VOLTAGE REGULATORS WITH OPAMP

I. OBJECTIVES

a) Analyzing voltage regulators with OpAmp, with fixed and adjustable output voltage.
b) Determining the output voltage and the output current.

II. COMPONENTS AND INSTRUMENTATION

Use the breadboard, an LM358P dual OpAmp, some resistors, and a potentiometer. The reference voltage is obtained from the dc regulated voltage supply. The input voltage is obtained from the signal generator. The output voltage is visualized on the oscilloscope, the output current is measured using the milliammeter.

The terminals of the LM358P OpAmp are shown in Fig. 1.

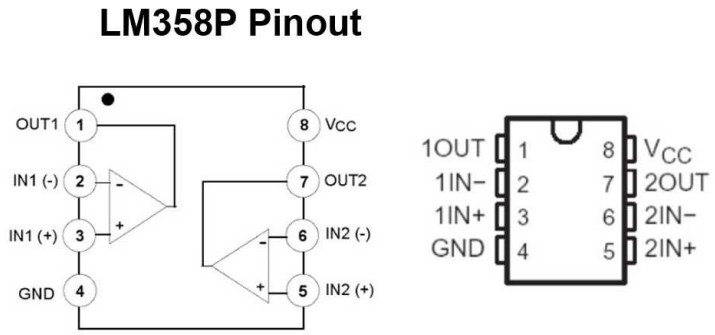


Fig. 1 LM358P pinout diagram

III. PREPARATION

1.P. Voltage regulator with Vo > V_{REF}

For the circuits in Fig. 2, assume OpAmp – rail to rail, V_{REF} = 1.5 V, $v_I(t)$= 9+1sinωt [V], R_1 = 10KΩ, R_2 = 24KΩ, P= 10KΩ. The milliammeter is used to measure the output current.

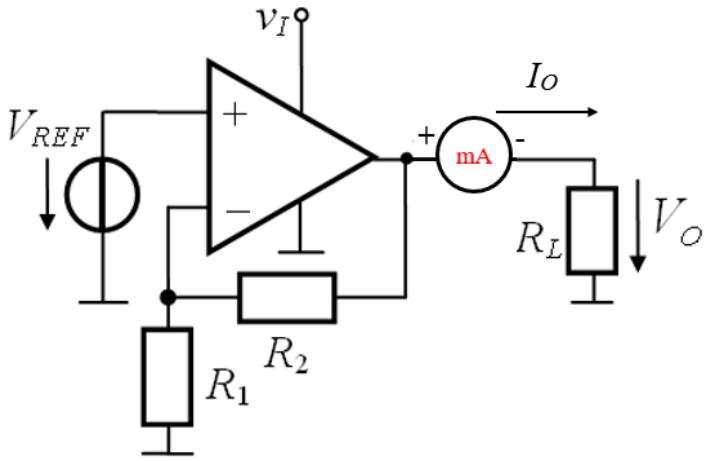
- What makes the circuit in Fig. 2 a) different from a common non-inverting amplifier?
- What type of voltage (AC/DC) is expected at the output?

For the circuit in Fig. 2 a):

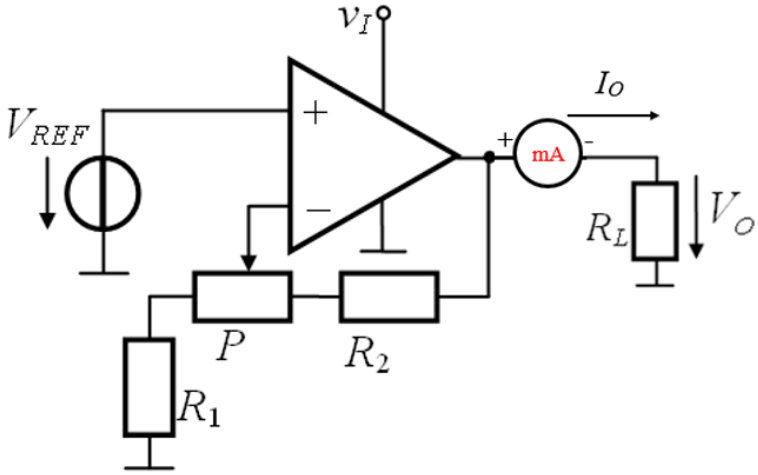
- What is the expression and value of the output voltage, V_O?
- Compute the value of the output current I_O for R_L = 0.47KΩ and for R_L = 0.23KΩ.
- Determine the minimum value of R_L for which the circuit works as a voltage regulator, assuming the maximum current at the output of the OpAmp is 20mA.
- Determine the maximum possible for V_O.

For the circuit in Fig. 2 b):

- What is the expression of the output voltage, V_O? What are the minimum and maximum values of this voltage?
- Compute the value of the output current I_O for R_L = 0.47KΩ and for R_L = 0.23KΩ.



a) Fixed output voltage



b) Adjustable output voltage

Fig. 2. Voltage regulators with Vo > V_{REF}

2.P. Voltage regulator with Vo < V_{REF}

For the circuit in Fig. 3, assume OpAmp – rail to rail, V_{REF} = 6 V, $v_I(t)$= 9+1sinωt [V], R_1 = 10KΩ, R_2 = 24KΩ, P= 10KΩ. The milliammeter is used to measure the output current.

- What is the expression and value of the output voltage, V_O?
- Compute the value of the output current I_O for R_L = 0.47KΩ and for R_L = 0.23KΩ.
- Determine the minimum value of R_L for which the circuit works as a voltage regulator, assuming the maximum current at the output of the OpAmp is 20mA.

Propose a circuit where Vo < V_{REF} and V_O is adjustable. Use Fig. 2 b) as a hint.

- What is the expression of the output voltage, V_O? What are the minimum and maximum values of this voltage?
- Compute the value of the output current I_O for R_L = 0.47KΩ and for R_L = 0.23KΩ.

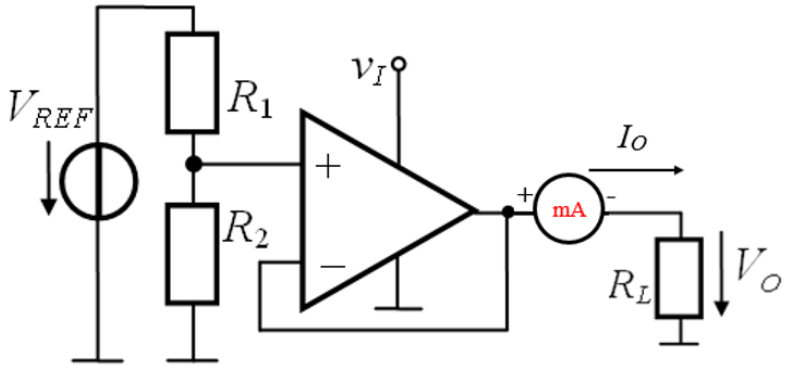


Fig. 3. Voltage regulator with Vo < V_{REF}, fixed output voltage

IV. EXPLORATION AND RESULTS

1. Voltage regulator with Vo > V_{REF}

Exploration

- Build the circuit in Fig. 2 a), using V_{REF} = 1.5 V, $v_I(t)$= 9+1sinωt [V], R_1 = 10KΩ, R_2 = 24KΩ, P= 10KΩ, R_L = 0.47KΩ.
- The milliammeter is set to the 60mA range, with the two measurement wires connected to "mA" and "COM" inputs.
- Visualize $v_I(t)$ and $v_O(t)$ on the oscilloscope, with both channels in DC mode.

- Read the DC value of the output voltage from the oscilloscope.
- Measure the output current.
- Repeat the measurements for R_L = 0.23KΩ (obtained by connecting two 0.47KΩ resistors in parallel). Does the circuit still work as a voltage regulator?
- Write the values in Table 1.

- Build the circuit in Fig. 2 b), using R_L = 0.47KΩ. Determine the minimum and maximum values for the output voltage.

Results

- Waveforms for $v_I(t)$ and $v_O(t)$, for both values of R_L.
- Table 1.

Table 1. Output voltage and output current, voltage regulator with Vo > V_{REF}

	Fixed output voltage		**Variable output voltage**			
	V_O	**I_O**	**V_{Omin}**	**I_O**	**V_{Omax}**	**I_O**
R_L = 0.47KΩ						
R_L = 0.23KΩ						

2. Voltage regulator with Vo < V_{REF}

Exploration

- Build the circuit in Fig. 3, using V_{REF} = 6 V, $v_I(t)$= 9+1sinωt [V], R_1 = 10KΩ, R_2 = 24KΩ, P= 10KΩ, R_L = 0.47KΩ.
- The milliammeter is set to the 60mA range, with the two measurement wires connected to "mA" and "COM" inputs.
- Visualize $v_I(t)$ and $v_O(t)$ on the oscilloscope, with both channels in DC mode.

- Read the DC value of the output voltage from the oscilloscope.
- Measure the output current.
- Repeat the measurements for R_L = 0.23KΩ (obtained by placing two 0.47KΩ resistors in parallel). Does the circuit still work as a voltage regulator?
- Write the values in Table 2.

- Build the circuit proposed at 2.P., using R_L = 0.47KΩ. Determine the minimum and maximum values for the output voltage.

Results

- Waveforms for $v_I(t)$ and $v_O(t)$, for both values of R_L.
- Table 2.

Table 2. Output voltage and output current, voltage regulator with Vo < V_{REF}

	Fixed output voltage		**Variable output voltage**			
	V_O	**I_O**	**V_{Omin}**	**I_O**	**V_{Omax}**	**I_O**
R_L = 0.47KΩ						
R_L = 0.23KΩ						

REFERENCES

1. Oltean, G., Electronic Devices, Editura U.T. Pres, Cluj-Napoca, ISBN 973-662-220-7, 2006
2. Sedra, A. S., Smith, K. C., Microelectronic Circuits, Fifth Edition, Oxford University Press, ISBN: 0-19-514252-7, 2004
3. http://www.bel.utcluj.ro/dce/didactic/fec