Open Loop Op- amp Configurations

In the case of amplifiers, the term open loop indicates that no connection, either direct or via another network, exists between the output and input terminals. When connected in open-loop configuration, the op-amp simply functions as a high-gain amplifier. There are three open-loop op-amp configurations:

1. Differential amplifier
2. Inverting amplifier
3. Non-inverting amplifier

1. The Differential Amplifier

Figure 1 shows the open-loop differential amplifier in which input signal v_{in1} and v_{in2} are applied to the positive and negative input terminals. Since the op-amp amplifies the difference between the two input signals, this configuration is called the differential amplifier.

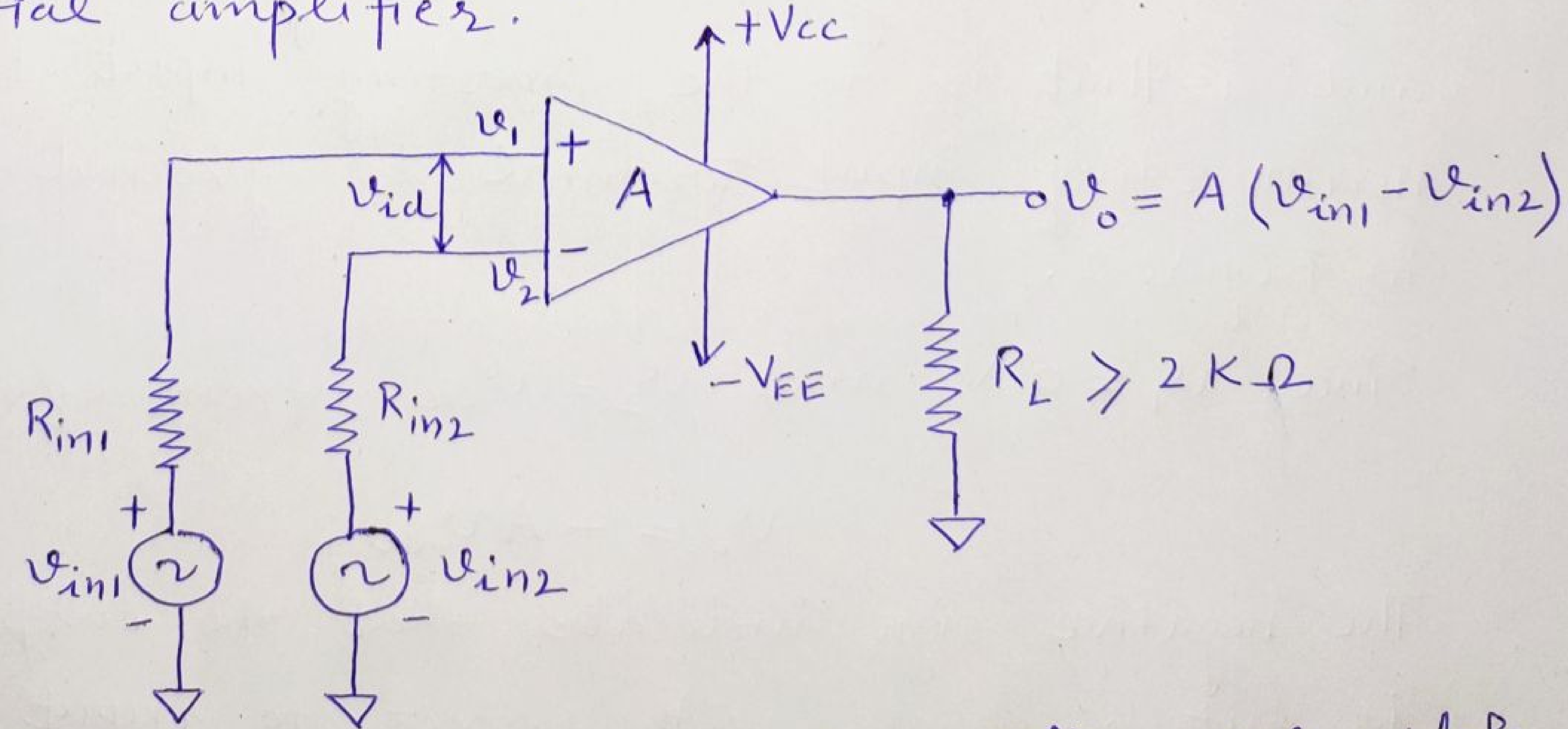

Figure 1. Open loop differential amplifier

v_{in1} and v_{in2} could be either ac or dc voltages. The source resistances R_{in1} and R_{in2} are normally negligible compared to the input resistance R_i. Therfore the voltage drop across these resistors can be assumed to be zero, which then implies that

$$v_1 = v_{in1}$$

and

$$v_2 = v_{in2}$$

Therefore, the output voltage is given by,

$$v_o = A(v_{in1} - v_{in2}) \quad \text{——} \quad (1)$$

Thus, the output voltage is equal to the voltage gain A times the difference between the two input voltages.

Also notice that the polarity of the output voltage is dependent on the polarity of the input difference voltage ($v_{in1} - v_{in2}$). In open-loop configuration, gain A is commonly referred to as open-loop gain.

2. The Inverting Amplifier

In the inverting amplifier only one input is applied and that is to the inverting input terminal. The noninverting input terminal is grounded as shown in Figure 2.

Since $v_1 = 0$ V, and $v_2 = v_{in}$, from equation (1),

$$v_o = -A\,v_{in}$$

The negative sign indicates that the output voltage is out of phase with respect to input by 180° or is of opposite polarity.

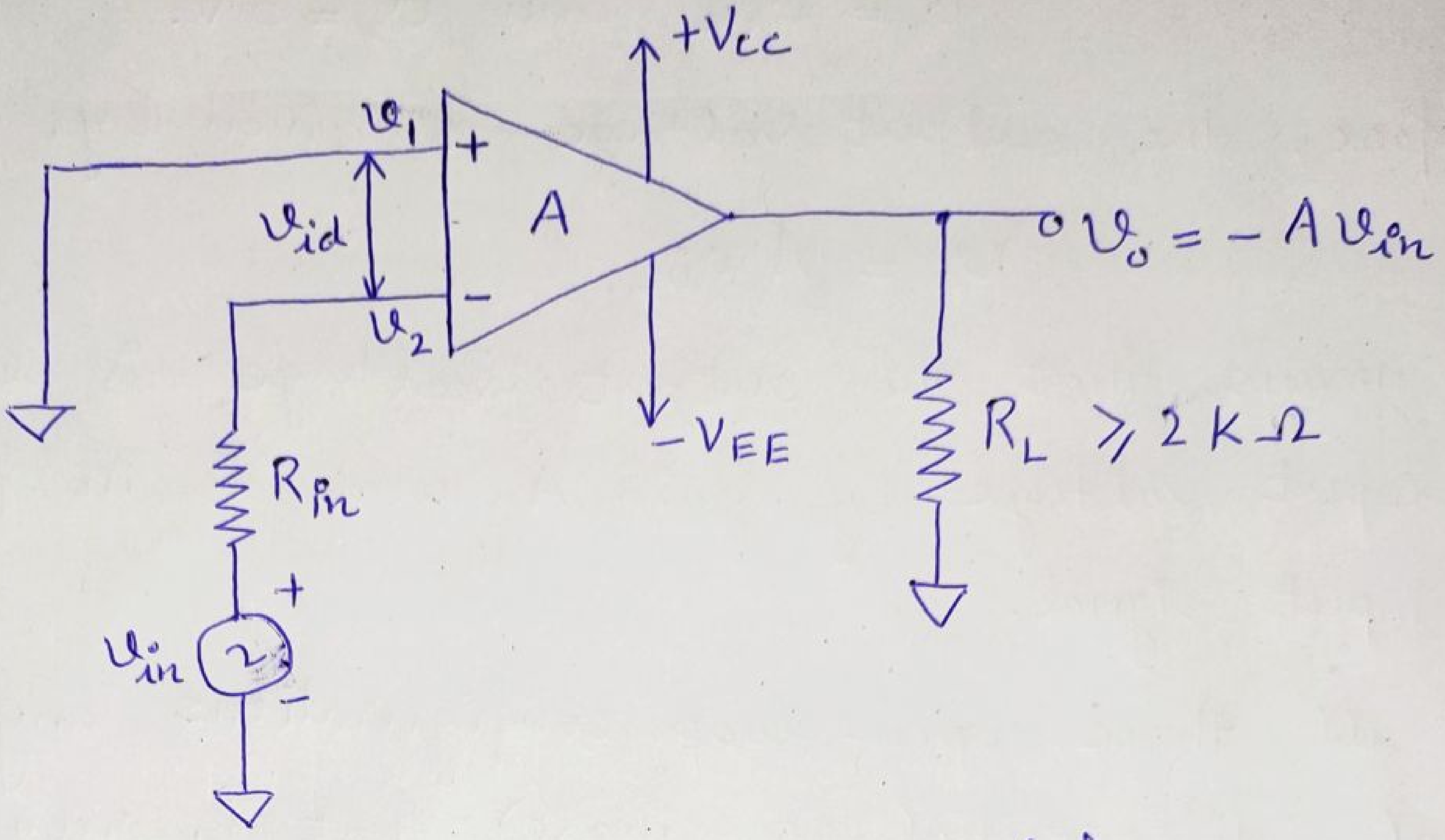

Figure 2. Inverting amplifier

Thus in the inverting amplifier, the input signal is amplified by gain A and is also inverted at the output.

3. The Noninverting Amplifier

Figure 3 shows the open-loop noninverting amplifier. In this configuration, the input is applied to the noninverting input terminal, and the inverting terminal is connected to ground.

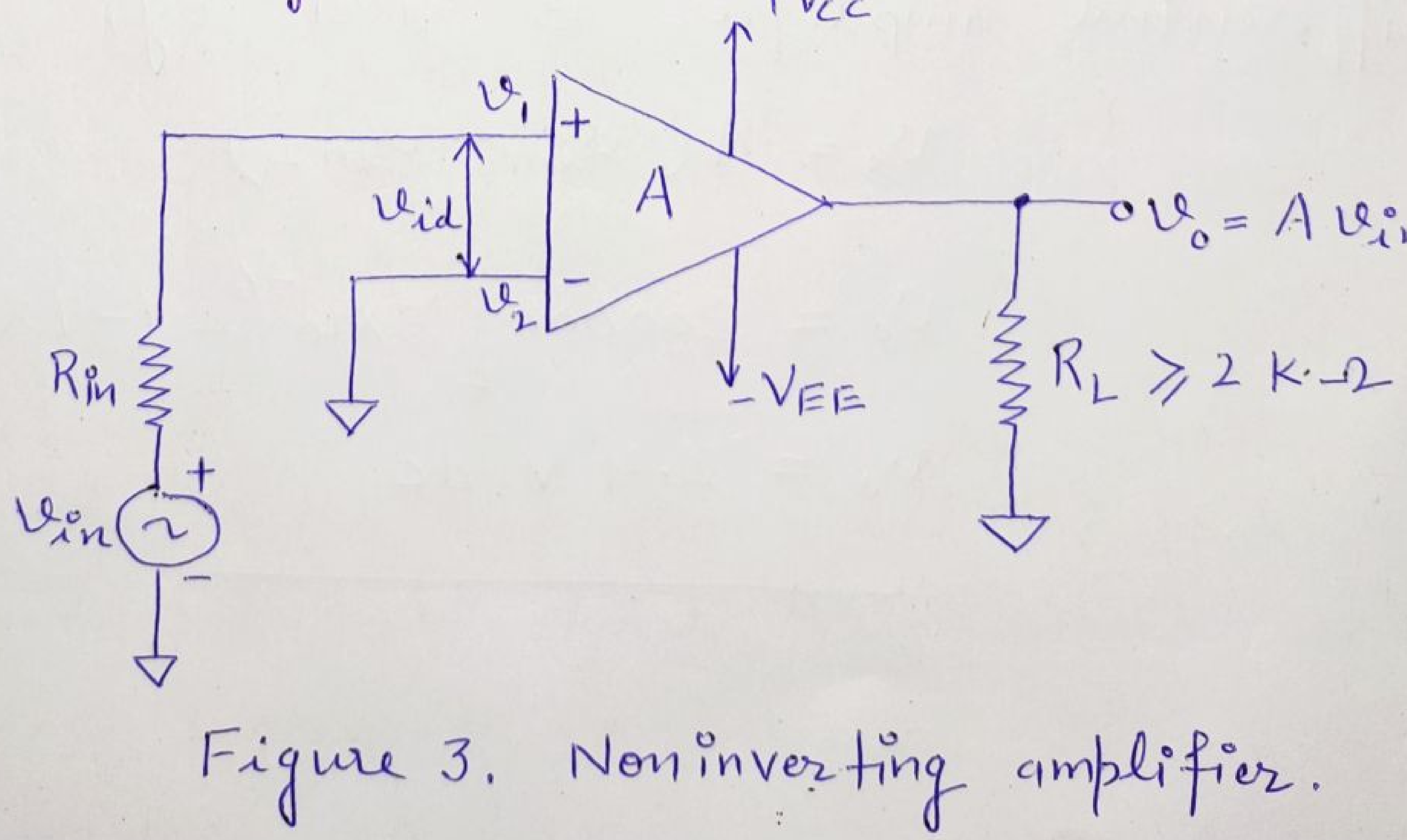

Figure 3. Noninverting amplifier.

In the circuit of Figure 3,

$$v_1 = v_{in} \text{ and } v_2 = 0\,V.$$

Therefore, the output voltage is given by,

$$v_o = A\, v_{in}$$

This means that the output voltage is larger than the input voltage by gain A and is in phase with the input signal.

In all three open-loop configurations, any input signal (differential or single) that is only slightly greater than zero drives the output to saturation level. This results from the very high gain (A) of the op-amp. For this reason, open-loop op-amp configurations are not used in linear applications.

Q1. Determine the output voltage in the following case for the open-loop differential amplifier:

$v_{in1} = 5\ \mu V$ dc, $v_{in2} = -7\ \mu V$ dc, $A = 200000$

Solution: The equation for output voltage of differential amplifier is given by,

$$v_o = A(v_{in1} - v_{in2})$$

$$v_o = 200000\left[5\times10^{-6} - (-7\times10^{-6})\right]$$

$$v_o = 2.4\ V \text{ dc}$$

Op-amp with Negative Feedback

Recall that clipping occurs in open-loop configuration when the output attempts to exceed the saturation levels of the op-amp. i.e only the smaller signals having very low frequency may be amplified accurately without distortion. The open loop voltage gain varies with change in temperature and power supply, which makes the open-loop op-amp unsuitable for many linear applications.

In addition, the bandwidth of most open-loop op-amp is negligibly small – almost zero. e.g the open-loop bandwidth of the 741C is approximately 5 Hz.

For the reasons stated, the open-loop op-amp is generally not used in linear applications.

We can control the gain of the op-amp by using feedback. If the signal fed back is of opposite polarity or out of phase by 180° with respect to the input signal, the feedback is called negative or degenerative feedback because when used it reduces the output voltag amplitude and in turn reduces the voltage gain.

On the other hand, if the signal fed back is in phase with the input signal, the feedback is called positive or regenerative feedback.

When used in amplifiers, negative feedback stabilizes the gain, increases the bandwidth, and changes the input and output resistance. The price paid for these improvements is reduced voltage gain. Negative feedback also reduces harmonic or nonlinear distortion, effect of input offset voltage at the output, effect of variations in temperature and power supply voltage on the output of the op-amp.

Block Diagram Representation of Feedback Configurations

An op-amp that uses feedback is called a feedback amplifier. A feedback amplifier is sometimes referred to as a closed-loop amplifier because the feedback forms a closed loop between the input and the output. A feedback amplifier essentially consists of two parts: an op-amp and a feedback circuit.

A closed-loop amplifier can be represented by using two blocks, one for an op-amp and another for a feedback circuit. There are four ways to connect these two blocks. These connections are classified according to whether the voltage or current is fed back to the input in series or in parallel, as follows:

1. Voltage - series feedback
2. Voltage - shunt feedback
3. Current - series feedback
4. Current - shunt feedback

The four types of configurations are illustrated in Figure 4. In Figure 4(a) and 4(b), the voltage across load resistor R_L is the input voltage to the feedback circuit. On the other hand, in the current series and current-shunt feedback circuits of Figure 4(c) and 4(d), the load current i_L flows into the feedback circuit.

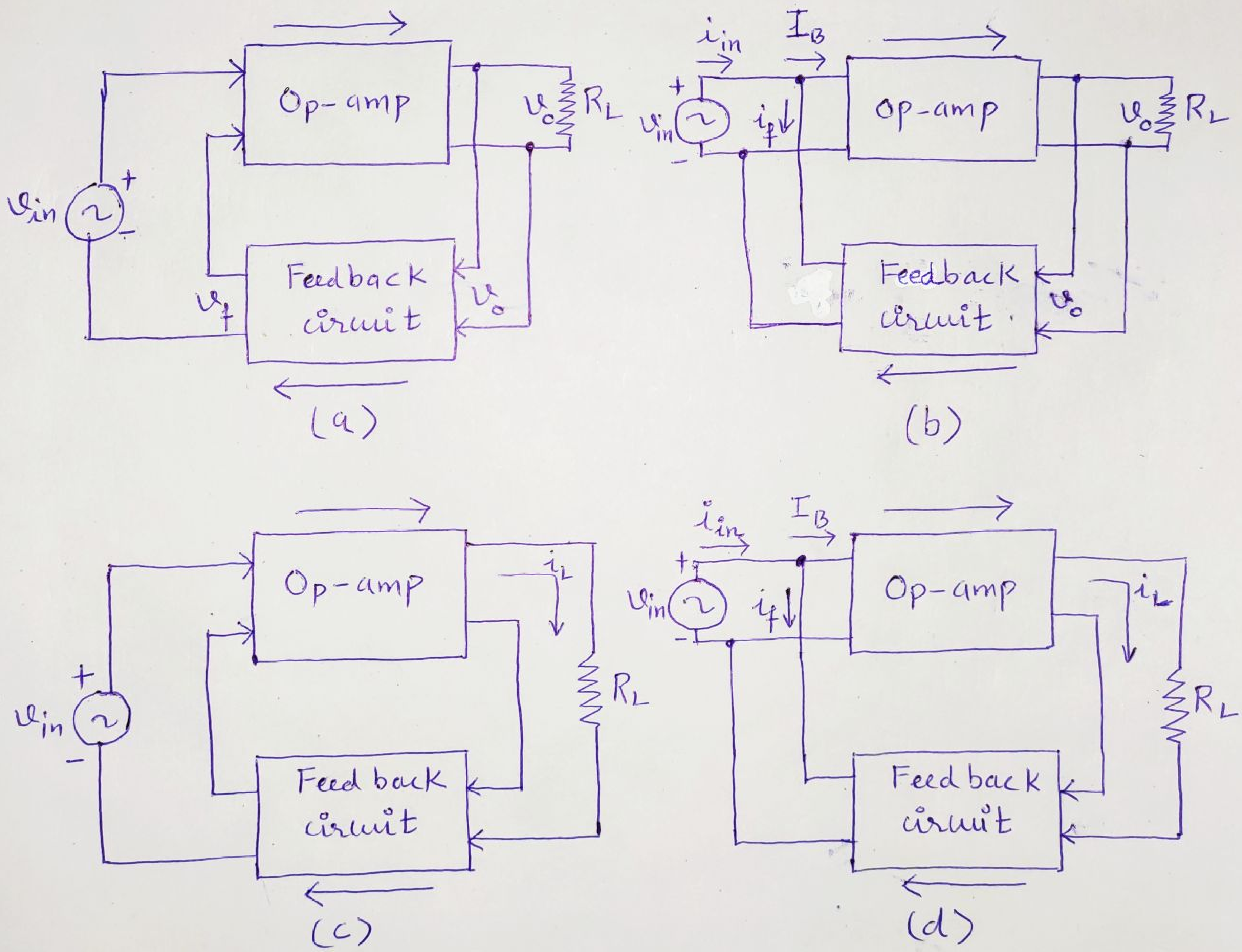

Figure 4. (a) Voltage-series (b) Voltage-shunt (c) Current-series (d) Current-shunt feedback configurations.

The output of the feedback circuit (either voltage or current) is proportional to the load current i_L.

Note that in all four of these configurations, the signal direction through the op-amp is from the input to output. On the other hand, the signal direction through the feedback circuit is exactly opposite: from output to input.