STUDIES ON ANALOG CIRCUITS USING OP-AMP

PROCEDURE:

I. Trace the circuit in the board. Locate the components of Fig.1a. Figure 1b shows the op-amp IC 741 pin configuration. The board is powered by a bipolar supply (+12 and -12 V versus ground). Near the top of the board is a voltage divider. If terminal V4 is grounded then we have the approximate no load voltages V1=+6.5V, V2=+3.3V and V3=2.2V. If instead -12V is applied to terminal V4 then we have approximately: V1=+1.0V, V2=-5.4V and V3=-7.7V.

II. DC Gain

a. Realise the op-amp in the **Inverting** configuration shown in Fig.2. Use R_i=10KΩ and R_f=10KΩ. Apply the bipolar supply to power the board and thereby the amplifier. **Note:** We have stopped indicating op-amp power supply connections. Remember that these connections must be made. Apply an input of 1V dc (use the voltage divider to obtain this voltage). Measure the actual values of V_{in} as this will be < 1V due to input resistance R_{in} of the circuit. Compare your results with V_{out}= $-(R_f/R_i).V_{in}$. Repeat this procedure for R_f= 27KΩ, 47KΩ and 100KΩ.

b. Virtual ground. With R_i=10KΩ and R_f=100KΩ, measure the voltage at the inverting input pin2 of the op-amp. Can you say that the pin2 is at virtual ground compared to V_{in}?

c. Input Resistance: Measure the voltage across R_i (which we will call V_i) and use this to calculate I_i. Now measure V_{in}. Calculate the input impedance $R_{in}=V_{in}/I_i$. Your answer, of course, will be very close to R_i.

With V_{in}=1V, R_i=1KΩ and R_f=10KΩ, calculate and then measure V_{out}. Repeat for R_f= 27KΩ, 47KΩ and 100KΩ. At what point does the amplifier cease to be linear? At what output voltages does the op-amp saturate? Repeat this procedure for V_{in} with other dc values. How are the saturation voltage levels related to the power supply voltages?

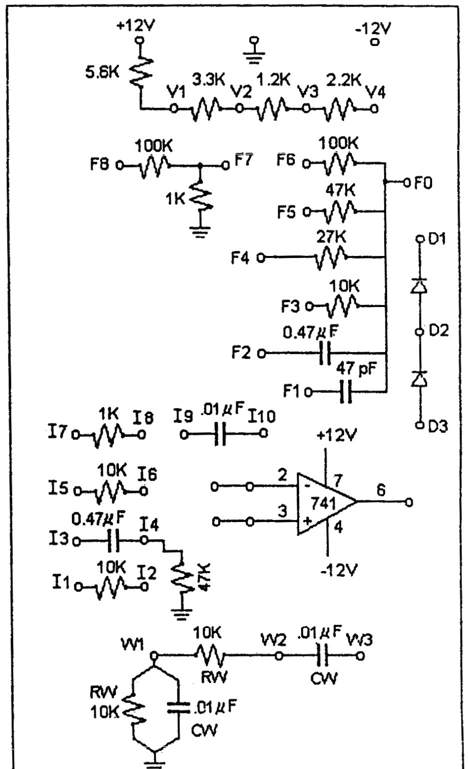


Fig.1a

Op-Amp 741

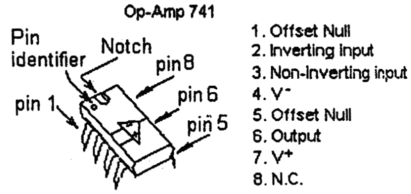


Fig.1b

III. Non Inverting Amplifier:

a. Realise the noninverting amplifier shown in Fig.3. Use R_i=10KΩ, R_f=10KΩ. Apply a $1V_{p-p}$, 10KHz input. Measure the gain and compare this with your calculations. Do this for R_f= 27KΩ, 47KΩ and 100KΩ as well. Make a table comparing experimental value for the gain and the computed values. Can you tell from what you see on the oscilloscope whether or not the output is inverted? Calculate the reactance of the capacitor at 10KHz. Is it necessary to include this in your gain calculations?

b. Frequency Response: Measure the gain A_f of the circuit in Fig.3 from 1 to 100KHz in convenient steps (say 10KHz), for R_f= 27KΩ, 47KΩ and 100KΩ, keeping R_i=10KΩ. You should notice that the high gain circuit begins to roll off sooner than the lower gain circuit. Determine the bandwidth and then the gainxbandwidth product in each case. The gain with feedback resistor R_f is given by $A_f= A_0 / (1+ \beta A_0)$ where $\beta= R_i/(R_i+ R_f)$. Use your data to calculate A_0.

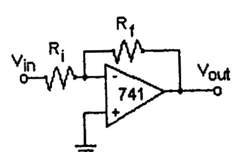


Fig.2

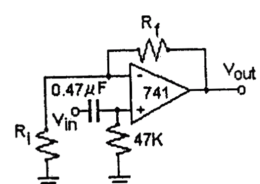


Fig.3

IV. Voltage follower:

Realise the circuit of Fig.4. Apply V_{in}=1V dc. Is the inverting pin2 at virtual ground? Explain. Verify that $V_{out}=V_{in}$. Also find the maximum (+ve) and minimum (-ve) voltages where this stops being true.

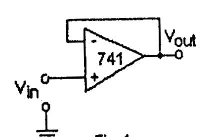


Fig.4

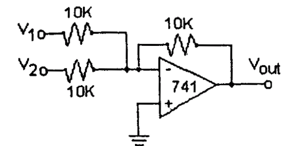


Fig.5

V. Adder:

a. Build the adder circuit of Fig.5. Apply dc voltages of V_1=2V and V_2=3V to the inputs. Measure and record the actual V_1, V_2 and V_{out}. Compare with theory.

b. Summing Amplifier The same circuit can be used to add DC offset to a signal. Apply a $1V_{p-p}$, 1KHz signal to V_1= V_{in}. Apply DC voltages ranging from 6.5V to -7.5V to V_2=V_{offset}. Display V_{out} in the scope and observe the DC offset (by switching the ac/dc switch of the scope input).

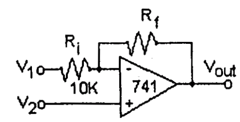


Fig.6a

VI. Superposition: a. We have till now considered circuits that accept signals at only one of the two input terminals of the op amp (the inverting or the noninverting inputs). In this experiment we shall work with an op-amp circuit (Fig.6a) that provides simultaneous inputs at the inverting and noninverting terminals. The relation between V_{out} and the inputs can be obtained using Horowitz and Hill's Golden Rules. However, use can also be made of the superposition theorem: which in this case implies that if V_{out1} (V_{out2}) is the response due to input V_1 (V_2) acting alone, i.e. with the other input V_2(V_1) being zeroed (grounded in this case). Then response due to both inputs V_1 and V_2 acting simultaneously is $V_{out}= V_{out1} + V_{out2}$.

Procedure: Choose R_f=10KΩ. Apply V_1=3V and V_2=2V dc. Measure V_1, V_2, and V_{out} and compare with theory. Repeat this procedure for R_f=47KΩ and 100KΩ.

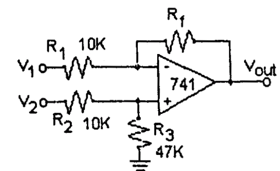


Fig.6b

b. Differential Amplifier: Realise the circuit of Fig.6b.

Here: $V_{out}= V_2 \times [R_3/(R_2+R_3)]\,(1+R_f/R_1) - V_1 \times (R_f/R_1)$

Choose R_1=10KΩ, R_2=10KΩ, R_3=47KΩ and R_f=27KΩ. Apply V_1=2V and V_2=3V dc. Measure and record the actual values of V_1, V_2 and V_{out}. Compare measured V_{out} with theory. Repeat this procedure for R_f=47KΩ. Note for R_2= R_1 and R_3= R_f the result is considerably simplified: V_{out}= $(R_f/R_1)\times(V_2-V_1)$. The output is directly proportional to the difference of the inputs.

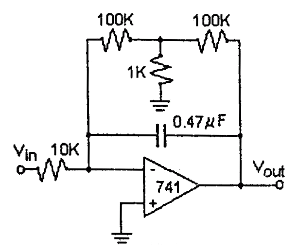


Fig.7

VII. Integrator

Realise the circuit of Fig.7. Apply a 5KHz sine-wave of $1V_{p-p}$. Observe V_{out} and V_{in} together in the scope and observe the phase difference. Also measure the gain and compare with theory. Next apply a $1V_{p-p}$, 5KHz square wave input. Observe and record V_{out} and V_{in} together in the scope. Record and trace the display. Repeat the above for frequencies ranging from 1KHz to 10KHz. Compare your results with theory [$V_{out}=-(1/RC) \int V_{in}dt$ +const].

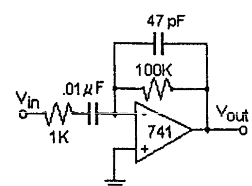


Fig.8

VIII. Differentiator

Realise the circuit of Fig.8. Apply a $0.2V_{p-p}$, 1KHz square wave to the input. Look at the input and output together in the oscilloscope. Record/Trace your results. Repeat the above with frequencies ranging from 1KHz to 10KHz. Compare your results with theory [V_{out}=-RC x (dV_{in}/dt)]. Repeat the above for a sine wave and then for a triangular wave.

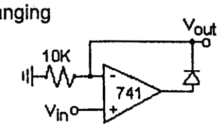


Fig.9a

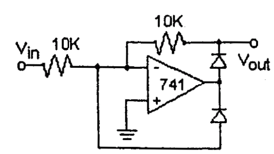


Fig.9b

IX. Active Rectifier

Realise the circuit of Fig.9a. Apply a sine wave (V_{p-p}=0.1V, 1KHz). Look at the output and input simultaneously in an oscilloscope. Record the display. Next construct the improved rectifier of Fig.9b and repeat the above. Compare these results.

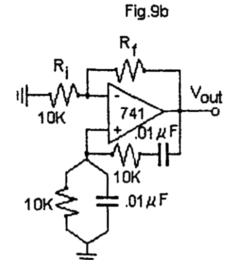
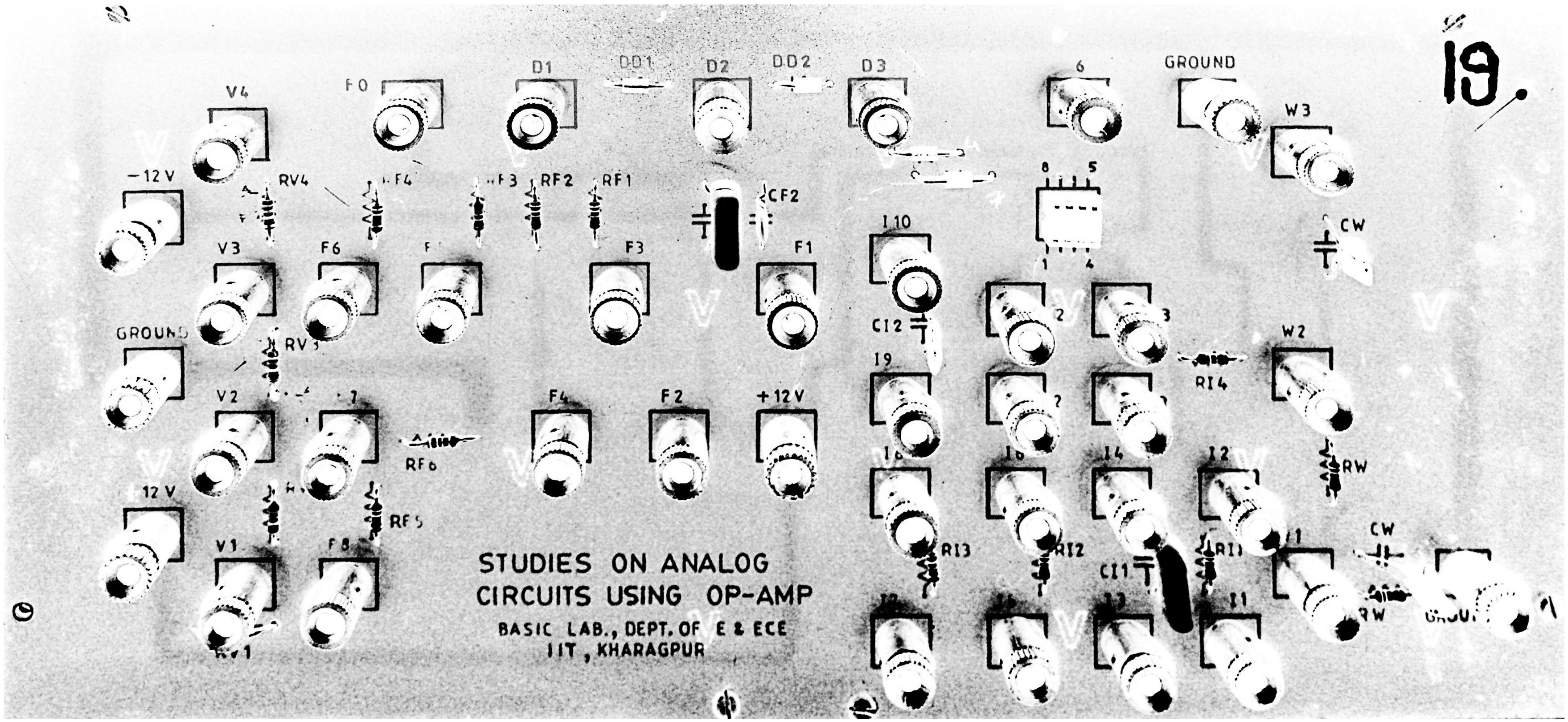


Fig.10

X. Wien Bridge Oscillator:

Realise the circuit shown in Fig.10. Choose R_i=10KΩ and R_f=10KΩ. If oscillations occur, measure the frequency of the output waveform. Compare with the theoretical f=(1/2πRC), where R=10K and C=0.01μF. Repeat this procedure for R_f=27KΩ, 27KΩ||100KΩ and 100KΩ. Use your data to obtain the ratio R_f /R_i for which oscillations occur. Also determine the ratio for which the output is a good sine-wave.


19.
D1
DD1
D2
DD2
D3
GROUND
W3
V4
F0
−12 V
RV4
RF2
RF1
CF2
CW
I10
V3
F6
F3
F1
GROUND
C12
I9
RI4
W2
V2
F4
F2
+12 V
RF6
RW
12 V
RF5
V1
F8
RI3
RI2
CI1
CW
RW
I4
I2
I1
STUDIES ON ANALOG
CIRCUITS USING OP-AMP
BASIC LAB., DEPT. OF E & ECE
IIT, KHARAGPUR