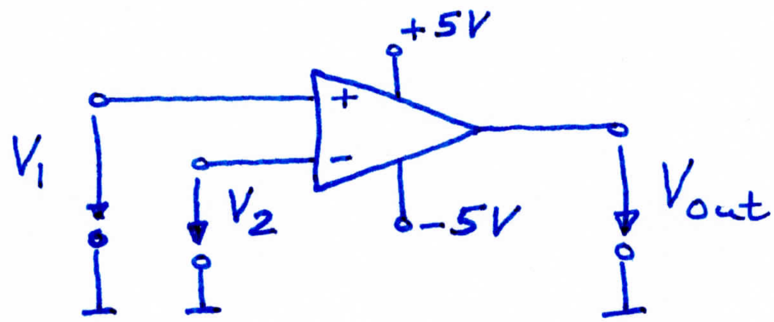
ITE - Homework 02 - Solution

Problem 01 Op Amp $V_{cc} = +5V$ $-V_{cc} = -5V$

(a) Op Amp circuit without feedback



Explain function:

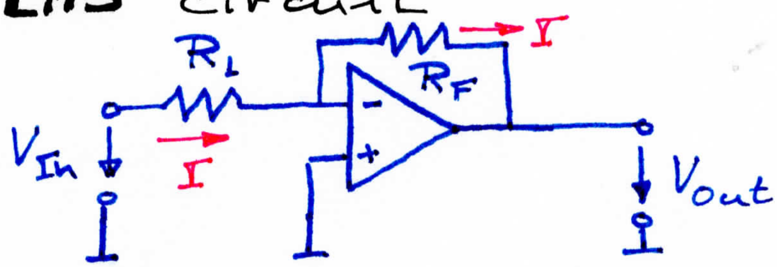
If $V_1 > V_2 \Rightarrow V_{out} = +5V$

If $V_1 < V_2 \Rightarrow V_{out} = -5V$

If $V_1 = V_2 \Rightarrow V_{out} = 0V$

Name of circuit: Comparator

(b) **LHS** circuit

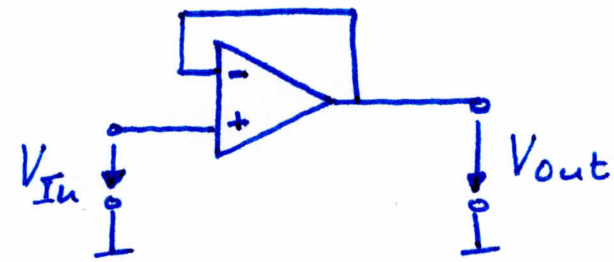


KVL: $V_{In} = R_1 I$

KVL: $I R_F + V_{out} = 0 \Rightarrow V_{out} = -I R_F$

$$\Rightarrow A_{voc} = \frac{V_{out}}{V_{In}} = \frac{-I R_F}{I R_1} = -\frac{R_F}{R_1} = -1$$

RHS circuit



KVL $\qquad V_{In} = V_{out}$

$\Rightarrow A_{voc} = \dfrac{V_{out}}{V_{In}} = 1$

$\Rightarrow$ Circuit may be called "voltage follower."

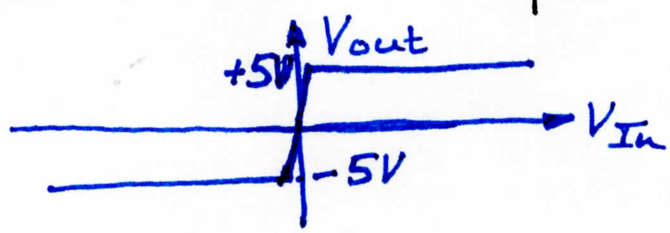
(c) Common feature: Both feedback elements feed back to the inverting input terminal of the Op Amp.

(d) Feedback goes to non-inverting input!

$\Rightarrow$ Runaway circuit $\Rightarrow$ Not useful.

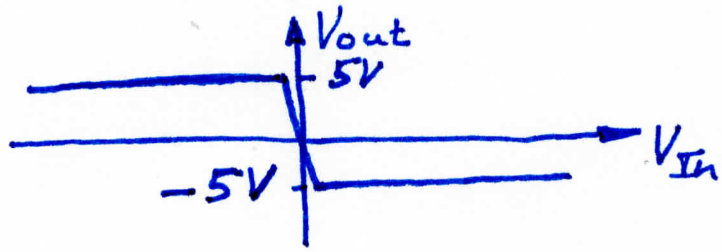
LHS circuit

$A_{voc} = \infty$

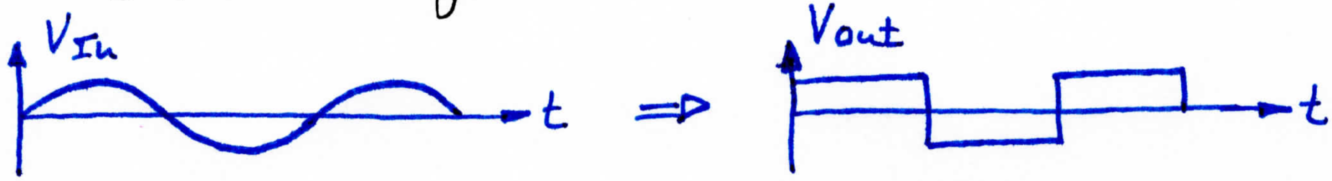


RHS circuit

$A_{voc} = -\infty$



(e) Circuits are not useful to amplify sinusoidal signal



$\Rightarrow$ Output signal is strongly distorted.

(f) LHS circuit

$V_{In} = 1\mu V \quad \Rightarrow \quad V_{out} = +5V$

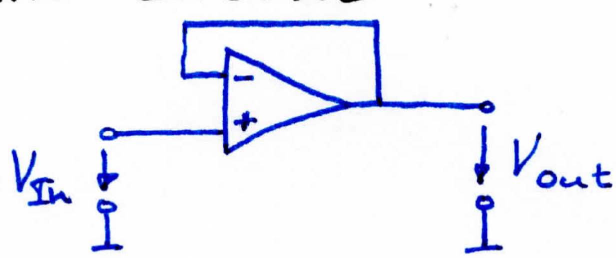
$V_{In} = -1\mu V \quad \Rightarrow \quad V_{out} = -5V$

(g) RHS circuit

$V_{In} = 1\mu V \quad \Rightarrow \quad V_{out} = -5V$

$V_{In} = -1\mu V \quad \Rightarrow \quad V_{out} = +5V$

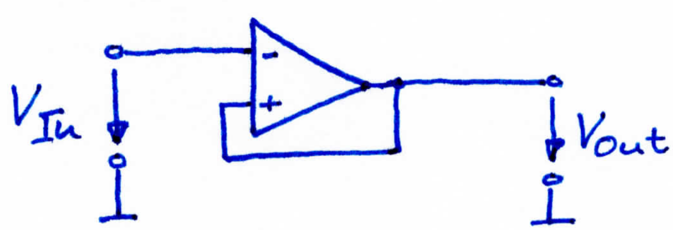
(h) LHS circuit



KVL: $V_{In} = V_{out}$

$\Rightarrow A_{voc} = 1$

RHS circuit



Positive feedback!

$\Rightarrow$ Runaway configuration

$\Rightarrow A_{voc} = -\infty$

The LHS circuit is a "voltage follower" because V_{out} follows V_{In}, that is, $V_{out} = V_{In}$.

Problem 2

(a) Superposition Theorem: The output voltage is the sum of the two output voltages caused by V_1 and V_2.

The theorem can be used for linear amplifiers. An Op Amp is a linear amplifier. Therefore the conditions are met.

(b) Employment of Superposition Theorem

V_{out} due to V_1:

$V_2 = 0 \Rightarrow \oplus$ at GND

KVL $\quad V_1 = I R_1$

KVL $\quad V_{out} = - I R_F$

Eliminating I from the two eqns. yields

$$V_{out} = - \frac{R_F}{R_1} V_1$$

V_{out} due to V_2:

$V_1 = 0$

$V_\oplus = V_2 \dfrac{R_G}{R_2 + R_G}$ (Voltage divider)

$V_\ominus = V_{out} \dfrac{R_1}{R_F + R_1}$ (Voltage divider)

$$V_{\oplus} = V_{\ominus} \Rightarrow V_{out} \frac{R_1}{R_F + R_1} = V_2 \frac{R_G}{R_2 + R_G}$$

$$\Rightarrow V_{out} = V_2 \frac{R_G}{R_2 + R_G} \frac{R_F + R_1}{R_1}$$

Superposition

$$V_{out} = -\frac{R_F}{R_1} V_1 + \frac{R_G}{R_2 + R_G} \frac{R_F + R_1}{R_1} V_2$$

Superposition

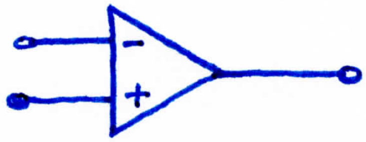
(c) $R_1 = R_F = R_2 = 1\,k\Omega$ $\qquad R_G = 100\Omega$

$$\Rightarrow V_{out} = -V_1 + \frac{100\Omega}{1k\Omega + 100\Omega} \times 2 \times V_2$$

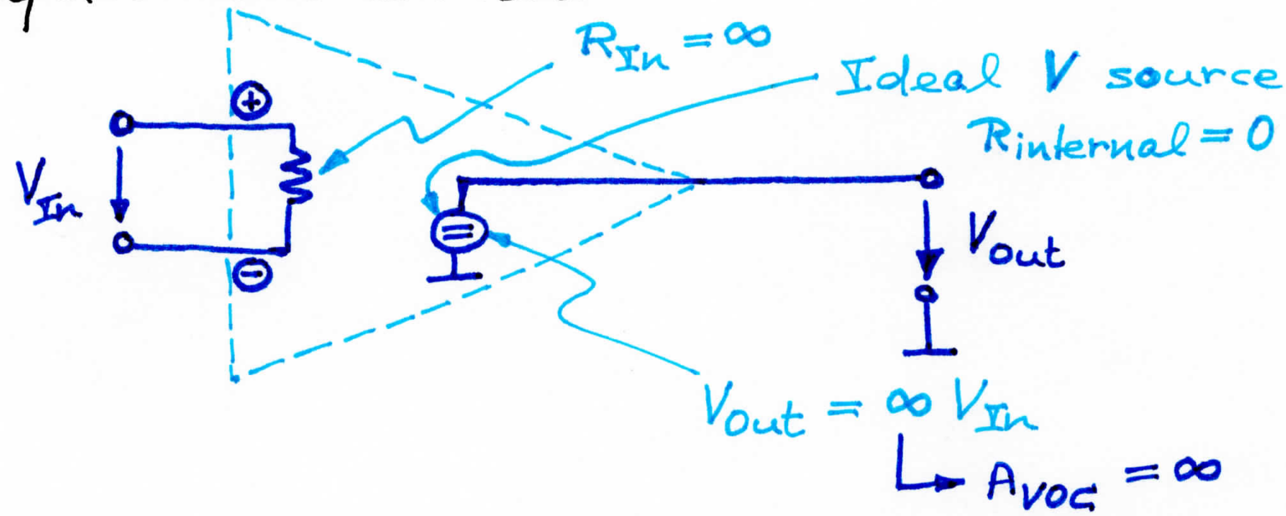
$$= -V_1 + \frac{2}{11} V_2$$

Problem 3

(a) Black box



Equivalent circuit



(b) $R_{In} = \infty$ Input resistance

$A_{voc} = \infty$ OC voltage amplification

$R_{out} = 0$ Output resistance

$\to$ Internal resistance of ideal V source

Problem 4

(a) Op Amp 1 is an ideal Op Amp. Accordingly, the voltage at its output is only determined by the ideal output voltage source of Op Amp 1. This voltage will not change for any voltage V_2 or V_3.

(b) Stage 1 = Inverting amplifier

$$A_{voc} = \frac{V_{OpAmp1}}{V_{In}} = -\frac{R_F}{R_1}$$

$$\Rightarrow V_{OpAmp1} = -\underbrace{\frac{R_F}{R_1}}_{R_F = R_1 \Rightarrow \text{same } R} V_{In} = -V_{In}$$

Stage 2

$$V_- = \underbrace{V_{OpAmp1}\frac{R_2}{R_3+R_2}}_{\text{Voltage divider}} = \frac{1}{2} V_{OpAmp1}$$

$$V_+ = 1\,V$$

Stage 2 has no feedback $\Rightarrow$ Comparator

If $V_- > 1V \Rightarrow V_{out} = -5V$

└→ Op Amp 2

If $V_- < 1V \Rightarrow V_{out} = +5V$

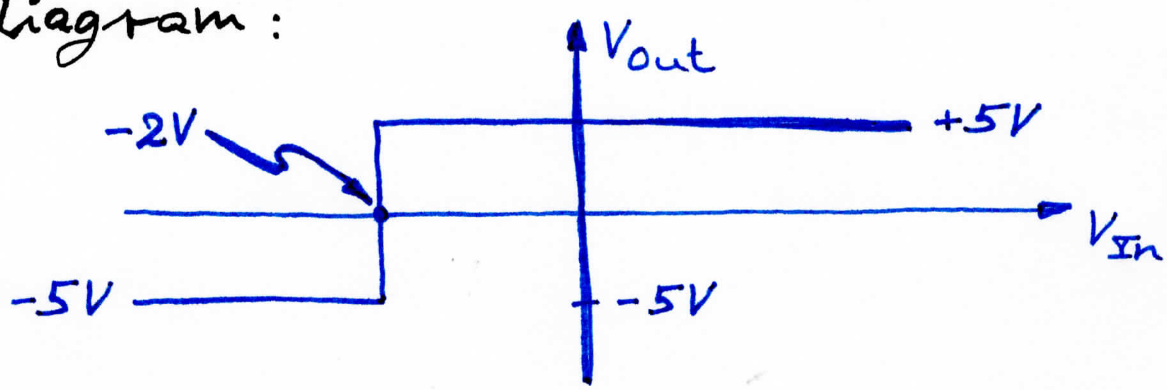
Recall $V_- = \frac{1}{2} V_{OpAmp1} = -\frac{1}{2} V_{In}$

Therefore

If $V_{In} < -2V \Rightarrow V_- > 1V \Rightarrow V_{out} = -5V$

If $V_{In} > -2V \Rightarrow V_- < 1V \Rightarrow V_{out} = +5V$

We can express this in terms of a diagram:



Problem 5

(a) True.

The two terms are frequently used synonymously.

(b) True.

An ideal Op Amp has zero output resistance (zero internal resistance of the voltage source).