9. Op Amp II

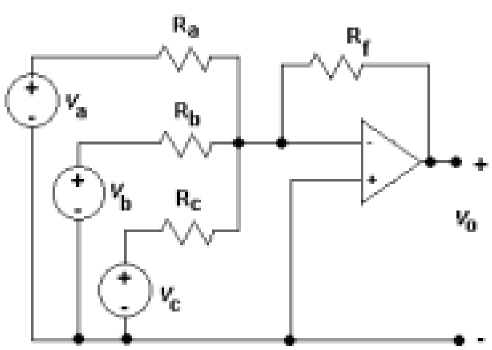
Objectives:
Illustration and realization of basic operations such as addition, subtraction, integration, and differentiation, by Op Amps.

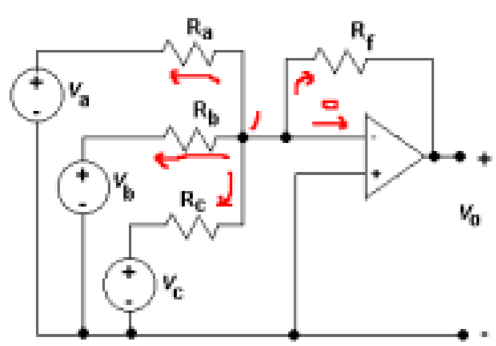
Equipment:
Op Amp 741
Function Generator
Power Supply
Resistors and Capacitors

Operational Circuits:

A. Summing Amplifier (Adder)

(a) A summing amplifier combines several inputs and produces an output that is the weighted sum of the inputs.
(b) A summing amplifier is also called a summer.
(c) A summing amplifier is a variation of the inverting amplifier.





(d) Input-Output relationship (see the figure above right for a 3-input summer)

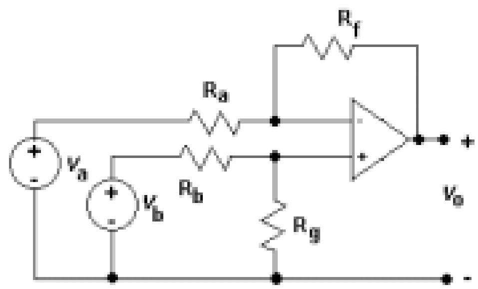
(i) By ideal op amp model: $V_1=0$ (Why? $V_p=0=V_n=V_1$)

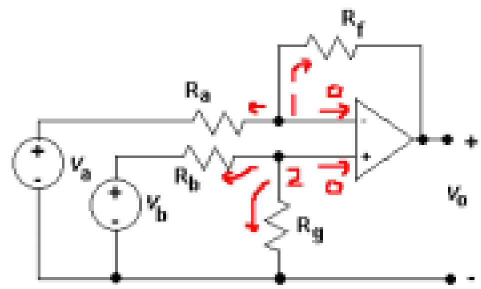
(ii) @ node 1: $\frac{0-V_a}{R_a}+\frac{0-V_b}{R_b}+\frac{0-V_c}{R_c}+\frac{0-V_o}{R_f}=0$ --->

$$V_o=-\left(\frac{R_f}{R_a}V_a+\frac{R_f}{R_b}V_b+\frac{R_f}{R_c}V_c\right)$$

B. Difference Amplifier (Subtractor)

(a) A difference amplifier amplifies the difference between two inputs but rejects any signals common to the two inputs.
(b) A difference amplifier is also called a differential amplifier.
(c) A difference amplifier is also known as the subtractor.





(d) Input-Output relationship (see the figure above right for a 3-input summer)

(i) By ideal op amp model: $V_1=V_2$ (Why? $V_p=V_n$)

(ii) @ node 1: $\dfrac{V_1-V_a}{R_a}+\dfrac{V_1-V_0}{R_f}=0$ ----> $V_o=\left(\dfrac{R_f}{R_a}+1\right)V_1-\dfrac{R_f}{R_a}V_a$ -----(1)

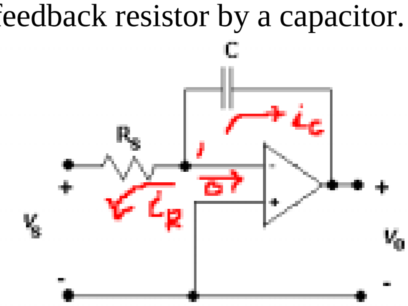
(iii) @ node 2: $\dfrac{V_1-V_b}{R_b}+\dfrac{V_1}{R_g}=0$ -----> $V_1=\dfrac{R_gV_b}{R_b+R_g}$ ----(2)

(iv) Substituting (2) into (1) yields:

$$V_o=\left(\frac{R_f}{R_a}+1\right)\cdot\frac{R_g}{R_b+R_g}V_b-\frac{R_f}{R_a}V_a=\frac{R_f}{R_a}\left(\frac{1+R_a/R_f}{1+R_b/R_g}\cdot V_b-V_a\right)\text{---------(3)}$$

C. Integrator

(a) An integrator is an op amp circuit whose output is proportional to the integral of the input signal.
(b) Consider a circuit below. This is the familiar inverting amplifier circuit, replacing the feedback resistor by a capacitor.



(i) A node-voltage equation at node 1: $i_R + i_C = 0$, where $i_R = \frac{0 - v_s}{R_s}$ and $i_C = -C\frac{dv_o}{dt}$.

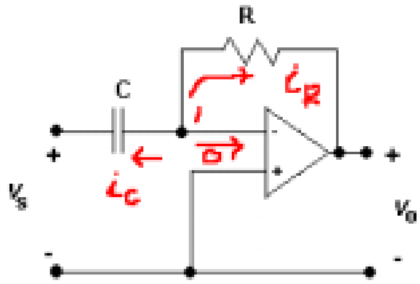
(ii) Therefore, the current equation becomes: $\frac{v_s}{R_s} = -C\frac{dv_o}{dt}$ ----> $dv_o = -\frac{1}{RC}v_s dt$

(iii) Integrating both sides gives $v_o(t) - v_o(0) = -\frac{1}{RC}\int_0^t v_s(t)dt$

(iv) Assuming $v_o(0)=0$ (discharging the capacitor prior to the application of the input signal), we have $v_o(t) = -\frac{1}{RC}\int_0^t v_s(t)dt$.

D. Differentiator

(a) A differentiator is an op amp circuit whose output is proportional to the rate of change of the input signal.
(b) Consider another circuit shown below.



(i) Applying KCL at node 1: $i_R + i_C = 0$ $i_R = \frac{0 - v_o}{R}$ and $i_C = -C\frac{dv_s}{dt}$.

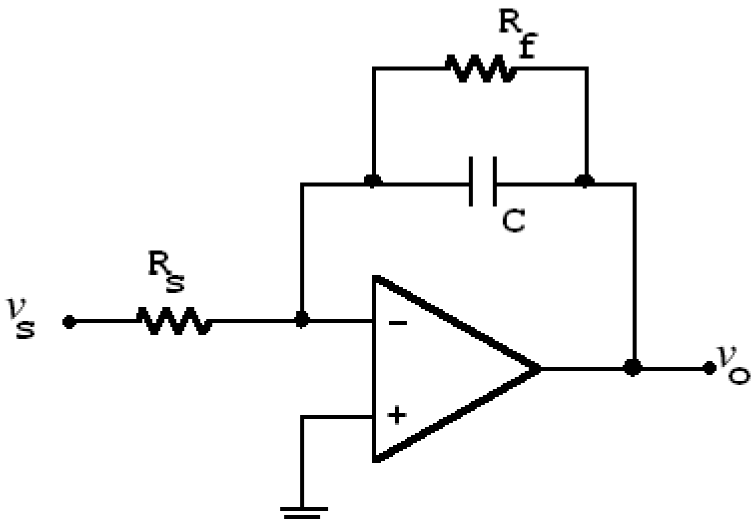
(ii) Therefore, we have: $\frac{v_o}{R} = -C\frac{dv_s}{dt}$ ----> $v_o(t) = -RC\frac{dv_s(t)}{dt}$

(iii) Caveat: Differentiator circuits are electronically unstable because any electrical noise within the circuit is exaggerated by the differentiator. Hence, the differentiator circuit is not as useful and popular as the integrator. It is seldom used in practice.

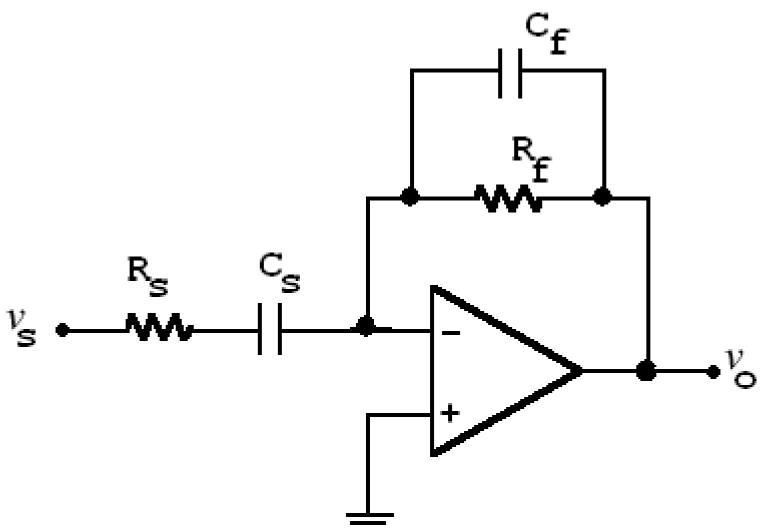
PRE-LAB-9 **NAME:___________** **ID:_________**

1. From the subtractor circuit and output equation (3), find the condition that makes the circut a subtractor with the output $V_o = V_b - V_a$

2. Express the output voltage V_o in terms of V_s, R_s, R_f, and C. What is this circuit?

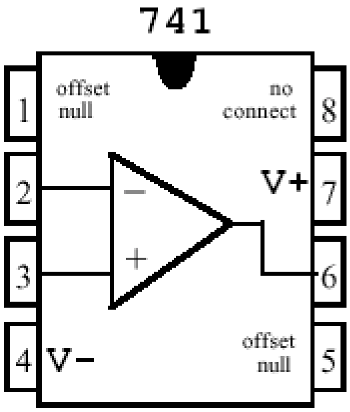


3. Express the output voltage V_o in terms of V_s, R_s, R_f, C_s, and C_f. What is this circuit?



LAB PROCEDURE

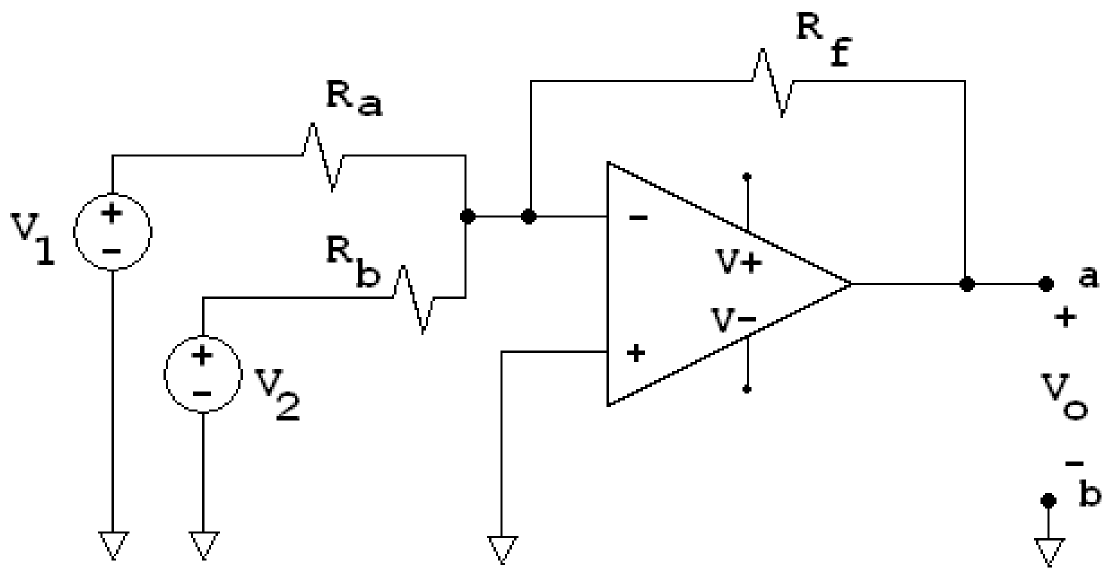
1. Pin-out diagram of 741 Op Amp



2. Addition Operation

(a) Construct a circuit as shown below. Choose R_a and R_b so that they are in the range of 1K - 100K and $R_a=R_b$. Pick Rf so that $R_a < R_f < (3*Ra)$.

$R_a=R_b=$ ___________________ Ω, $R_f=$ ___________________ Ω



(b) Supply DC **-15V** to V- and DC **+5V** to V+ pins of the Op Amp using a power supply. Then, what is the output voltage range?

____

(c) Write the theoretical value for the output voltage V_o in terms of V_1 and V_2.

____

(d) Supply a sinusoidal input for V_1 using a function generator.

(e) Supply a DC voltage for V_2 using a power supply.
(f)Measure using a Scope and sketch the output voltage Vo for the following values of V_1 and V_2.

(i) V_1 is sinusoidal source with magnitude of 1[V] and frequency of 1 kHz. V_2 is a DC voltage of 1[V].

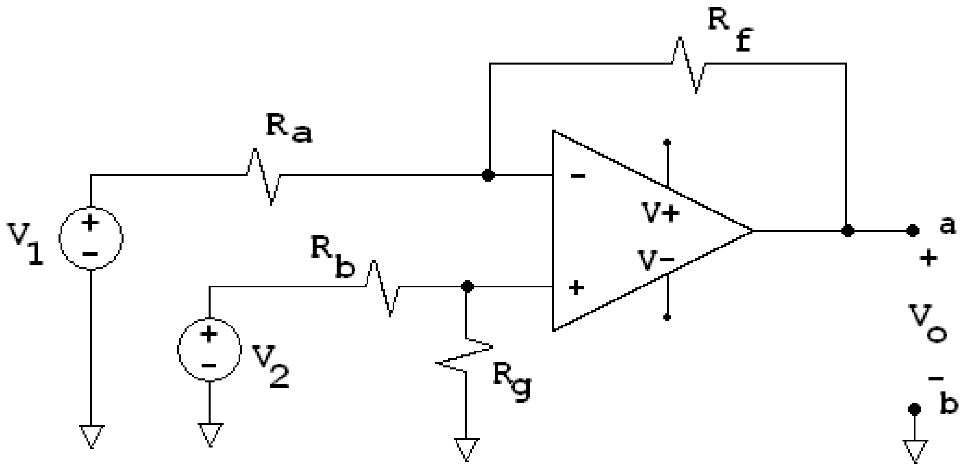
(ii) V_1 is sinusoidal source with magnitude of 1[V] and frequency of 1 kHz. V_2 is a DC voltage of 2[V]

(iii) V_1 is sinusoidal source with magnitude of 2[V] and frequency of 1 kHz. V_2 is a DC voltage of 2[V]

(g) Comment about the gain, % error in the gain, and saturation of the circuit.

3. Subtraction Operation

(a) Construct a circuit shown below. Choose the same resistance value for all the resistors in the range of 1K - 100K. R_a=R_b=R_g=R_f= ___________________ Ω



(b) Sipply DC **+5V** to V+ and DC **-15V** to V- pins of the Op Amp chip.

(c) Write the theoretical value for the output voltage V_o in terms of V_1 and V_2.

____

(d) Supply a sinusoidal input for V_1 using a function generator.

(e) Supply a DC voltage for V_2 using a power supply.

(f)Measure using a Scope and sketch the output voltage Vo for the following values of V_1 and V_2.

(i) V_1 is sinusoidal source with magnitude of 1[V] and frequency of 1 kHz. V_2 is a DC voltage of 1[V].

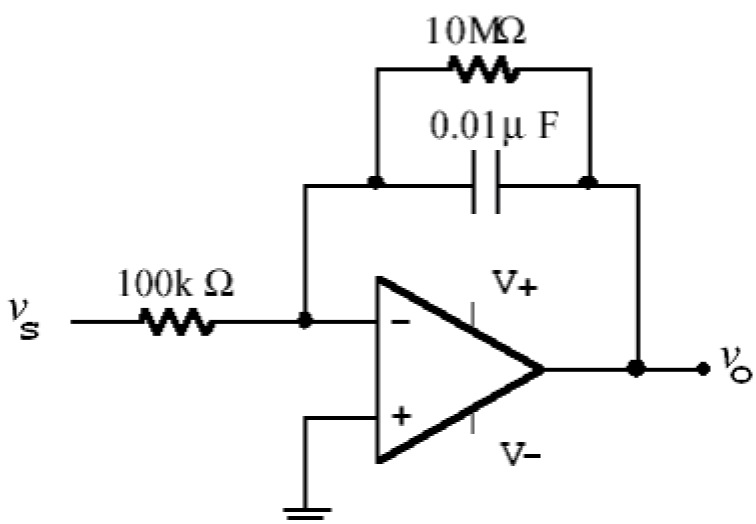
(ii) V_1 is sinusoidal source with magnitude of 1[V] and frequency of 1 kHz. V_2 is a DC voltage of 2[V].

(iii) V_1 is sinusoidal source with magnitude of 1[V] and frequency of 1 kHz. V_2 is a DC voltage of -5[V].

(g) Comment about the % error in the output voltage and saturation of the circuit.

4. Integration Operation

(a) Construct the following circuit with numeral values provided. Supply +15V to V+ and -15V to V- pins.



(b) Express the output voltage V_o in terms of the input voltage V_s.

(c) Measure the output voltage using a Scope and sketch V_s and V_o for the following inputs.

(i) Supply a square wave of magnitude 1[V] and frequency 1kHz for V_s.

(ii) Supply a sinusoidal wave of magnitude 1[V] and frequency 1kHz for V_s.

(iii) Supply a triangle wave of magnitude 1[V] and frequency 1kHz for V_s.

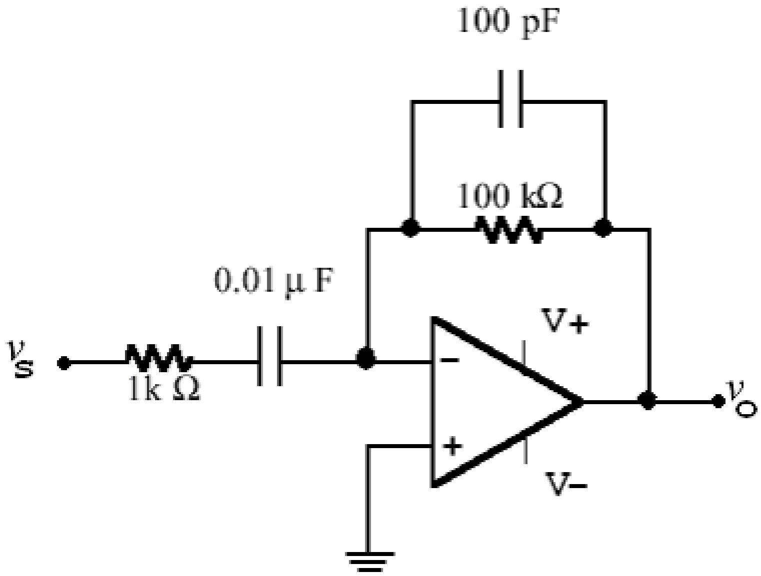
(d) From the Integration Operation circuit, remove the 10MΩ resistor. And measure the output voltage using a Scope and sketch V_s and V_o for the following inputs.

(i) Supply a square wave of magnitude 1[V] and frequency 1kHz for V_s.

(e) From (c) and (d), describe the differences and discuss the function of the 10MΩ resistor. And also discuss that the output waveform is indeed the integration of the input waveform.

5. Differentiation Operation Circuit

(a) Construct the following circuit. Supply +15V to V+ and -15V to V- pins of the Op Amp chip.



(b) Express the output voltage V_o in terms of the input voltage V_s.

____

(c) Measure the output voltage using a Scope and sketch V_s and V_o for the following inputs.

(i) Supply a square wave of magnitude 1[V] and frequency 1kHz for V_s.

(ii) Supply a sinusoidal wave of magnitude 1[V] and frequency 1kHz for V_s.

(iii) Supply a triangle wave of magnitude 1[V] and frequency 1kHz for V_s.

(d) From the Integration Operation circuit, remove the 100pF capacitor resistor. And measure the output voltage using a Scope and sketch V_s and V_o for the following inputs.

(i) Supply a square wave of magnitude 1[V] and frequency 1kHz for V_s.

(e) From (c) and (d), describe the differences and discuss the function of the 100pF capacitor. And also discuss that the output waveform is indeed the differentiation of the input waveform.