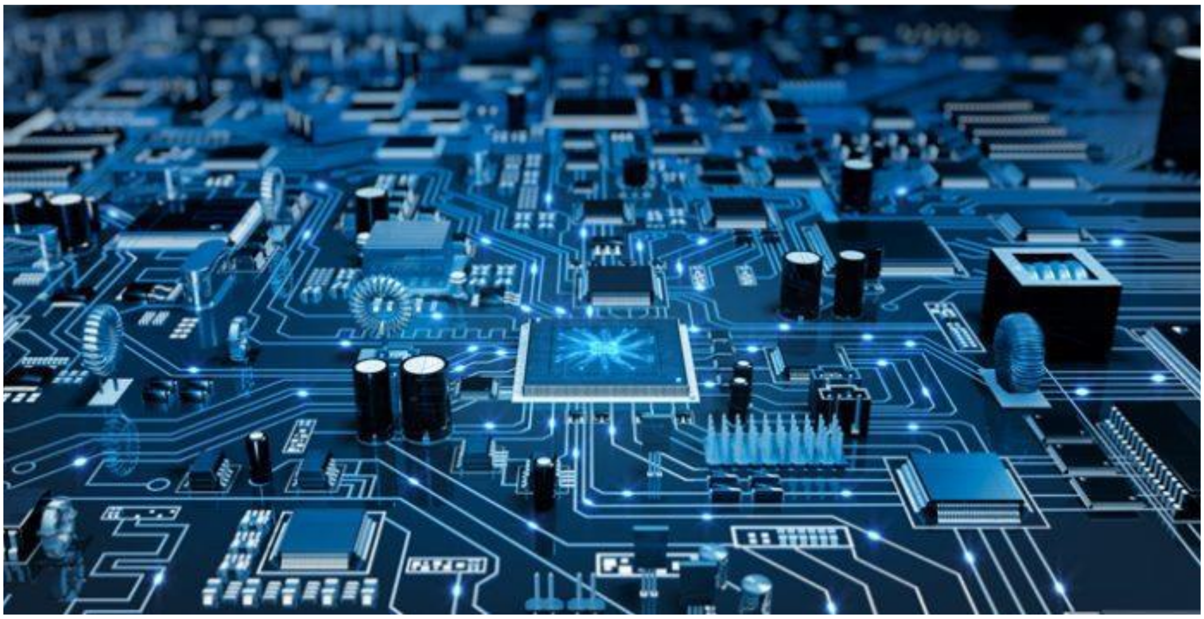
Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Systems
Lecturer: Prof. Adnan Ali
Lecture:8

Mode Unit 6

Operational Amplifier (Op-Amp) Part 1

For
Students of Third Stage
Department of Medical Instrumentation Techniques Engineering



By

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Dep. Medical Instrumentation
Techniques Engineering

2025

1. Overview

a. Target population:

For students of third class of Department of Medical Instrumentation Techniques Engineering, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq.

b. Rationale:

An operational amplifier (often op amp or Op-Amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op amp produces an output potential (relative to circuit ground) that is typically 100,000 times larger than the potential difference between its input terminals. Operational amplifiers had their origins in analog computers, where they were used to perform mathematical operations in linear, non-linear, and frequency-dependent circuits.

c. Objectives:

The student will be able after finishing lecture on:

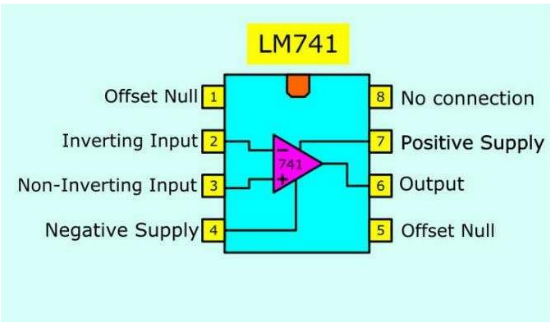
- Draw the waveform of Operational Amplifier (Op-Amp).
- Identify the main types of Operational Amplifier (Op-Amp).

Operational Amplifier (Op-Amp)

An operational amplifier IC is a solid-state integrated circuit that uses external feedback to control its functions. It is one of the most versatile devices in all of electronics.

The term 'op-amp' was originally used to describe a chain of high-performance dc amplifiers that was used as a basis for the analog type computers of long ago. The very high gain op-amp IC's our days uses external feedback networks to control responses.

The op-amp without any external devices is called 'open-loop' mode, referring actually to the so-called 'ideal' operational amplifier with infinite open-loop gain, input resistance, bandwidth and a zero-output resistance. However, in practice no op-amp can meet these ideal characteristics. And as you will see, a little later on, there is no such thing as an ideal op-amp. Since the LM741/NE741/µA741 Op-Amps are the most popular one, this tutorial is direct associated with this particular type. Nowadays the 741 is a frequency compensated device.



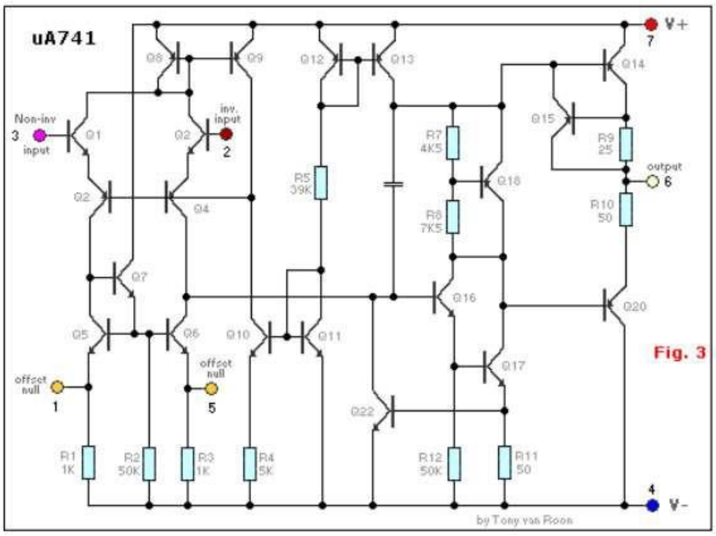
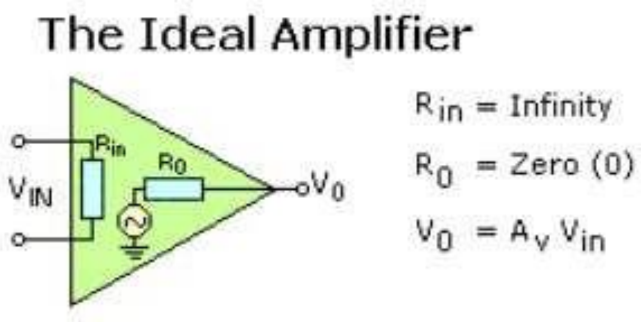


Fig. Internal 741 schematic circuit.

Open-Loop Gain:

Lets have a look how the 'ideal' amplifier would look like in Fig. 1. The search for an ideal amplifier is, of course, a futile exercise. The characteristics of the operational amplifier are good enough,
however, to allow us to treat it as ideal. Below are some amplifier properties that make this so. (Please realize that these ratings are next to impossible to achieve).

1. Gain--infinite
2. Input impedance--infinite
3. Output impedance--zero
4. Bandwidth--infinite
5. Voltage out--zero (when voltages into
each other are equal)



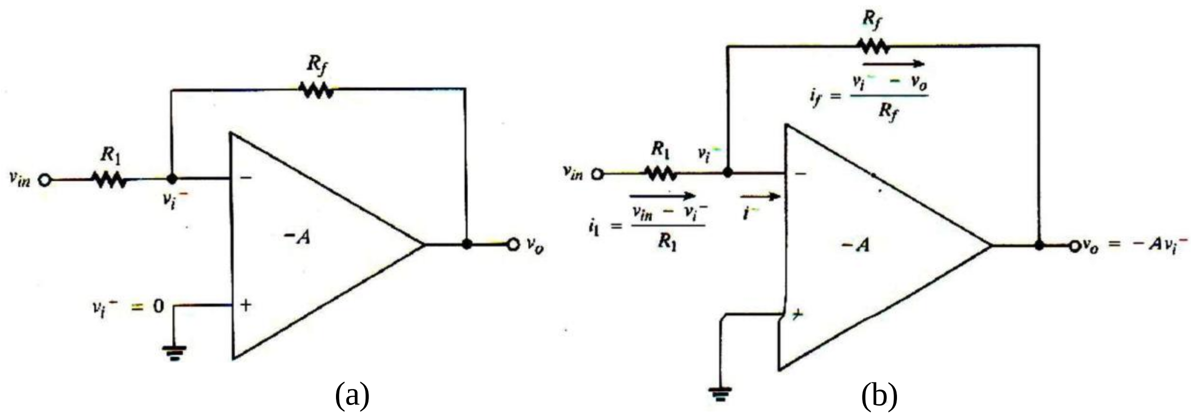
In general op-amps are designed to be powered from a dual or bipolar voltage supply which is typically in the range of +5V to +15Vdc with respect to ground, and another supply voltage of -5V to -15Vdc with respect to ground. Although in certain cases an op-amp, like the LM3900 and called a 'Norton Op-Amp', may be powered from a single supply voltage.

Consider the configuration shown in Fig. 1-9(a). In this very useful application of an operational amplifier, the noninverting input is grounded, v_{in} is connected through R_1 to the inverting input, and feedback resistor R_f is connected between the output and v_i^-. Since we are using the amplifier in an inverting mode, we denote the voltage gain by $-A$, $v_{in} \neq v_i^-$, we define $v = -Av^-$.

From Fig. 1-9(b); $i_1 = (v_{in} - v_i^-)/R_1$, $i_f = (v_i^- - v_o)/R_f$, $i_1 = i_f + i^-$,
and $Z_i = \infty$ => $i^- = 0$ => $i_1 = i_f$,
or $(v_{in} - v_i^-)/R_1 = (v_i^- - v_o)/R_f$ or $\frac{v_{in}}{R_1} - \frac{v_i^-}{R_1} = \frac{v_i^-}{R_f} - \frac{v_o}{R_f}$,
and $v_i^- = -\frac{v_o}{A}$, $|A| = \infty$ => $v_i^- = 0$ => $\frac{v_{in}}{R_1} = -\frac{v_o}{R_f}$ or

$$\frac{v_o}{v_{in}} = -\frac{R_f}{R_1}$$

In Eqn. [1-6] the gain is negative, signifying that the configuration is an inverting amplifier, also the magnitude of v_o/v_{in} depends only on the ratio of the resistor values. The gain v_o/v_{in} is a *closed-loop gain* of the amplifier, while A is called the *open-loop gain*.



(a) (b)
Fig.

Exercise 1 :

Assuming that the operational amplifier in Fig. 1-10 is ideal, find
(a) the rms value of v_o ... 1.5 V ...
(b) the rms value of th... 1.5 V rms, and
(c) the output voltage ...
... 60 μA rms, (c) 3.3 V dc]

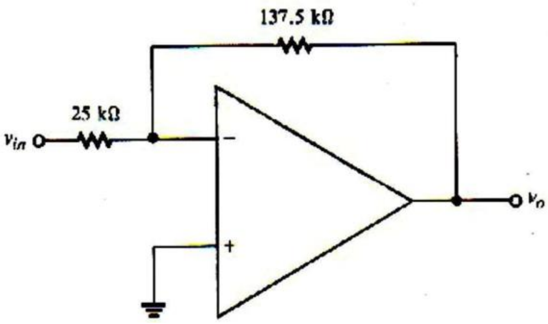


Fig.

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Exercise 1:

Assuming that the operational amplifier in Fig. 1-10 is ideal, find

(a) therms value of v_0 when v_{in} is 1.5 V rms,

(b) therms value of the current in the 25-kQ resistor when vi_{11} is 1.5 V m1s, and

(c) the output voltage when v_{in}= -0.6 V de.

[Ans ers: (a) 8.25 V rms, (b) 60 µA rrns, (c) 3.3 V de]

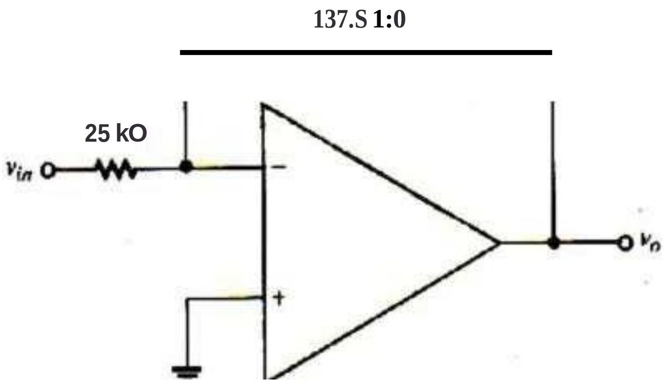
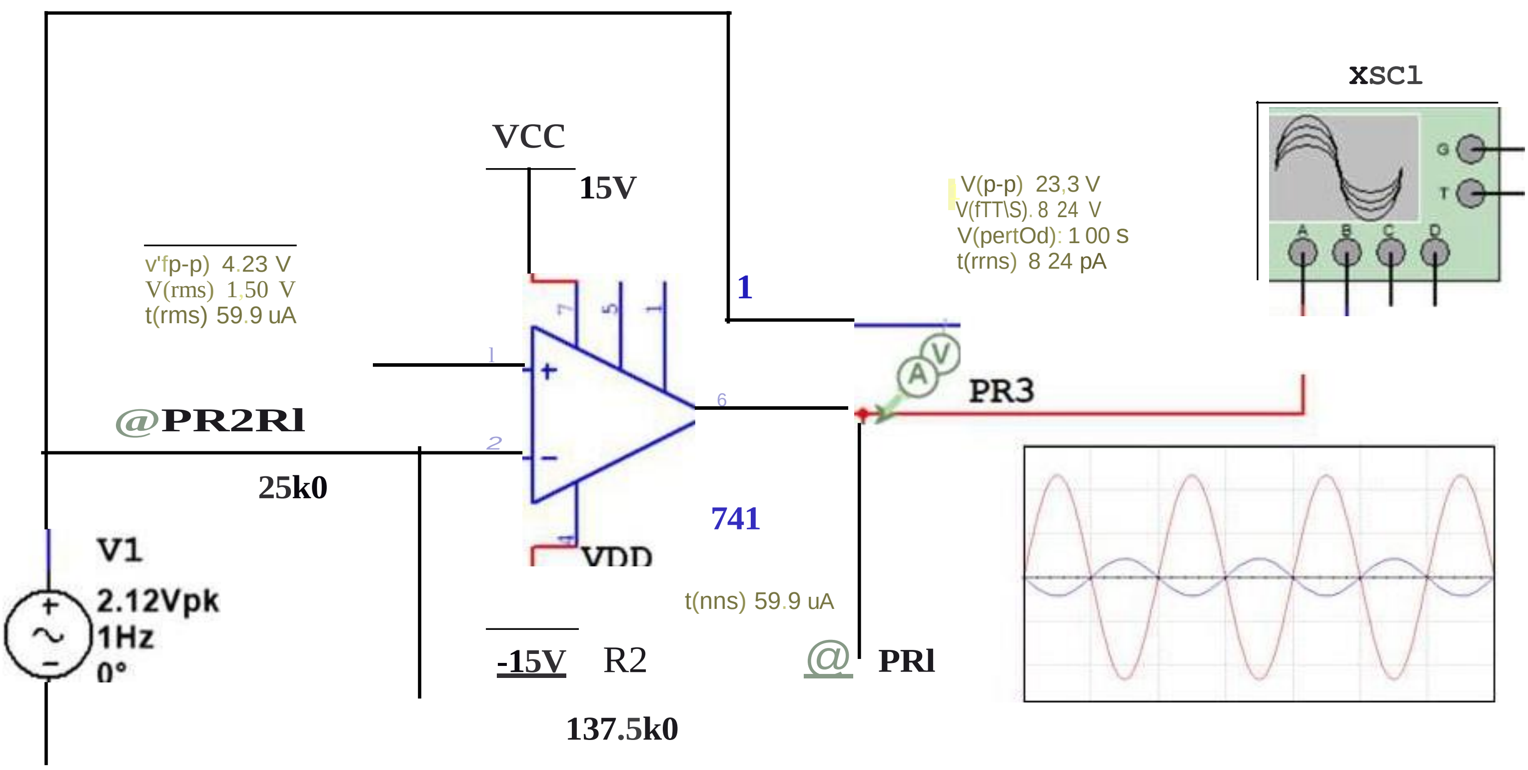


Fig. 1-10

Answer in MULTISIM



1.2 The Noninverting Op-Amp:

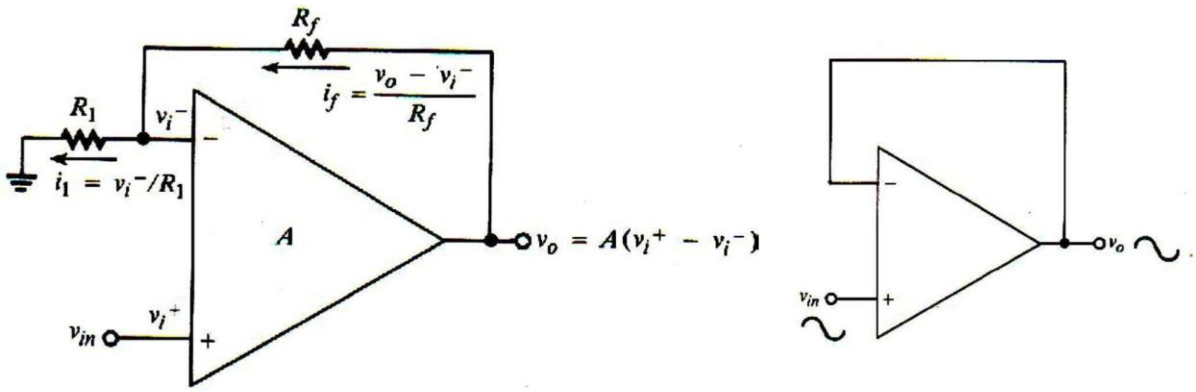
Fig. 1-11(a) shows another useful application of an operational amplifier, called the noninverting configuration. The input signal v_{in} is connected directly to the noninverting input and R_1 is connected from the inverting input to ground. Under the ideal assumption of infinite input impedance, no current flows into the inverting input, so $i_1 = i_f$.

$$\text{Thus, } \frac{v_i^-}{R_1} = \frac{v_o - v_i^-}{R_f} \quad \text{and} \quad v_o = A(v_i^+ - v_i^-) \Rightarrow v_i^- = v_i^+ - v_o/A \ ,$$

$$|A| = \infty \Rightarrow v_o/A = 0 \Rightarrow v_i^- = v_i^+ \quad \text{and} \quad \frac{v_i^+}{R_1} = \frac{v_o - v_i^+}{R_f}, \text{ where } v_i^+ = v_{in} \Rightarrow$$

$$\frac{v_o}{v_{in}} = 1 + \frac{R_f}{R_1} = \frac{R_1 + R_f}{R_1}$$

Eqn. [1-7] shows that the closed-loop gain of the noninverting amplifier, like that of the inverting amplifier, depends only on the values of external resistors. Fig.
shows a special case of noninverting amplifier, used in applications where power gain and impedance isolation are of primary concern. When $R_f = 0$ and $R_1 = \infty$, so the closed-loop gain is v /v = 1 + R_f/R_1 = 1. This configuration is called a *voltage follower* because v_o has the same magnitude and phase as v_{in}. It has large input impedance and small output impedance, and is used as a *buffer* amplifier between a high-impedance source and a low-impedance load.



(a) (b)

Exercise2

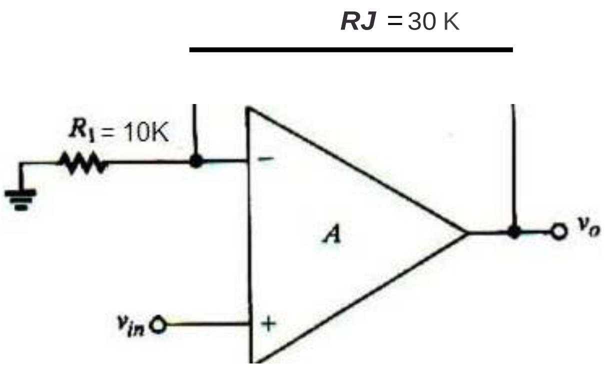
Assuming that the operational amplifier in Fig.below is ideal, find

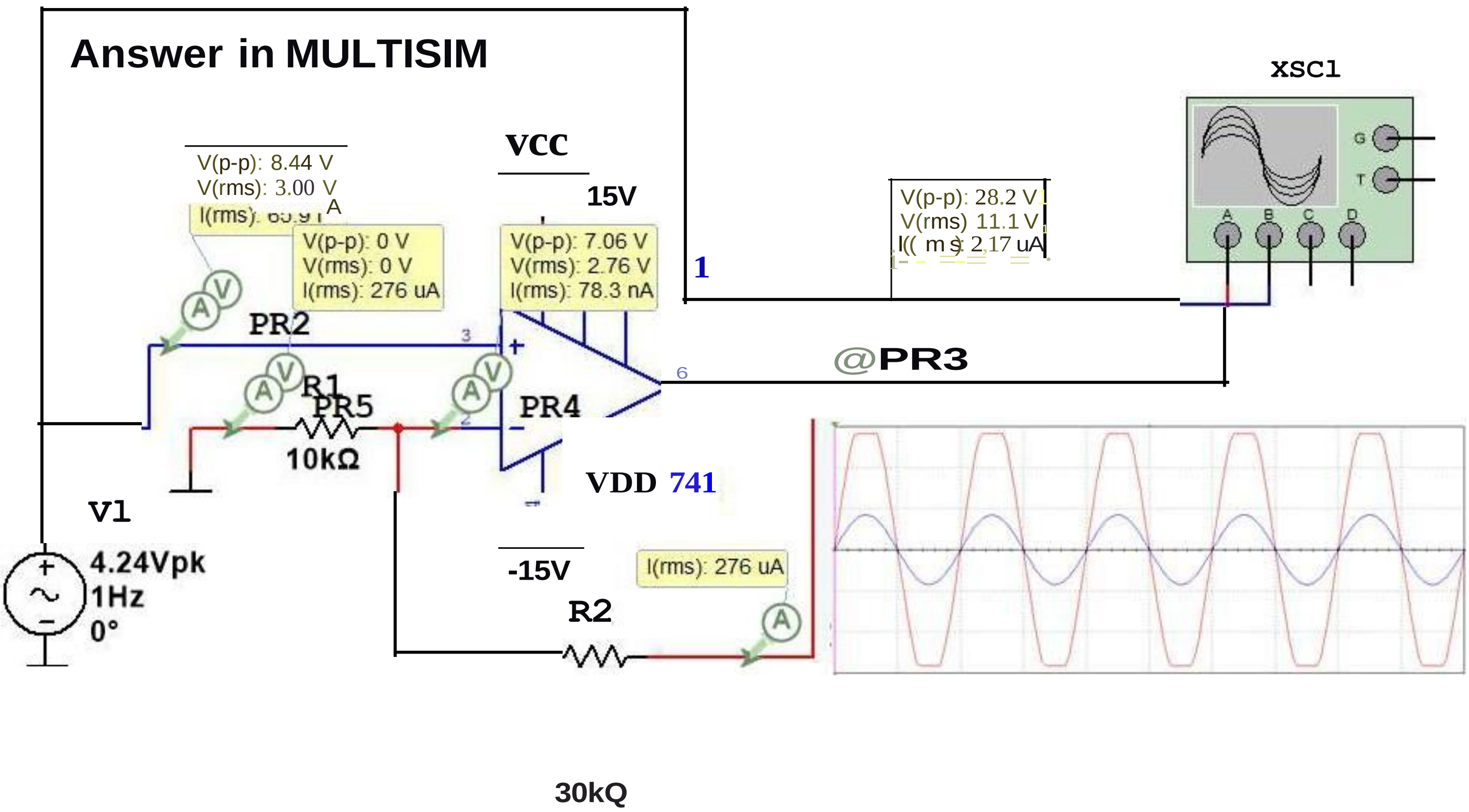
(a) therms value of v_0 when v_{in} is 3 V rms,

(b) the rms value of the current in the10 -kn resistor when vi_{11} is 3 V m1s, and

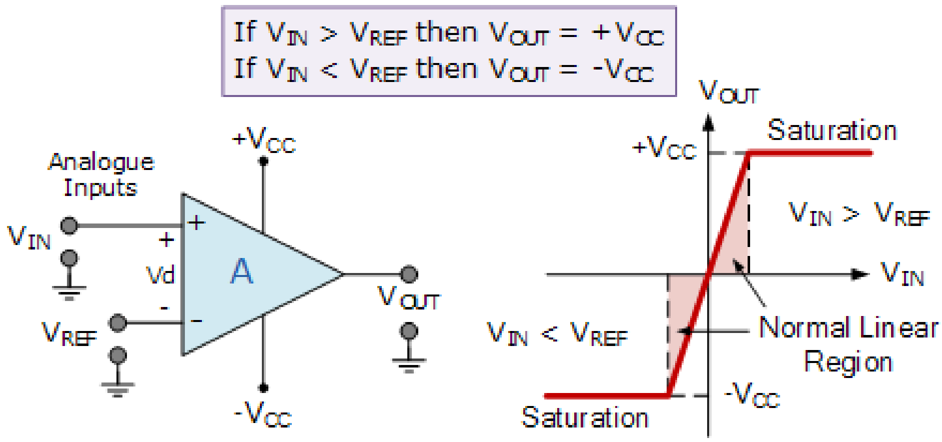
(c) the output voltage when v_{in}= 0.6 V de.

[Ans ers: (a) 12 V rms, (b)300µA rrns, (c) 2.4V de]

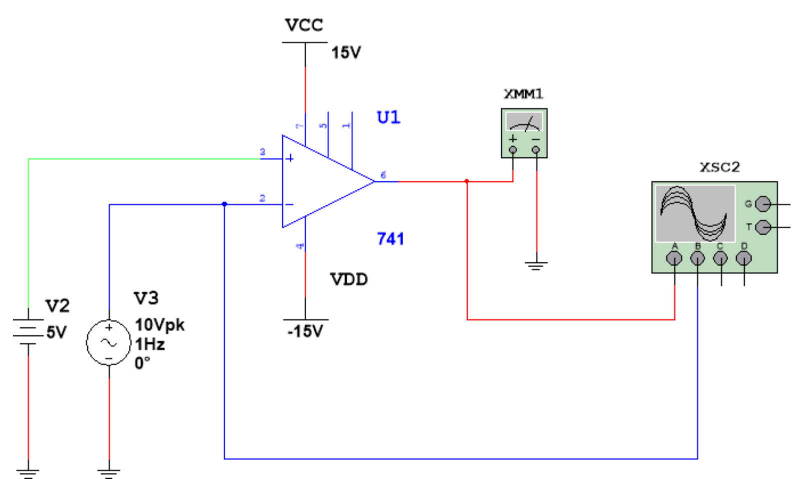


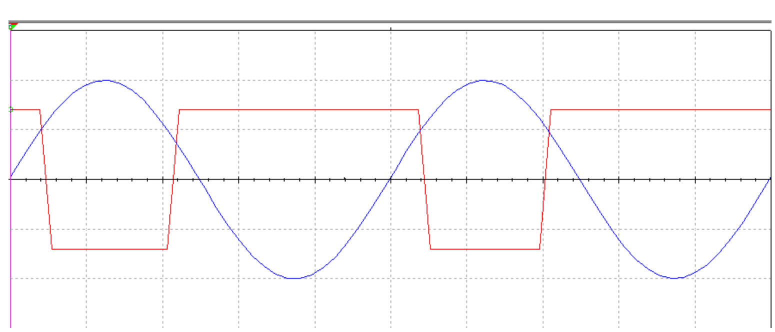


The Comparator

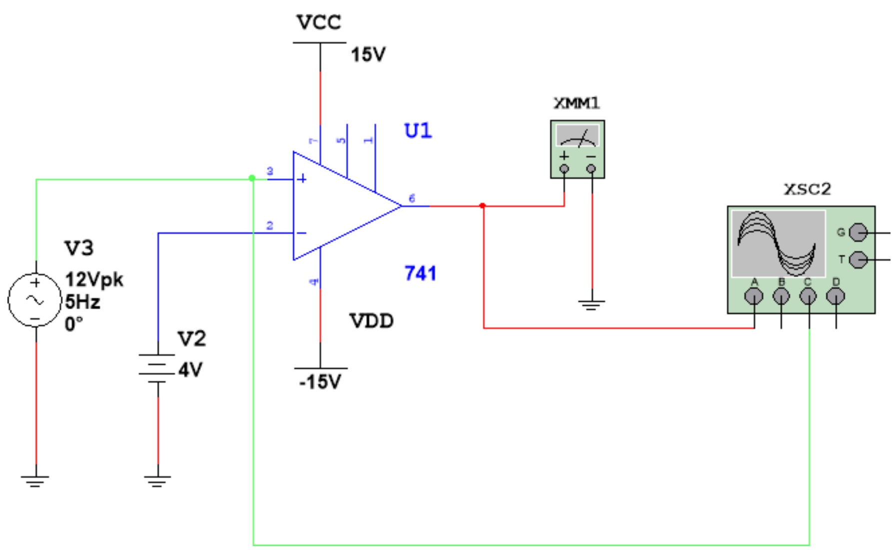


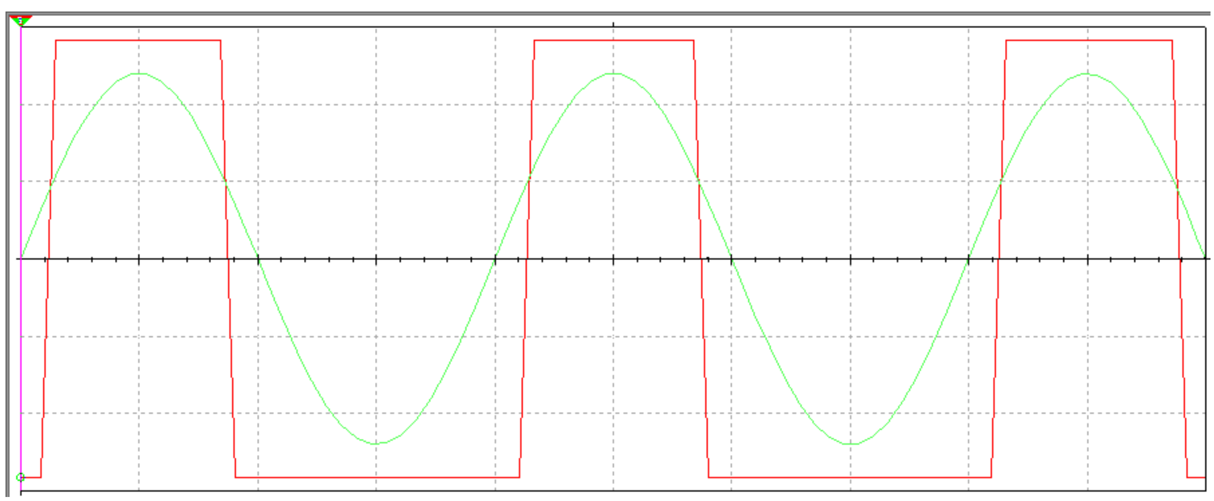
Ex3: For the comparator circuit below, if $V_{in\,(-)} = 10 \sin 6.28t$, $V_{ref\,(+)} = 5\ V_{DC}$, Vcc=±15 V, draw the output voltage V_o.





Ex4: For the comparator circuit below, if $V_{in\,(+)}$ = 12 sin 31.4t, $V_{ref\,(-)}$ = 4 V_{DC} , Vcc=±15 V, draw the output voltage V_o.





Ex5 (H.W): For the comparator circuit, if $V_{in\,(+)}$ = 13 sin 75.36t, $V_{ref\,(-)}$ = 7 V_{DC} , Vcc=±15 V, draw the output voltage V_o.

Ex6(H.W): For the comparator circuit, if $V_{in\,(-)}$ = 11 sin 75.36t, $V_{ref\,(+)}$ = 3 V_{DC} , Vcc=±12 V, draw the output voltage V_o.