DEPARTMENT OF ELECTRONICS ENGINEERING

Analog Integrated Circuits Lab (ECC18201)

(Electronics Main Lab-I)

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Contents

Experiment-1

Aim: To study and design first-order LPF using an op-amp IC 741 and to obtain frequency response.

Equipments and components: Opamp(IC 741), Resistors(15k, 10k), Capacitor(0.01µF), Semiconductor trainer kit, Function generator, Cathode ray oscilloscope.

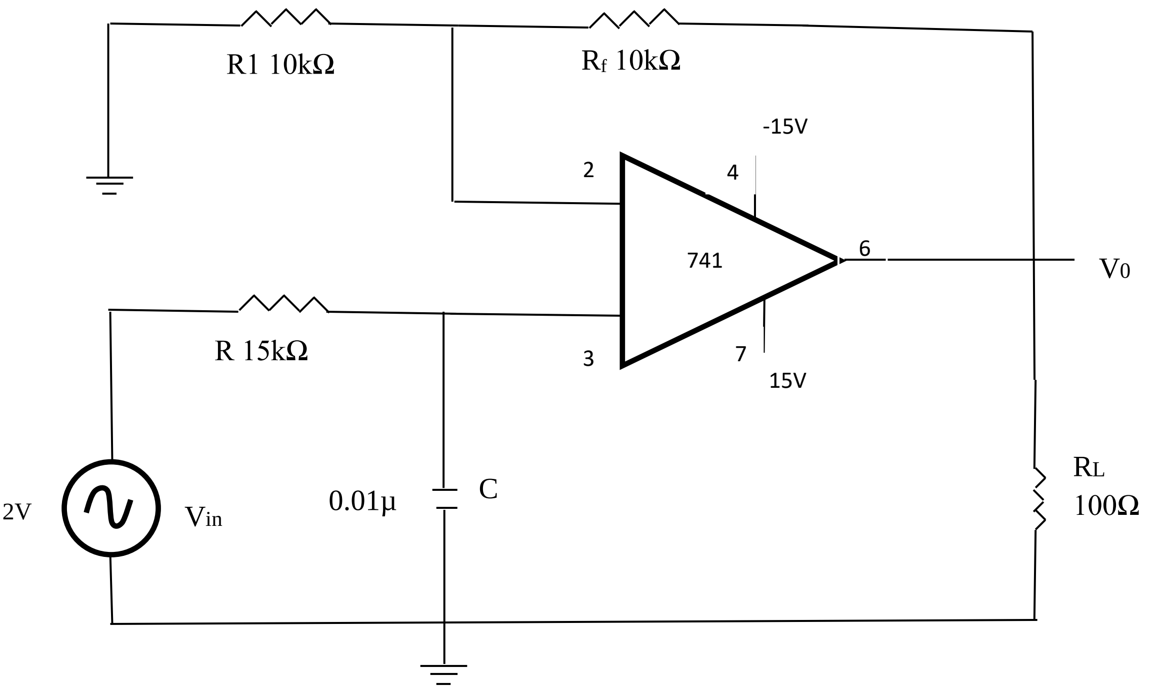
Theory: A frequency selective electric circuit that passes electric signals of a specified band of frequencies and attenuates the signals of frequencies outside the band is called an electric filter. The first-order lowpass filter consists of a single RC network connected to the non-inverting input terminal of the operational amplifier. Resisters R_1 and R_F determine the gain of the filter in the passband. The lowpass filter has maximum gain at f = 0 Hz. The frequency range from 0 to f_h is called the passband and the frequency range $f > f_h$ is called the stopband.

The first order low pass butter worth filter uses an RC network for filtering. The op-amp is used in the noninverting configuration, hence it does not load down the RC network. Resistors R1 and R2 determine the gain of the filter.

$$\mathbf{V_0/V_{in}} = A_f /(\sqrt{}1 +(f/f_h)^2$$

Where, $A_f = 1+ R_f /R_1$= passband gain of filter, f = frequency of the input signal, $f_h=1/2\Pi RC$ = high cut-off frequency of the filter, and V_0/V_{in} = gain of the filter as a function of frequency. The gain magnitude and phase angle equations of the LPF can be obtained by converting V_0/V_{in} into its equivalent polar form as follows $|V_0/V_{in}| = A_f /(\sqrt{}1 +(f/f_h)^2$, $\Phi = - \tan^{-1} (f/f_h)$. Where Φ is the phase angle in degrees. The operation of the LPF can be verified from the gain magnitude equation.

Circuit Diagram:



Observations:

S.NO	Input frequency	Output Voltage	Gain in dB 20 log(Vo/Vi)
1.			
2			
3			
4.			
5.			
6.			
7.			

Calculations:

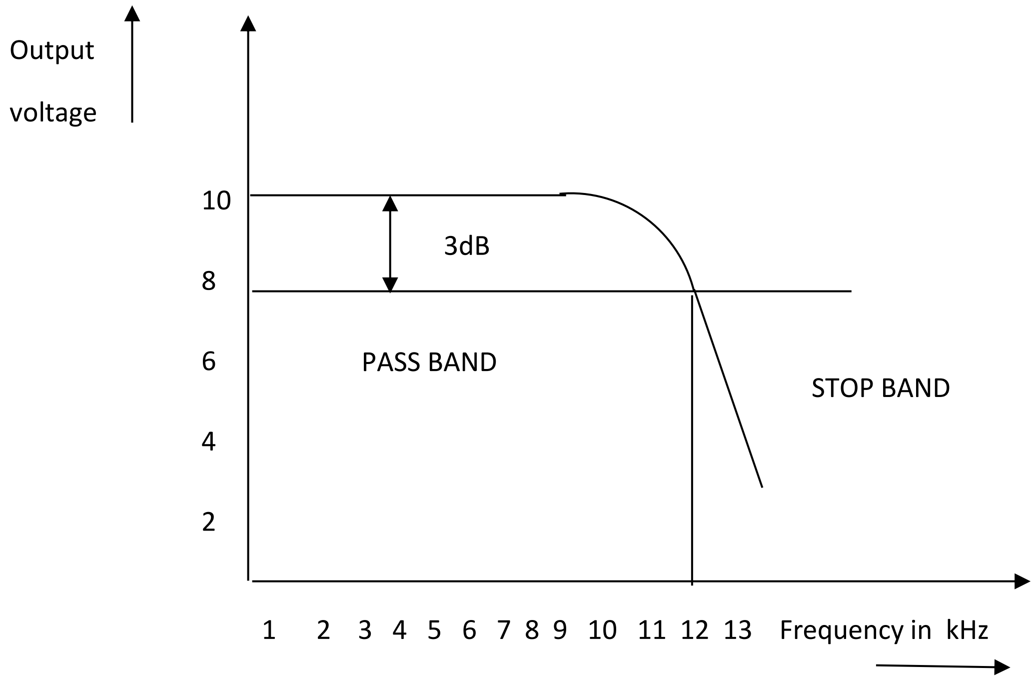
Choose a standard value of Capacitor C say 0.01 µF

$F_h=1/2\pi RC$

$F_h=1/2\pi*15k*0.01\mu f = 1k$

$Av=1+R_f/R_1$ & With this $R_1=10k$, $R_f=10k$

Model Graph:



Experiment-2

Aim: To study and design first-order HPF using an op-amp IC 741 and to obtain frequency response.

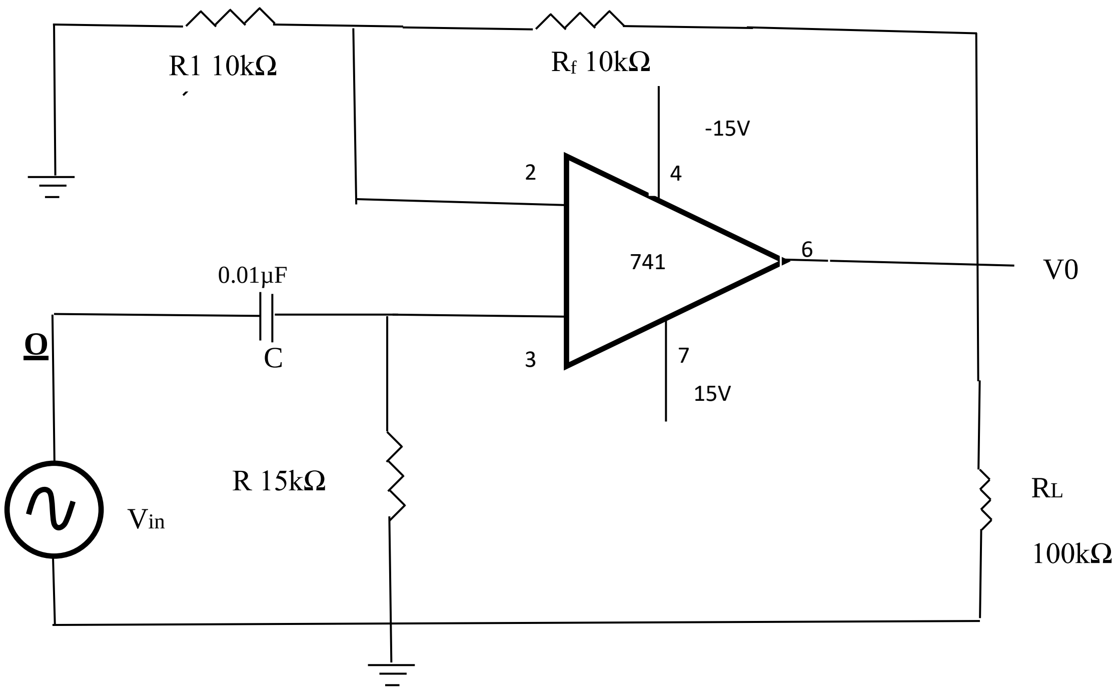
Equipment and components: Op-Amp(IC 741), Resistors(15k, 10k), Capacitor(0.01µF), Semiconductor trainer kit, Function generator, Cathode ray oscilloscope.

Theory: High pass filters are often formed simply by interchanging frequency. Determining resistors and capacitors in LPFs that is, a first-order HPF is formed from a first-order LPF by interchanging components 'R' and 'C'. The figure show first-ordered butter worth HPF with a lower cut-off frequency of 'F_l'. This is the frequency at which the magnitude of the gain is 0.707 times pass band and value. All frequencies, with the highest frequency determined by the closed-loop band width of the op-amp. For the first order, HPF the gain is

$$V_0/ Vin = A_f\, [\, (f/f_c) /\sqrt{}\, (1+ (f/f_c)^2]$$

Where, $A_f = 1 + R_f / R_1$ = Passband gain of the filter, f = frequency of input signal, $f_c = 1/2\Pi RC$ = lower cut off frequency. Since HPFs are formed from LPFs simply by interchanging Rs and Cs. The design and frequency scaling procedures of the LPFs are also applicable to HPFs.

Circuit Diagram:



Observations:

S.NO	Input frequency	Output Voltage	Gain in dB 20 log(Vo/Vi)
1. 2 3 4. 5. 6. 7.			

Calculations-

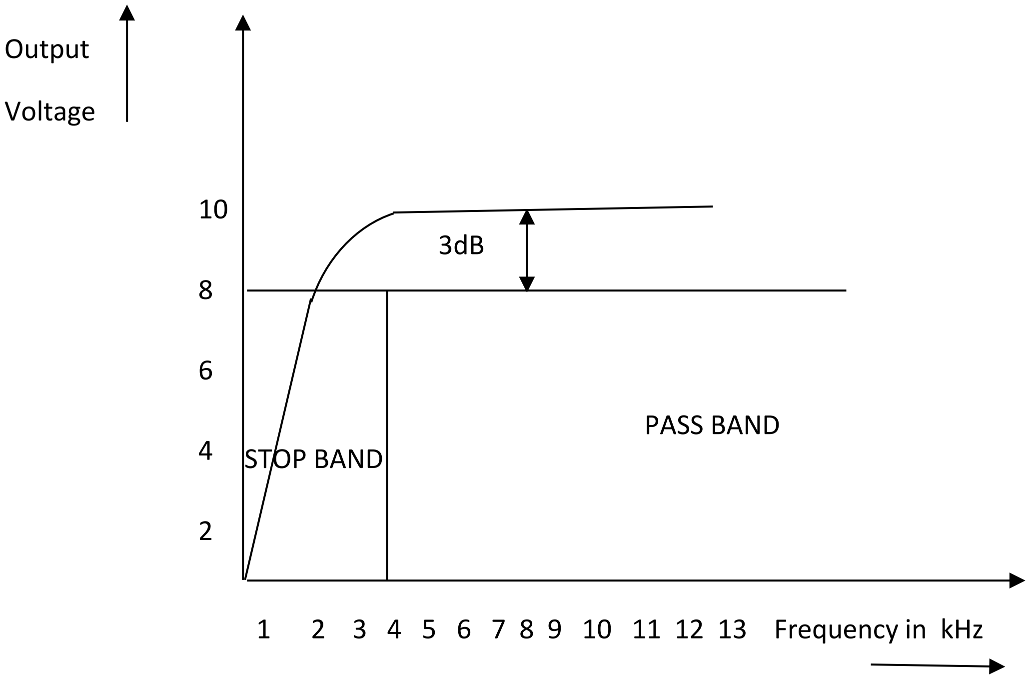
Choose a standard value of Capacitor C say 0.01 µF

Then $f_L = 1/2\pi R = 1/2\pi * 15k * 0.01\mu = 1k$

f_L=1k

$Av=1+R_f/R_1$ & With this R_1=10k, R_f=10k

Model Graph:



Experiment-3

Aim: To study and design of first-order LPF using an op-amp IC 741 in OrCad.

Equipment: OrCad software

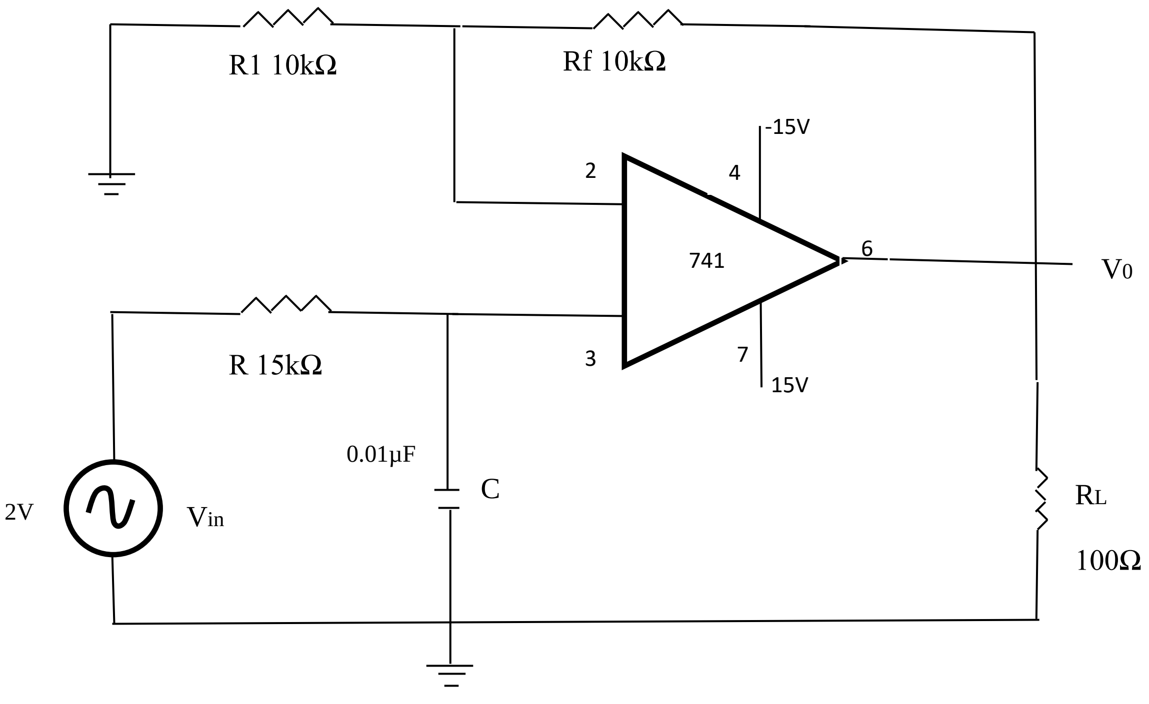
Theory: A frequency selective electric circuit that passes electric signals of a specified band of frequencies and attenuates the signals of frequencies outside the band is called an electric filter. The first-order lowpass filter consists of a single RC network connected to the non-inverting input terminal of the operational amplifier. Resisters R_1 and R_F determine the gain of the filter in the passband. The lowpass filter has maximum gain at f = 0 Hz. The frequency range from 0 to F_H is called the passband and the frequency range $f > f_h$ is called the stopband.

The first order low pass butter worth filter uses an RC network for filtering. The op-amp is used in the noninverting configuration, hence it does not load down the RC network. Resistors R1 and R2 determine the gain of the filter.

$$\mathbf{V_0/V_{in}} = A_f /(\sqrt{1} +(f/f_h)^2$$

Where, $A_f = 1+ R_f /R_1$= passband gain of filter, f = frequency of the input signal, $f_h = 1/2\Pi RC$ = High cut-offf frequency of the filter, V_0/V_{in}= Gain of the filter as a function of frequency. The gain magnitude and phase angle equations of the LPF can be obtained by converting V_0/V_{in} into its equivalent polar form as follows $|V_0/V_{in}| = A_f /(\sqrt{1} +(f/f_h)^2$,$\Phi =- \tan^{-1} (f/f_h)$. Where Φ is the phase angle in degrees. The operation of the LPF can be verified from the gain magnitude equation.

Circuit Diagram:



Observations: Simulate in OrCad and observe the output.

Experiment-4

Aim: To study and design first-order HPF using op-amp IC 741 in OrCad.

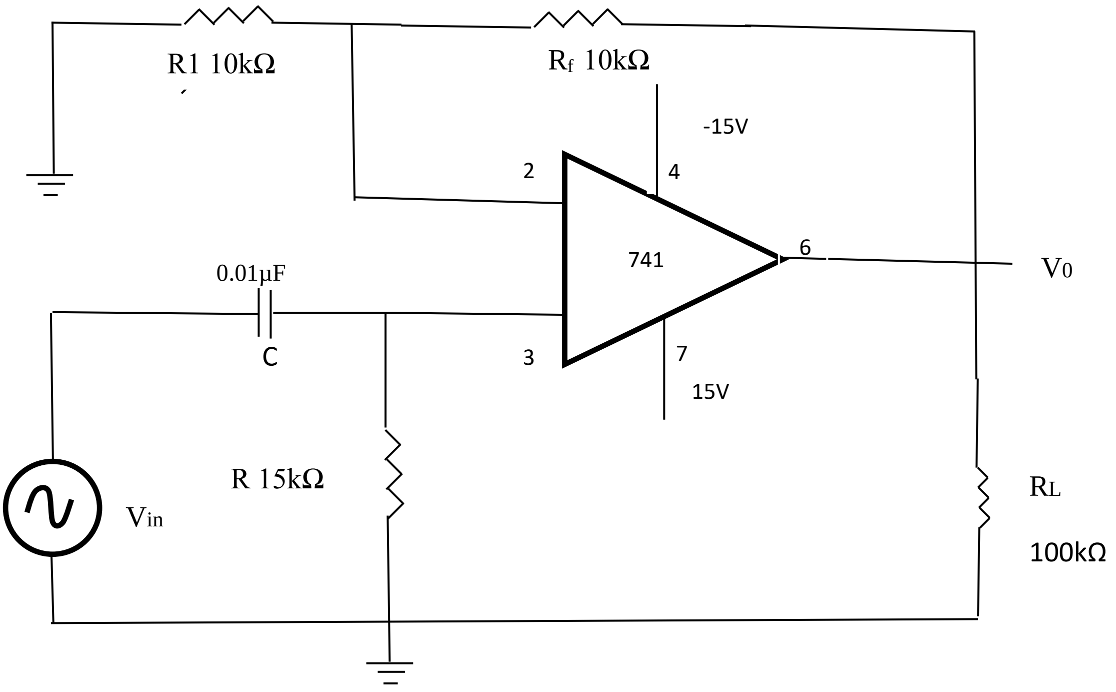
Equipment and components: Op-Amp(IC 741), Resistors(15k, 10k), Capacitor(0.01µF), Semiconductor trainer kit, Function generator, Cathode ray oscilloscope.

Theory: High pass filters are often formed simply by interchanging frequency. Determining resistors and capacitors in LPFs that are a first-order HPF is formed from a first-order LPF by interchanging components ‘R’ and ‘C’. Figure Shows a first-order butter worth HPF with a lower cut-off frequency of ‘ F_l’. This is the frequency at which the magnitude of the gain is 0.707 times its passband value. Obviously all frequencies, with the highest frequency determined by the closed-loop bandwidth of the op-amp. For the first order, HPF the gain is

$$V_0 / Vin = A_f [(f/f_c) / \sqrt{(1 + (f/f_c)^2}]$$

Where $A_f = 1 + R_f / R_1$ = Passband gain of the filter, f = frequency of input signal, $f_c = 1/2\Pi RC$ = lower cut off frequency. Since HPFs are formed from LPFs simply by interchanging Rs and C’s. The design and frequency scaling procedures of the LPFs are also applicable to HPFs.

Circuit Diagram:



Observation: Simulate in OrCad and observe the output.

Experiment-5

Aim: To understand the behavior of logarithmic and anti-logarithmic amplifiers.

Components and Equipment: Resistors(100KΩ, Diodes, IC 741, Transistor-BC548, Breadboard, and Multimeter.

Theory: Log amplifiers are widely used for analog signal compression applications. When a diode is used in the feedback loop of an operational amplifier is forward biased via a constant current of amplitude V_i/R then it develops a potential $V_D = V_T \ln V_i/RI_o$ across the diode. Note that the input voltage and diode voltage are related in a logarithmic fashion. If we take the diode voltage as an output voltage then the input and output will be related in a logarithmic approach. The base-emitter junction of a bipolar junction transistor can be used as a diode when the collector and base are shorted. So a transistor can also be used in the feedback loop of an op-amp.

Antilog is the inverse operation of log operation so antilog amplifiers can be designed by reversing the arrangement of diodes and resistors in the log amplifiers. It is important to note that a single polarity of current can only forward bias the diode. That means the log operation or antilog operation is a single quadrant operation.

Log Amplifier using Diode:

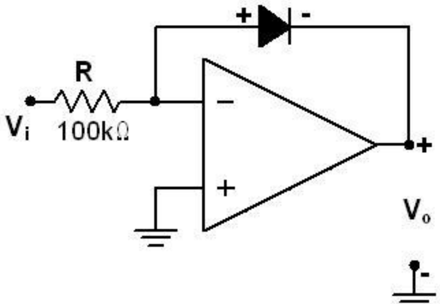


Fig:1

Observation Table:

S. No.	Input Voltage (V)	Output Voltage (V)

Log Amplifier Using a BJT:

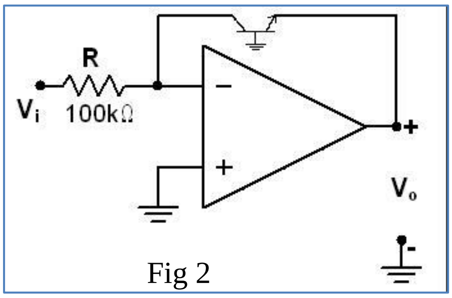


Fig 2

Anti-log Amplifier:

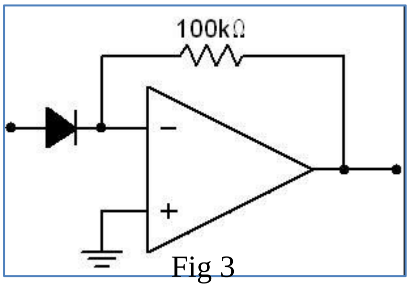


Fig 3

Observation Table:

S. No.	Input Voltage (V)	Output Voltage (V)

Experiment-6

Aim: To verify and plot (V_D- I_{out}) characteristics of the operational transconductance amplifier.

Apparatus required: Power Supply, Bread Board, Resistances, variable (Pot) resistances, Connecting Leads, Voltmeter, and Ammeter.

Theory: The operational transconductance amplifier (OTA) is an amplifier whose differential input voltage produces an output current.Thus, it is a voltage controlled current source(VCCS).There is usually an additional input for a current to control the amplifier's transconductance. For ideal OTA, The output current is a linear function of differential input voltages. $I_{out} = g_m (V_{in+} - V_{in-}) = g_m V_d$

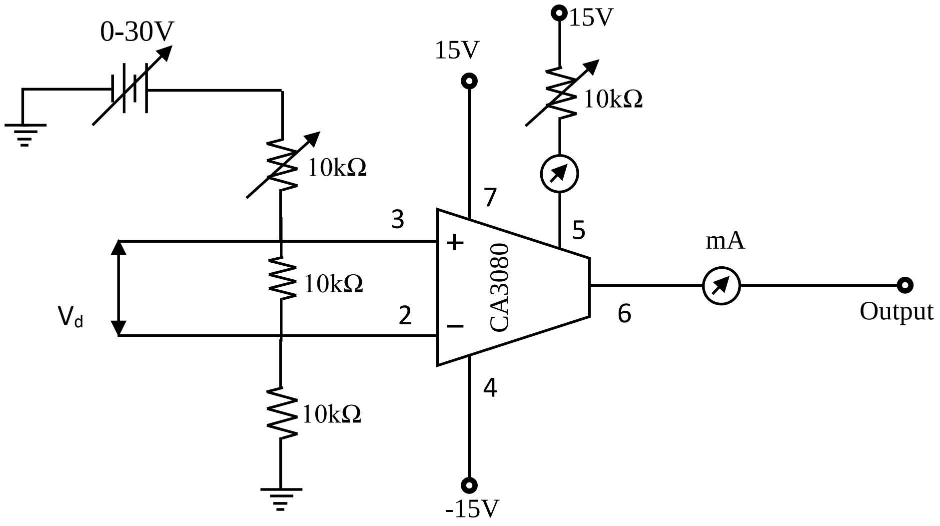
Where, g_m is transconductance of OTA

Transconductance tells output current variation according to applied differential voltage. For BJT based OTA g_m is

$$g_m = \frac{I_B}{2V_T} \tag{1}$$

This show $g_m \propto I_B$ .It means I_B increase g_m also increases.

Circuit Diagram:



Observation table:

Sl. No.	Input bias current (uA)	Output current (I_{out})	Differential Voltage (V_D)	% Error
1.				
2.				

Experiment-7

Aim: To verify and plot (I_B-gm) characteristics of operational transconductance amplifier calculate gm of OTA.

Apparatus required: Power Supply, Bread Board, Resistances, Variable (Pot.) resistances, Connecting Leads, Voltmeter and Ammeter.

Theory: The operational transconductance amplifier (OTA) is an amplifier whose differential input voltage produces an output current.Thus,it is a voltage controlled current source (VCCS). There is usually an additional input for a current to control the amplifier's transconductance. For ideal OTA, the output current is a linear function of differential input voltages.

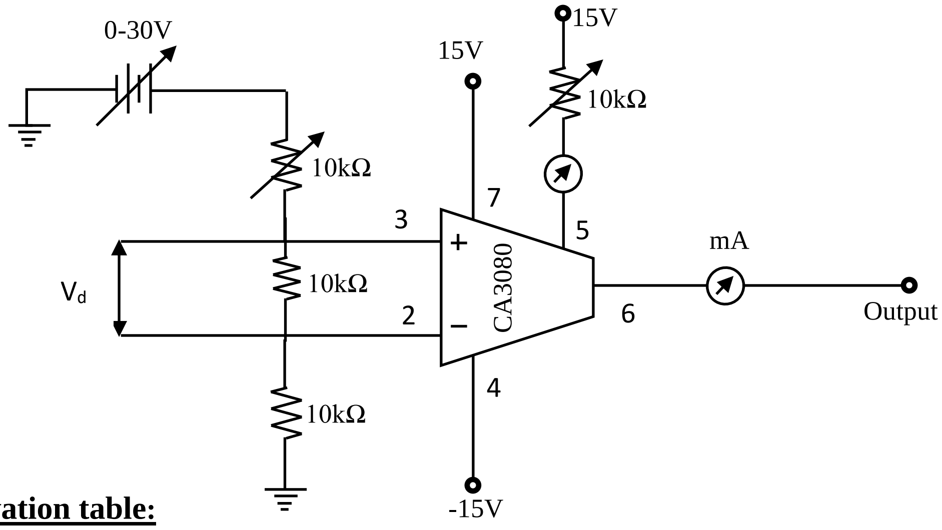
$$I_{out} = g_m (V_{in+} - V_{in-}) = g_m V_d$$

Where, g_m is transconductance of OTA.Transconductance tells output current variation according to applied differential voltage. For BJT based OTA g_m is

$$g_m = \frac{I_B}{2V_T} \qquad (1)$$

This show $g_m \propto I_B$ .It means I_B increase g_m also increases.

Circuit Diagram:



Observation table:

Sl. No.	Input bias current (uA)	Theoretical g_m (S)	Practical g_m (S)	% Error
1.				
2.				

Experiment-8

Aim: To implement various kinds of resistances using operational transconductance amplifier.

Apparatus required: Power supply, Bread board, Resistances, Variable resistances, Connecting leads, Voltmeter, and Ammeter.

Theory: For ideal OTA. The output current is a linear function of differential input voltages.

$$\mathrm{I}_{\mathrm{out}} = \mathrm{g_m}\,(\mathrm{V_{in+}} - \mathrm{V_{in-}}) = \mathrm{g_m V_d}$$

Where, g_m is transconductance of OTA

Transconductance tells output current variation according to applied differential voltage. For BJT based OTA g_m is

$$\mathrm{g_m} = \frac{\mathrm{I_B}}{2\mathrm{V_T}} \dots\dots\dots\dots (1)$$

Resistors can be simulated using OTAs. Figure (a) shows a simple single OTA connection. This circuit is equivalent to a grounded resistor with resistance equal to the inverse of the OTA transconductance, that is,

$$\mathrm{R} = \frac{1}{g_m} \dots\dots\dots\dots (2)$$

Floating resistor simulation may require more OTAs. Figure (b) shows a circuit with two identical OTAs. It can be shown that it is equivalent to a floating resistor of resistance equal to$\mathrm{R} = 1/g_m$. Finally, for the ideal voltage input, the first OTA in the input terminated floating resistor simulation is redundant and can thus be eliminated, as shown in Fig. (c).This simulation not only saves one OTA but also has a high input impedance, a feature useful for cascade design.

Circuit Diagram:

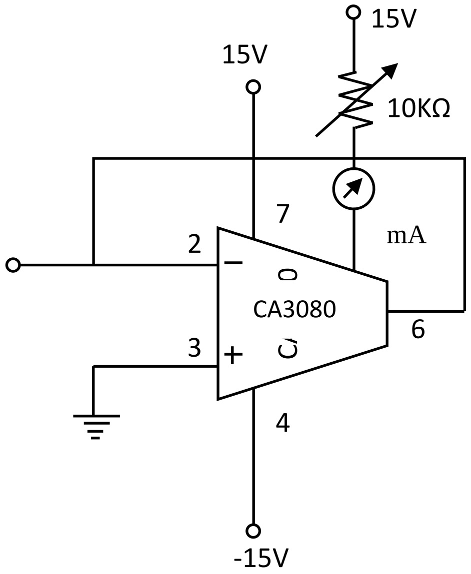
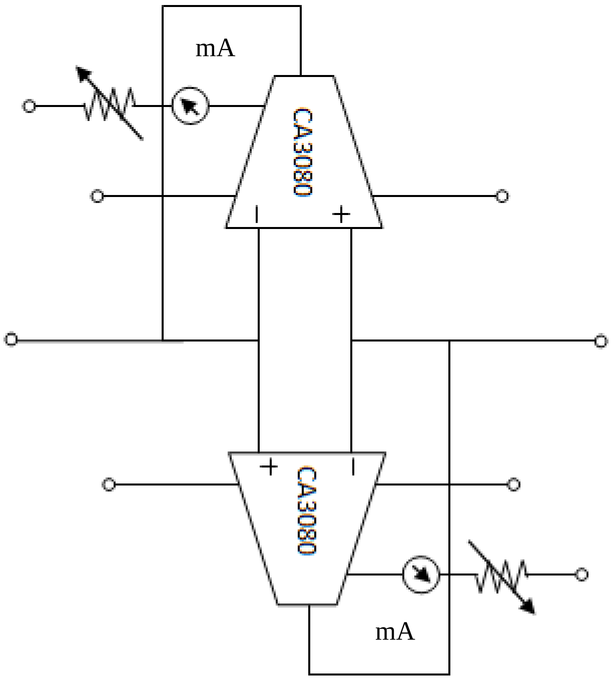


Figure (a)



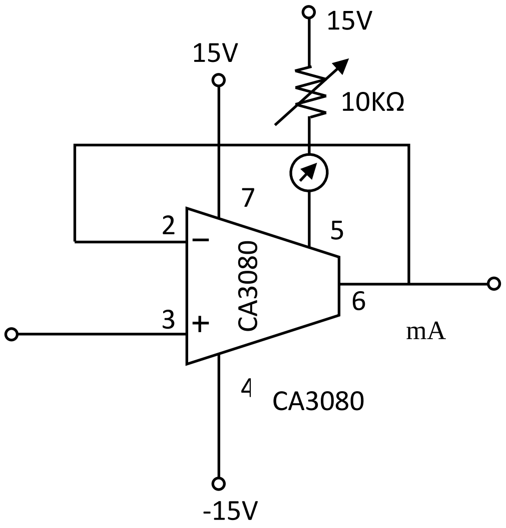


Figure (c)

Observation table:

Sl. No.	Input bias current (uA)	Resistance(Ω) for Figure (a)	Resistance(Ω) for Figure (b)	Resistance(Ω) for Figure (c)
1.				
2.				
3.				
4.				
5.				

Experiment-9

Aim: Implementation of inductances using OTA.

Apparatus required: IC, Power Supply, Capacitor, Bread board, Resistances, Connecting leads, Voltmeter, and Ammeter.

Theory: Inductors which are difficult to simulate with op-amps are very easy to be simulated by the use of OTA.

Figure shows a simple method, which needs only one additional OTA.

$$I_{02} = -g_{m2}.V_2 \quad \text{..........................(1)}$$

$$I_{01} = g_{m1}.V_1 \quad \text{..............................(2)}$$

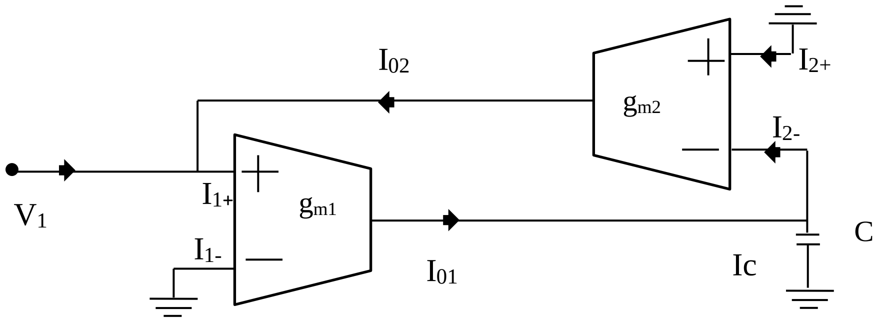
$$V_2 = \frac{g_{m1}(V_1)}{SC} \quad \text{............................(3)}$$

$$I_1 = -I_{02} = \frac{g_{m1}g_{m2}(V_1)}{SC} \quad \text{............................(4)}$$

$$\frac{V_1}{I_1} = Z_i = sL = s\frac{C}{g_{m1}g_{m2}} \quad \text{..................................} \quad (5)$$

inductor of value: $\therefore \; L = \frac{C}{g_{m1}g_{m2}}$

Circuit Diagram:



Observation table:

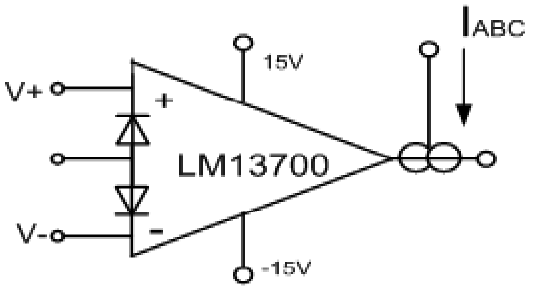
Sl. No.	Input bias current (uA)	Inductance (Henry)
1.		
2.		
3.		

Experiment-10

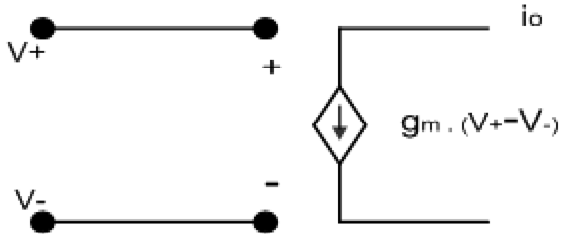
Aim: Implementation of low pass filter and high pass filter using OTA.

Apparatus required: IC, Power supply, Capacitor, Bread board, Resistances, Connecting leads, Voltmeter, and Ammeter.

Theory: Active filter design by using current division topology. Figure 1 and 2, shows that design of low pass filter (LPF) in which applying input at non-inverting terminal. Connecting a feedback resistance R from output terminal to inverting terminal of OTA. Capacitance of one terminal is connected with inverting terminal of OTA. Another terminal is grounded. Whereas high pass filter (HPF) which is shown in figure 2. In which applying input at non-inverting terminal of OTA. Inverting terminal is directly grounded here. But in this design changing the position (or) place of capacitance. Components such as resistor and capacitor of design connection also different from low pass filter. Response (or) behavior of HPF design is opposite to the LPF design. Transconductance term, ($g_m \equiv \frac{Current}{Volts}$) is used to characterize any semiconductor device that uses its input voltage to control the output current. Other semiconductor devices can be characterized as a trans-resistance type (the input current controls the output voltages). The OTA is a transconductance type device, which means that the input voltage controls the output current by means of the device transconductance. This classifies the OTA as a voltage-controlled current source (VCCS). In contrast to the OTA, the conventional op-amp is characterized as a voltage-controlled voltage source (VCVS). One can draw an immediate conclusion about the difference between VCCS and VCVS that lie in the output stage of the amplifier. The output stage in the VCCS is a current source, which means that the output resistance is very high. On the contrary, the VCVS has a very low output resistance. The most important feature in OTA is that the transconductance parameter can be controlled by an external current called the amplifier bias current. The symbol and the equivalent circuit of a commercial OTA are shown in figure.



OTA symbol



OTA model

The transconductance g_m can be written as

$$g_m = \frac{i_o}{v^+ - v^-} \text{............................} \quad (1)$$

The transconductance g_m is assumed to be linearly dependent on the bias current I_{ABC} in all circuit configurations operating in linear region. Thus,

$$g_m = hI_{ABC} \text{............................}(2)$$

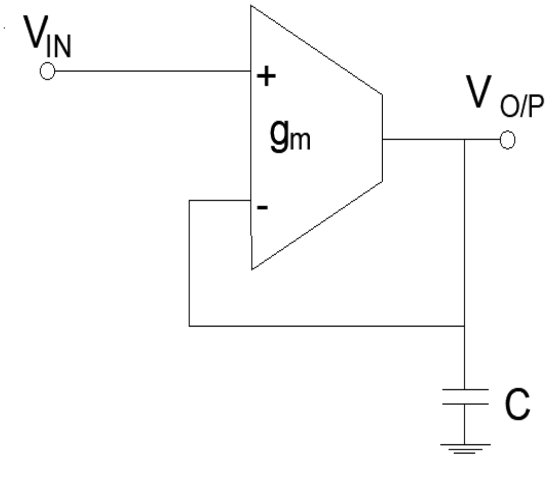
The proportionality constant is dependent upon temperature,device geometry and the process.

The 3dB cutoff frequency of the lowpass filter and high pass filter is given by the expression:

$$f_{3dB} = \frac{g_m}{2\Pi C}$$

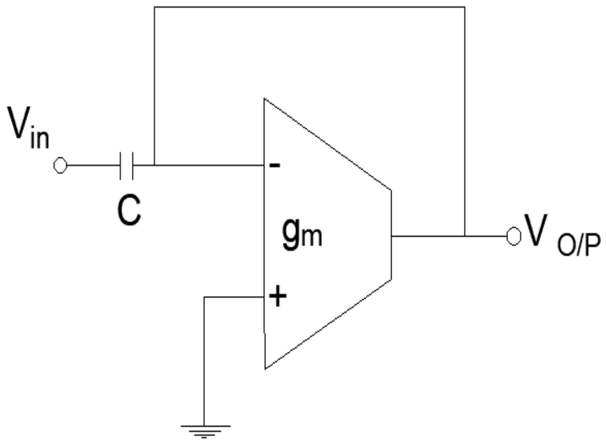
Here the dc voltage Vc is used to supply the dc biasing current I_{ABC} which in turn determines g_m.

Circuit Diagram:



$$\mathbf{V_{o/p}} = \frac{g_m}{S_c + g_m}$$

Figure 1: Low pass filter implementation using OTA



$$\mathbf{V_{o/p}} = \frac{g_m}{S_c + g_m}$$

Figure 2: High pass filter implementation using OTA

Observation table:

Sl. No.	**Input bias current (uA)**	**Transconductance (g_m)**	**Frequency (Hz)**	**Gain (dB)**
1.				
2.				
3.				
4.				
5.				

Experiment -11

Aim: Implementation of oscillator using OTA

Apparatus and Components required: Bread board, Active components (OTA IC CA3080), Passive components (resistor and capacitor), Connecting wires, Power supply, CRO, Multimeter etc.

Theory: An oscillator provides a source of repetitive A.C. signal across its output terminals without needing any input (except a D.C. supply). The signal generated by the oscillator is usually of constant amplitude.

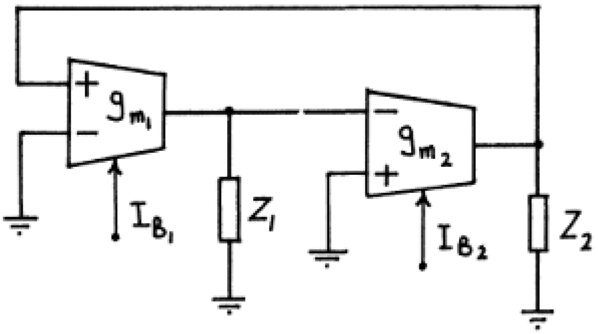


Figure: Oscillator Structure

The wave shape and amplitude are determined by the design of the oscillator circuit and choice of component values.This figure 2 show the output of sinusoidal oscillator using OTA.

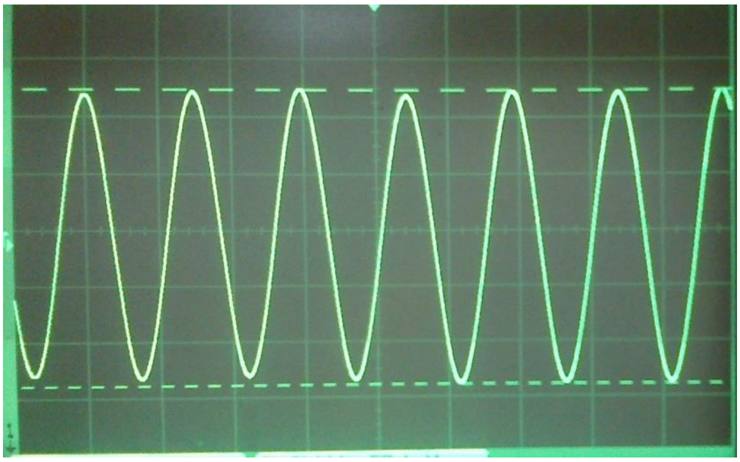


Figure2: Output Waveform of Sinusoidal Oscillator

Experiment-12

Aim: Implementation of PLL using OTA

Apparatus and Components required: Bread board, Active components (OTA, IC CA3080), Passive components (resistor & capacitor), Connecting wires, power supply, CRO, Multimeter etc.

Theory: Phase lock loops(PLL) are widely used in many diverse areas, such as power systems, communications, control systemsfor the tuning of frequency and phase.

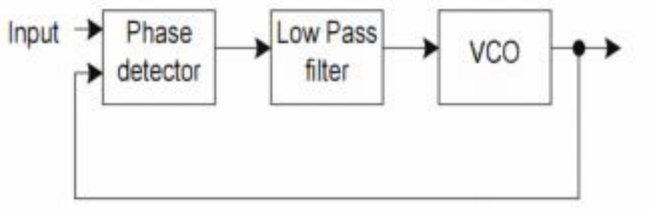


Figure: Conventional analog PLL circuit

Figure shows a conventional analog PLL consisting of a phase detector (PD), a low-pass filter (LPF) and a voltage-controlled oscillator (VCO). The VCO signal along with the input signal is applied to the PD where their phases are compared. The output of the PD is fed to a LPF, which attenuates the high-frequency components of the PD output. The filter output is applied to the VCO and under certain conditions, the VCO signal is synchronized with the input signal.