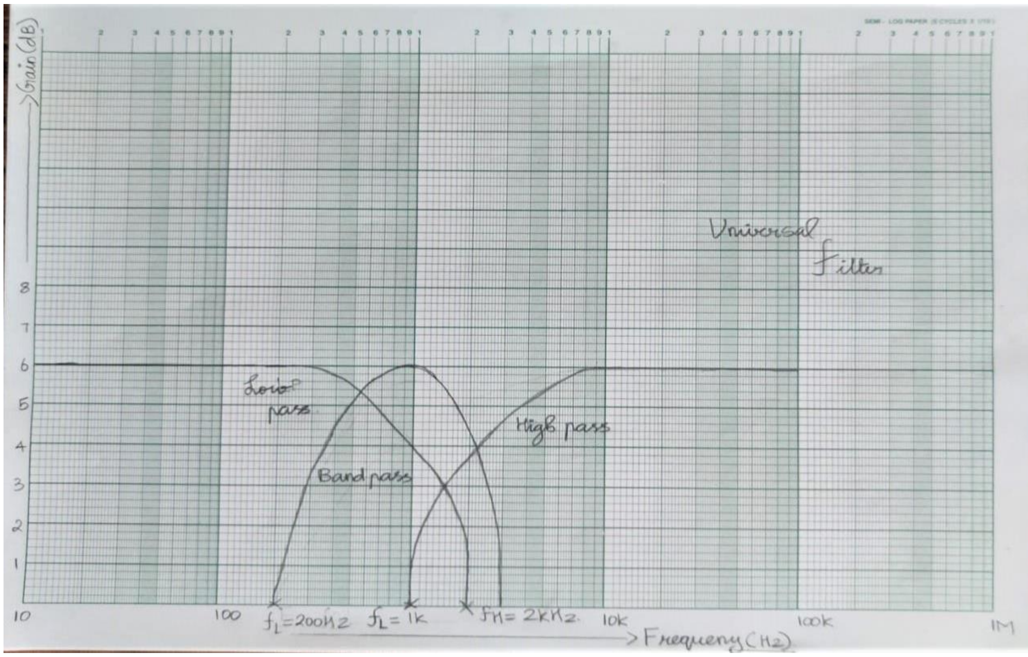
Output Waveform:



Model Graph:



Frequency Response plot:



3.6. Inference:

- The output is observed through the oscilloscope and the cut off frequencies are found.
- The graph is drawn using the semi – log sheet and found to be the same as that of the model graph.

EXP:4 VOLTAGE CONTROLLED OSCILLATOR

4.1. Aim

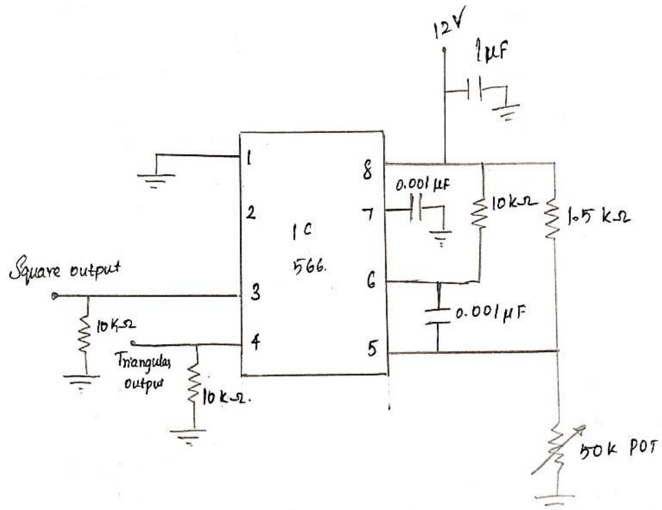
To analyse the frequency and timeperiod of voltage controlled oscillator

4.2. Materials required:

component	range	quantity
Ic-566		1
resistance	10kΩ, $1.5k\Omega$	2,1
capacitor	0.001,0.1	2,1
potentiometer	50kΩ	1

4.3. Theory:

LM566 is a **monolithic voltage controlled oscillator** can be used to generates square and triangle waveforms simultaneously. The frequency of the output waveform can be adjusted using an external control voltage. The output frequency can be also programmed using a set of external resistor and capacitor. Typical applications of LM566 IC are signal generators, FM modulators, FSK modulators, tone generators etc. The LM566 IC can be operated from a single supply or dual supply. While using a single supply, the supply voltage range is from 10V to 24V. The IC has a very linear modulation characteristic and has excellent thermal stability. The circuit diagram of a voltage controlled oscillator using LM566 is shown in the figure below.



4.4. Design steps:

VCO can be in the form of either LC, crystal oscillator, RC oscillator or Multivibrator..For RC type oscillator the frequency is given as,

$$f = \frac{1}{2\pi RC}$$

In case of an LC type oscillator, the frequency is given as,

$$f = \frac{1}{2\pi\sqrt{LC}}$$

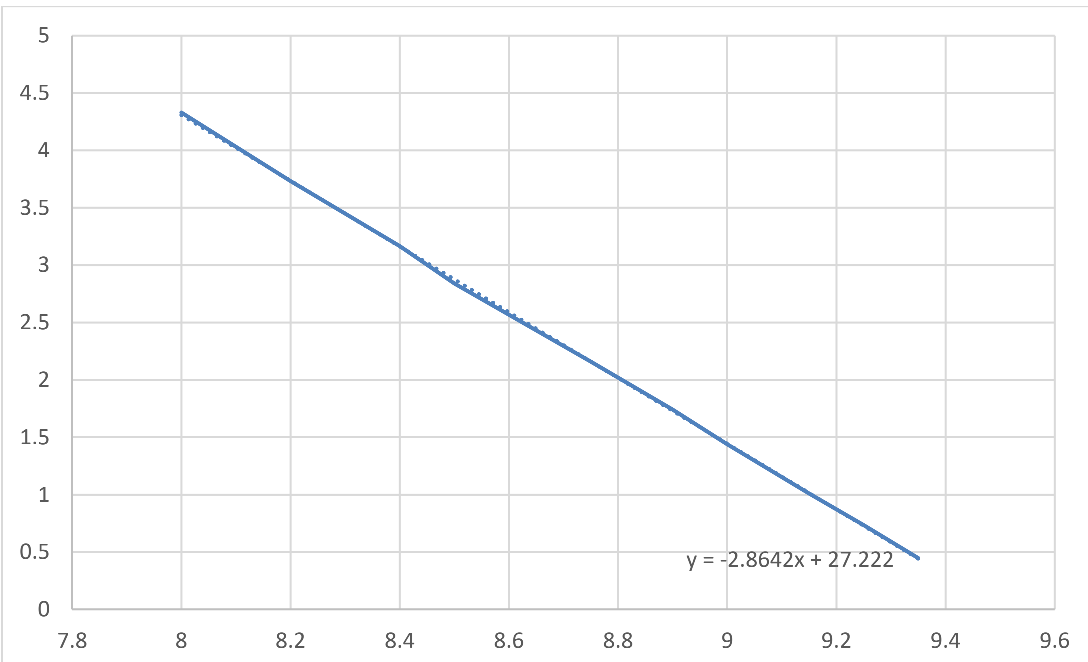
4.5. Results:

Observation:

Voltage	**Frequency(kHz)**	**Amplitude**		**Time Period**	
		square	**triangular**	**Square(μs)**	**triangular(μs)**
7.5	**5.49**	**4.50**	**1.75**	**181.5**	**181.5**
7.7	**4,95**	**4.50**	**1.75**	**202**	**202**
7.9	**4,61**	**4.50**	**1.75**	**216.5**	**216.5**
8	**4.33**	**4.50**	**1.75**	**230**	**230**
8.2	**3.731**	**4.50**	**1.75**	**268**	**268**

8.4	**3.165**	**4.50**	**1.75**	**316**	**316**
8.5	**2.84**	**4.50**	**1.75**	**350**	**350**
8.75	**2.16**	**4.50**	**1.75**	**462**	**462**
8.9	**1.742**	**4.50**	**1.75**	**574**	**574**
9	**1.44**	**4.50**	**1.75**	**494**	**494**
9.15	**1.010**	**4.50**	**1.75**	**990**	**990**
9.25	**0.735**	**4.50**	**1.75**	**1364**	**1364**
9.35	**0.447**	**4.50**	**1.75**	**2230**	**2230**

Graph:



Slope=-2.8642

4.6. Applications:

- Electronic jamming equipment.
- Function generator.
- Production of electronic music, for the production of different types of noise.
- Phase-locked loop.
- Frequency synthesizers, used in communication circuits.

EXP:5 STUDY OF PLL

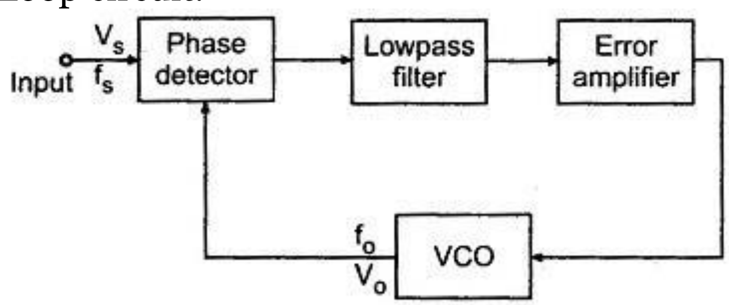
STUDY OF PHASE-LOCKED LOOP

5.1.THEORY:

A phase-locked loop (PLL) is a control system that generates an output signal whose phase is related to the phase of the input signal provided to it. There are several different types of PLL available; the simplest is an electronic circuit consisting of a variable frequency oscillator and a phase detector in a feedback loop. The oscillator generates a periodic signal, and the phase detector compares the phase of that signal with the phase of the input periodic signal, adjusting the oscillator to keep the phases matched. Keeping the input and output phase in lock step also implies keeping the input and output frequencies the same.

Consequently, in addition to synchronizing signals, a phase-locked loop can track an input frequency, or it can generate a frequency that is a multiple of the input frequency. These properties are used for computer clock synchronization, demodulation, and frequency synthesis.

The following diagram illustrates the various blocks present in a Phase-Locked Loop circuit.



The following are the stages, as seen from the block diagram of a basic PLL, above.

- •Phase Detector
- Low-Pass Filter
- Error Amplifier
- Voltage-Controlled Oscillator (VCO)

Phase detector:

The Phase Detector generates a voltage, which represents the phase difference between two signals. In a PLL, the two inputs of the phase detector are the reference input and the feedback from the VCO. The phase detector output voltage is used to control the VCO such that the phase difference between the two inputs is held constant, making it a negative feedback system. The output frequency of the phase detector has two frequency components, which are the sum and difference of the phase detector's input frequencies. Thus, the output voltage of a PLL is an error voltage, with a combination of sum and difference frequencies. The phase detector is of two main types: Analog Phase Detector (Electronic Switch-type) and Digital Phase Detector.

Low-Pass Filter:

A Low-Pass Filter is used to filter out the output of the phase detector/comparator, and allow only the lower frequency components to pass through it. Thus, it is the difference frequency component is the one which passes through, and the sum frequency component is the one which gets filtered by the filter. It also helps in governing many loop characteristics like loop stability and controlling the capture range.

Error Amplifier:

The error amplifier amplifies the error voltage signal coming from the low pass filter. The amplified output of the error amplifier is known as the control voltage signal, which is fed as the input to the next block of the circuit, that is, the Voltage-Controlled Oscillator (VCO).

Voltage-Controlled Oscillator:

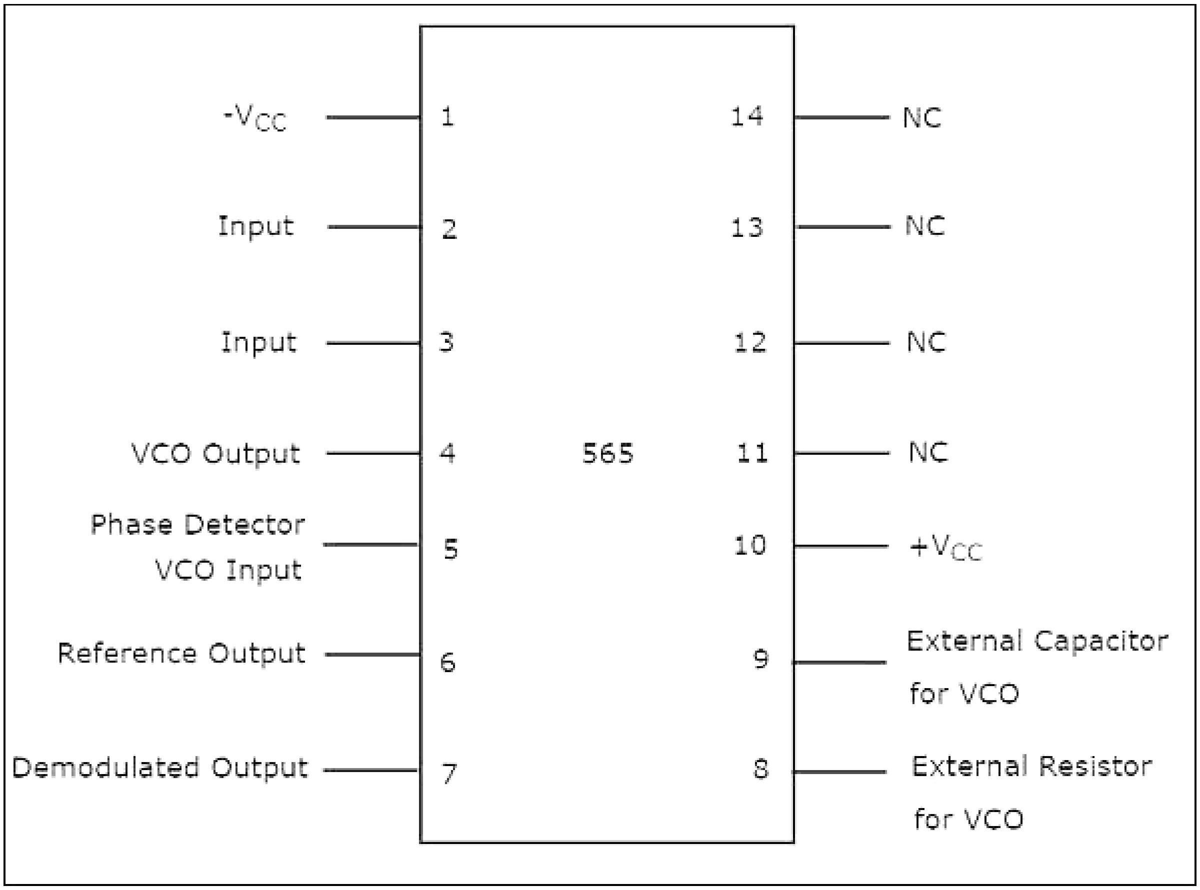
The voltage-controlled oscillator, takes the control voltage as its input signal, and causes a shift in its output frequency. This frequency shift is towards the input signal's frequency, so that they tend to become equal/locked-in eventually. Once the frequencies are locked, there is a small phase difference $\emptyset$ existing between the input and VCO output signals. This phase difference causes the VCO to keep a track of the change in the input frequencies.

Some important definitions are:

Capture Range: The range of frequencies over which the PLL tends to acquire a lock with the input signal.

Lock-in Range: The range of frequencies over which the PLL can maintain lock with the incoming signal. Since the PLL also tracks the changes in the input frequencies in this stage, it is also known as the Tracking Range.

The Integrated Circuit chip which implements the operation of PLL, is the IC 565 chip. It is a 14-pin Dual-Inline Package. The timing capacitor and resistor are connected to the IC externally, through pins 9 and 8 respectively. These components primarily decide the free-running frequency of the PLL. The pin diagram of an LM 565 IC is being shown below.



5.2.Applications:

Phase-locked loops are widely employed in radio, telecommunications, computers and other electronic applications. They can be used to demodulate a signal, recover a signal from a noisy communication channel, generate a stable frequency at multiples of an input frequency (frequency synthesis), or distribute precisely timed clock pulses in digital logic circuits such as microprocessors. Since a single integrated circuit can provide a complete phase-locked loop building block, the technique is widely used in modern electronic devices, with output frequencies from a fraction of a hertz up to many gigahertz.

7. Conclusion :

The objective of these experiments were to design of the of Adder subtractor and average,Instrumentation amplifier,Universal filter, VCO

,Study of PLL and to study their operations .The Laboratory objectives were accomplished using resistors ,capacitors and required IC's.Also multisim simulations for all the circuits were made and were used to verify the correctness of the laboratory results

8. References:

- www.elprocus.com
- en.wikipedia.org
- www.electronicshub.org