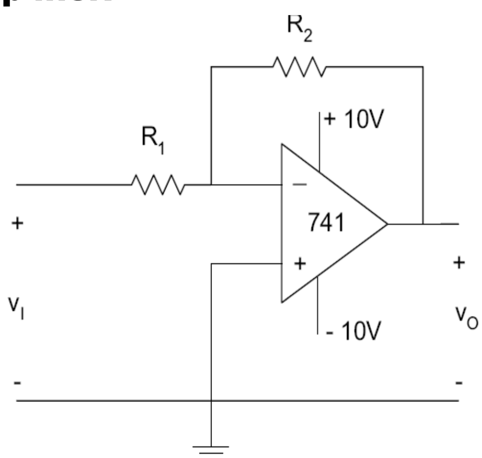
Experiment 8
Op-Amp Circuits

Objectives:

In this experiment you will investigate the characteristics of the following op-amp circuits:

- inverting amplifier
- non-inverting amplifier
- unit-gain buffer
- inverting adder
- integrator
- differentiator

❶ Inverting Amplifier:



The inverting amplifier is the most popular op-amp circuit. The basic disadvantage of this circuit is that its input impedance is low (equal to the value of R1 in the circuit shown above). Low input impedance is considered a disadvantage because for an ideal op-amp:

$$V_o = -\frac{R_2}{R_1}V_I$$

Why is a low input impedance considered a disadvantage?

The inverting amplifier is the most popular op- amp circuit. The basic disadvantage of this circuit is that its input impedance is low (equal to the value of R_1 in the circuit shown above). Theoretically we have considered that the input voltage of the op- amp is equal to zero due to high impedance that is I_{in}=0. Thus changing the theoretical value of the input voltage would affect our next calculations. Moreover, we note that the low input impedance would force high current to flow in the circuit (op-amp) that would be greater than a certain threshold value (since impedance and current are inversely proportional). This will damage the op- amp and will cause heat dissipation in the above circuit.

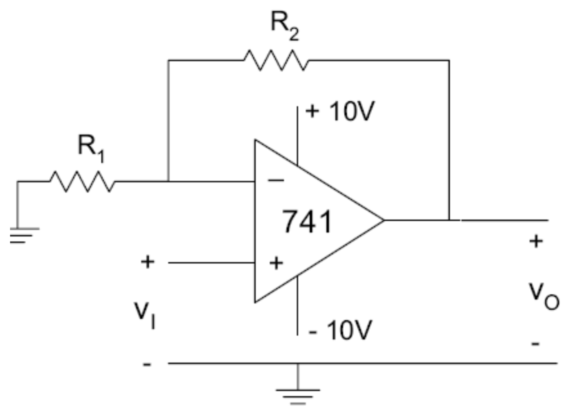
❷The bandwidth of the inverting op-amp: The bandwidth in this case is equal to the frequency at which the magnitude of the gain V_o/V_I drops to $1/\sqrt{2}$ of its low frequency value (which, theoretically, is R_2/R_1.)

The absolute value of the gain: $|A| = V_o/V_1 = R_2/R_1$. To find a relation between the low-frequency gain and bandwidth, we refer to our experimental results:
For gain = 10, bandwidth = 79 KHz
For gain = 4.54, bandwidth = 161.22 KHz
=> When the gain increases the bandwidth decreases.
We conclude that the bandwidth is inversely proportional to the low-frequency gain.

❸*Notes:* Corner frequency is when gain ($A=V_O/V_I$) = 0.707 from its original value
The product between bandwidth and gain is approximately constant.

****In the experiment we measure V_0 peak to peak using the oscilloscope (measure then read the value on the right of the screen). The output voltage is 180 degree out of phase with the input voltage. This is the particularity of an inverting amplifier which give us an inverted output thus 180 degree phase angle.

❹ *N*on-Inverting Amplifier:



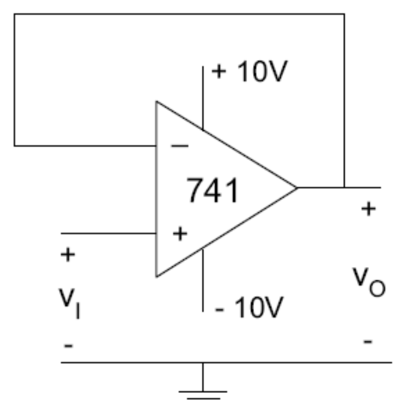
The non-inverting amplifier offers an advantage over the inverting configuration in that the input impedance is that of the op-amp itself (which, ideally, is *infinite*) rather than R_1.
Theoretically for an ideal op-amp:

$$v_O = \left(1 + \frac{R_2}{R_1}\right) v_I$$

❺ The bandwidth of the non-inverting op-amp is equal to the frequency at which the magnitude of the gain drops to of its low frequency value (which, theoretically, is 1+R2/R1.)
For R_1 = 1 KΩ and R_2 = 4.7 KΩ, measure the output when the input is a 200 mV peak-to-peak sinusoidal with variable frequency. Increase the frequency starting from 1000 Hz until the gain drops to 0.7071 times its *measured* low frequency value. Note the value of this frequency.

******In a non-inverting amplifier the output is with phase with the input. The phase angle is 0 degree.
We get the value of V0 peak to peak as usual we use measure in oscilloscope and read peak to peak value.

❻ Unity-Gain Non-Inverting Amplifier:

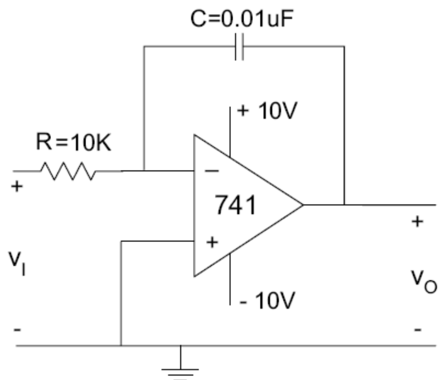


$V_o = V_I$

Determine the range of frequencies for which the gain is almost unity (i.e. $V_o = V_I$)
Find the upper limit of this range that is the frequency f_0 beyond which the gain starts to drop below 1. Note that beyond f_0, the circuit acts effectively as an attenuator. This frequency f_0 is the corner frequency.

The bandwidth of the unity-gain non-inverting op-amp is as before, equal to the frequency at which the magnitude of the gain Vo/VI drops to $1/\sqrt{2}$ (since its low -frequency gain is theoretically equal to 1)

❼ *I*ntegrator:



The fundamental operation of an op-amp integrator is similar to the inverting amplifier except that the input current is transferred to a feedback capacitor rather than resistor.

$$v_O = -\frac{1}{RC}\int v_I dt$$

Apply a *symmetrical square* wave signal at the input. *To verify experimentally that*

$v_O = -\frac{1}{RC}\int v_I dt$ ***, we should prove that the peak to- peak output voltage is equal (in absolute value) to the area enclosed under the square wave (for 0 < t < T/2 or for T/2 < t < T) divided by the product* RC*.***

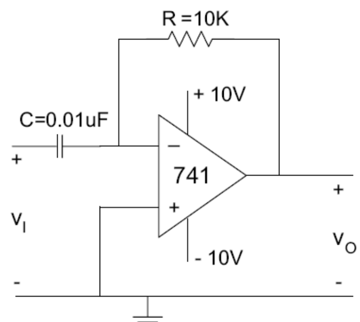
********In the experiment we measured the frequency of the output signal V_0 using measure-then read the frequency. Also we read the peak to peak value of V0 using the oscilloscope.**

❽ Increase the frequency of the input above 10 KHz, and observe the output. At what frequency does the output stop corresponding to the integral of the input (i.e. the output waveform stops resembling a triangular waveform)? Note that

you may need to increase the peak-to-peak value of the input voltage to be able to observe the output at high frequencies. Find out what causes the deterioration in the integration action of the op-amp in the circuit shown above.

At the value of 20 kHz, the output stops corresponding to the integral of the input. The output waveform stops looking like a triangular waveform. Initially it should look like one because of the integrating property of the circuit. Once we increase the frequency of the input above 10 KHz and observe the output we notice that the square wave gets distorted.
The deterioration in the integration action of the op-amp in the circuit shown above is caused by the high frequency, at which the capacitor charges and discharges so quickly. So, the waveforms look like impulses that destroy the integration form of the output waveform. At high frequencies, the charging and discharging of the capacitor occurs so fast, that they tend to be like impulses that distort the waveform pattern.

❾ Differentiator:



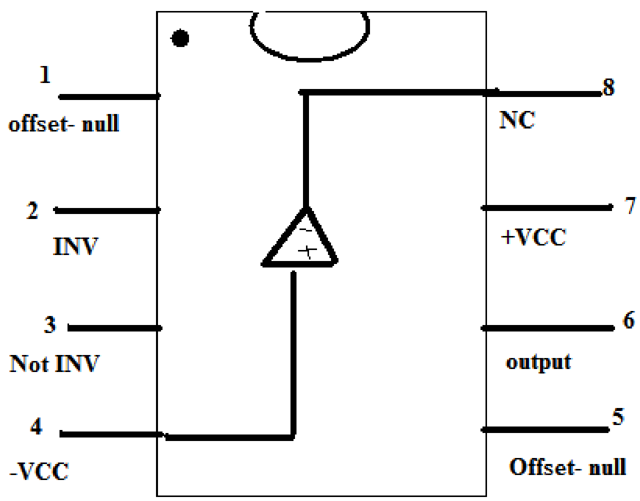
$$v_O = -RC\frac{dv_I}{dt}$$

Apply a *symmetrical triangular* wave signal at the input.
To prove experimentally that:

$v_O = -RC\frac{dv_I}{dt}$ ***, we should prove that the output voltage level equal, in absolute value, to the product*** **RC** ***multiplied by the slope of the triangular input signal.***

********Similarly as before in the experiment we measured the frequency of the output signal V_0 using measure-then read the frequency.**
Also we read the peak to peak value of V_0 using the oscilloscope.

General Shape of the OP-Amp



Place a variable resistor between 1 and 5 and adjust the variable resistor until we get a zero offset.