Differential Configuration

Using a basic differential op-amp configuration, a subtractor and a summing amplifier may be constructed as described below:

A Subtractor

A basic differential amplifier can be used as a subtractor as shown in Figure 1. In this Figure, input signals can be scaled to the desired values by selecting appropriate values for the external resistors; when this is done, the circuit is referred to as scaling amplifier. However, in Figure 1, all external resistors are equal in value, so the gain of the amplifier is equal to 1.

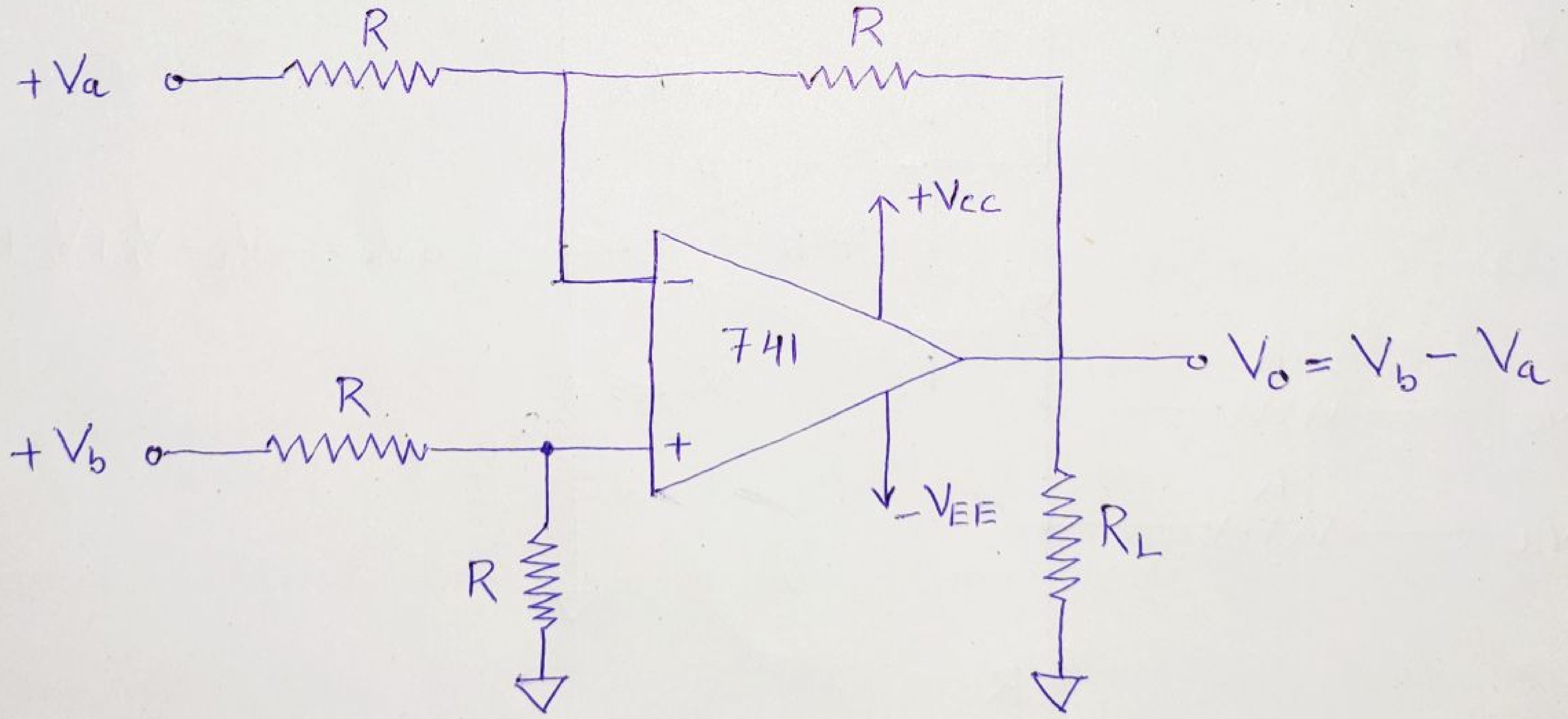

Figure 1. Basic differential amplifier used as a subtractor.

From this figure, the output voltage of the differential amplifier with a gain of 1 is

$$V_o = -\frac{R}{R}(V_a - V_b)$$

That is,

$$V_o = V_b - V_a \quad \text{———} \quad (1)$$

Thus the output voltage V_o is equal to the voltage V_b applied to the noninverting terminal minus the voltage V_a applied to the inverting terminal; hence the circuit is called a subtractor.

Summing Amplifier

A four-input summing amplifier may be constructed using the basic differential amplifier of Figure1, if two additional input sources are connected, one each to the inverting and noninverting input terminals through resistor R (see Figure 2).

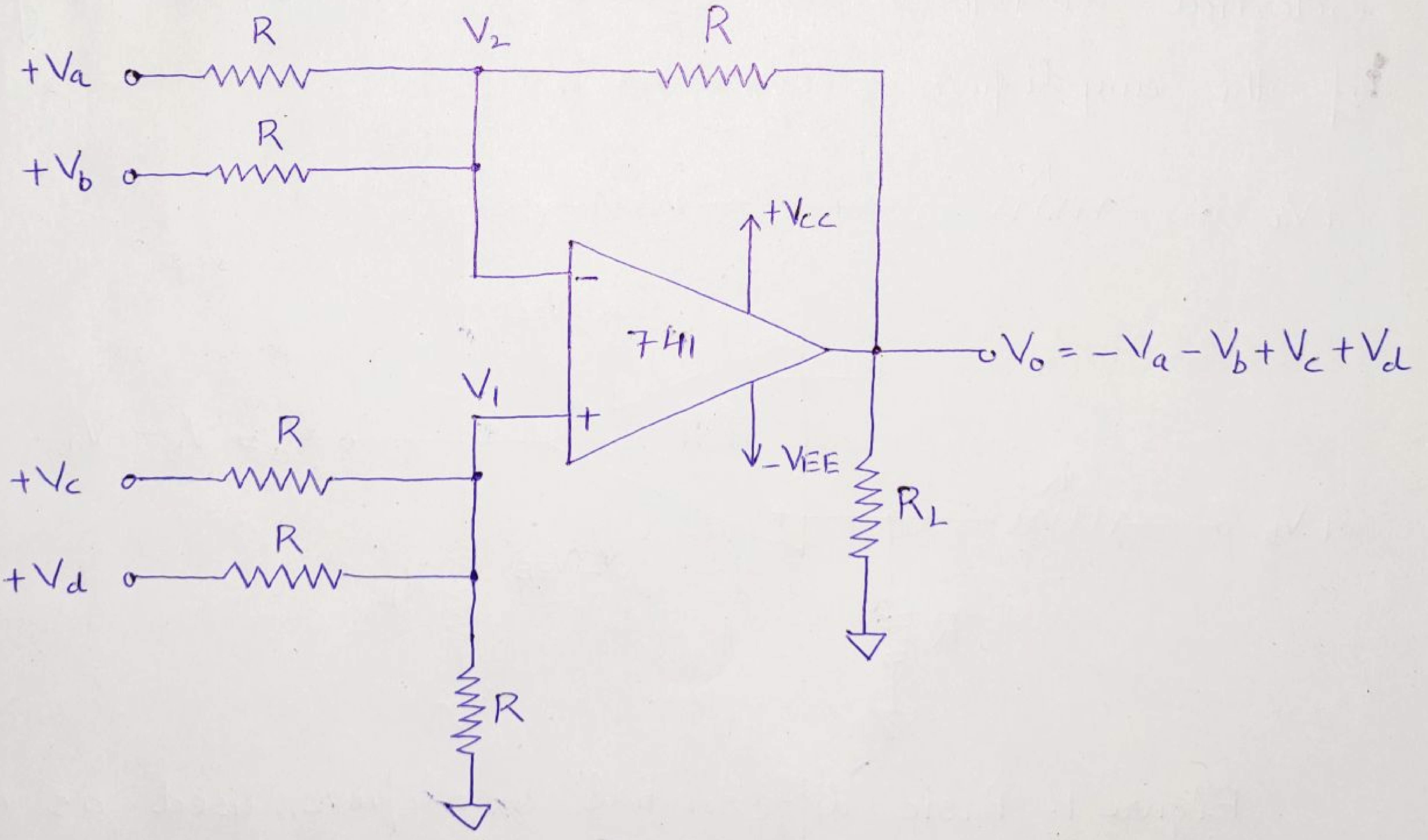

Figure 2. Summing amplifier using differential configuration.

The output voltage equation for this circuit can be obtained by using the superposition theorem. For instance,

to find the output voltage due to V_a alone, reduce (3)
all other input voltages V_b, V_c and V_d to zero as shown in Figure 3. In fact, this circuit is an inverting amplifier in which the inverting input is at virtual ground ($V_2 = 0V$). Therefore, the output voltage is

$$V_{oa} = -\frac{R}{R} V_a = -V_a$$

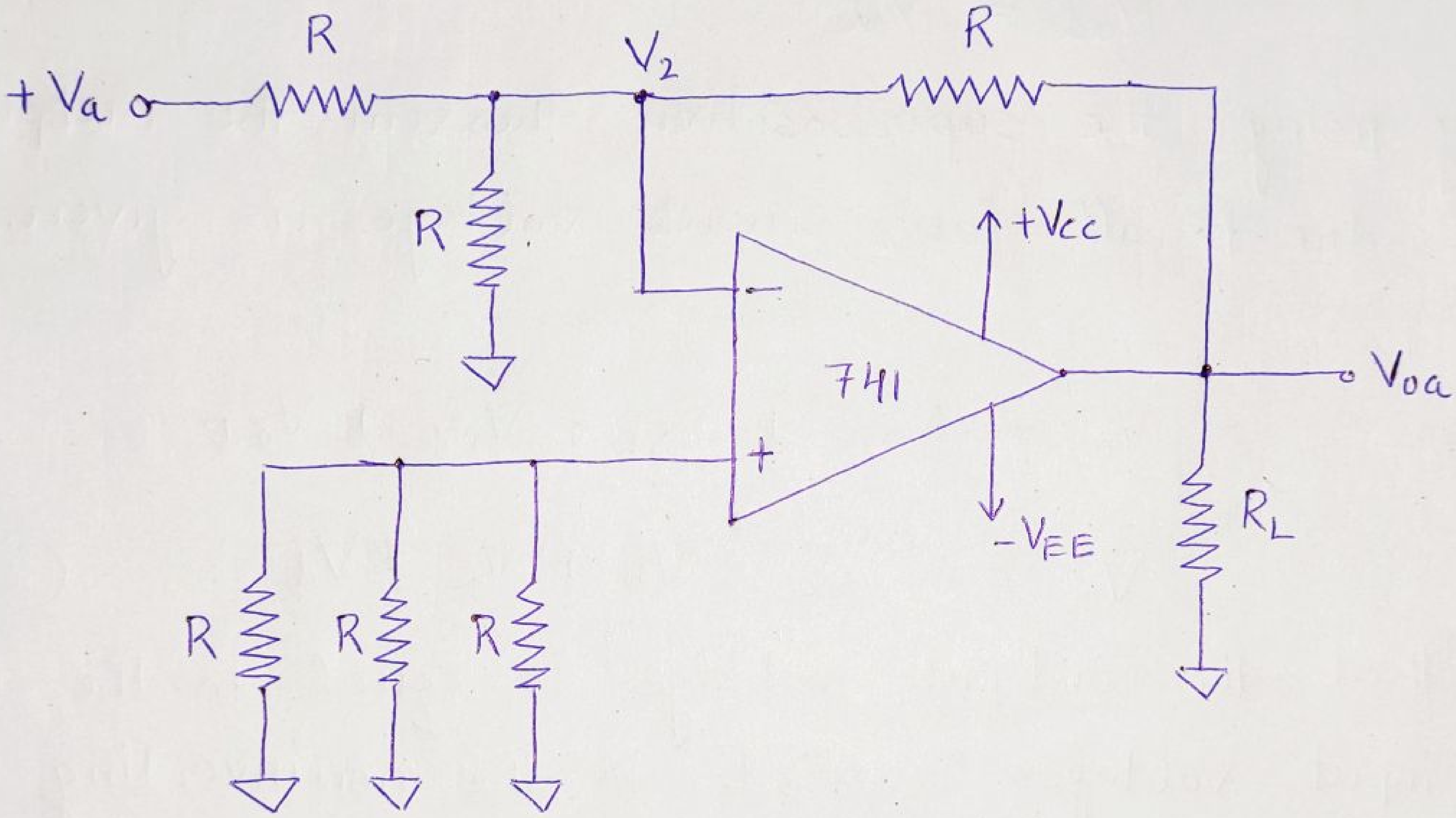

Figure 3. Deriving the output voltage equation for the summing amplifier of Figure 2.

This result can also be obtained by Thevenizing the input circuit looking back from node V_2.

Similarly, the output voltage due to V_b alone is

$$V_{ob} = -V_b$$

Now, if input voltages V_a, V_b and V_d are set to zero, the circuit in Figure 2 becomes a noninverting amplifier in which the voltage V_1 at the noninverting input is

$$V_1 = \frac{R/2}{R + R/2} V_c = \frac{V_c}{3}$$

This means that the output voltage due to V_c alone is

$$V_{oc} = \left(1 + \frac{R}{R/2}\right) V_1 = (3)\left(\frac{V_c}{3}\right) = V_c$$

Similarly, the output voltage due to input voltage V_d alone is

$$V_{od} = V_d$$

Thus by using the superposition theorem, the output voltage due to all four input voltages is given by

$$V_o = V_{oa} + V_{ob} + V_{oc} + V_{od}$$

$$V_o = -V_a - V_b + V_c + V_d \quad \text{—— (2)}$$

Notice that the output voltage is equal to the sum of the input voltages applied to the noninverting terminal plus the negative sum of the input voltages applied to the inverting terminal. Even though in Figure 2, the gain of the summing amplifier is 1, any scale factor can be used for the inputs by selecting proper external resistors.

Q1. In the circuit of Figure 2, $R = 1\,K\Omega$, $V_a = +2V$, $V_b = +3\,V$, $V_c = +4\,V$, $V_d = +5\,V$, and supply voltages $= \pm 15V$. Determine the output voltage V_o.

Solution: From equation (2),

$$V_o = -2 - 3 + 4 + 5 = +4\,V.$$

Instrumentation Amplifier

In many industrial and consumer applications, the measurement and control of physical conditions are very important. For example, measurements of temperature and humidity inside a diary or meat plant permit the operator to make necessary adjustments to maintain product quality. Similarly, precise temperature control of a plastic furnace is needed to produce a particular type of plastic.

An instrumentation system is used to measure the output signal produced by a transducer and often to control the physical signal producing it. Figure 1 shows a simplified form of such a system.

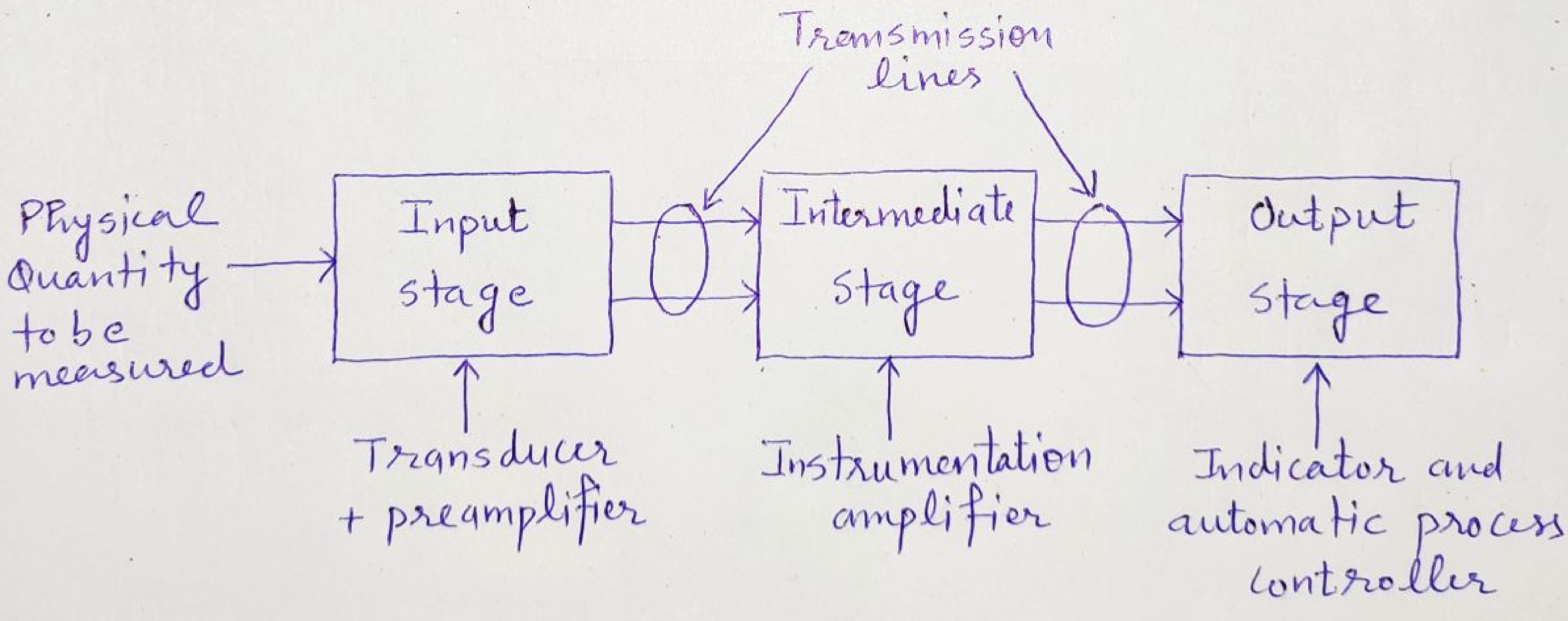

Figure 1. Block diagram of an instrumentation system.

The input stage is composed of a preamplifier and some sort of transducer, depending on the physical quantity to be measured. The output stage may use devices such as meters, oscilloscopes, charts or magnetic recorders.

The transmission lines permit signal transfer from unit to unit.

The instrumentation amplifier is intended for precise, low-level signal amplification where low noise, low thermal & time drifts, high input resistance, and accurate closed-loop gain are required. Besides, low power consumption, high common-mode rejection ratio, and high slew rate are desirable for superior performance.

However, where the requirements are not too strict, the general-purpose op-amp can be employed in the differential mode. We call such amplifiers differential instrumentation amplifiers.

Voltage-to-Current Converter with Floating Load

Figure 1 shows a voltage-to-current converter in which load resistor R_L is floating (not connected to ground). The input voltage is applied to the non-inverting input terminal, and the feedback voltage across R_1 drives the inverting input terminal. This circuit is also called a current-series negative feedback amplifier because the feedback voltage across R_1 (applied to the inverting terminal) depends on the output current i_o and is in series with the input difference voltage v_{id}.

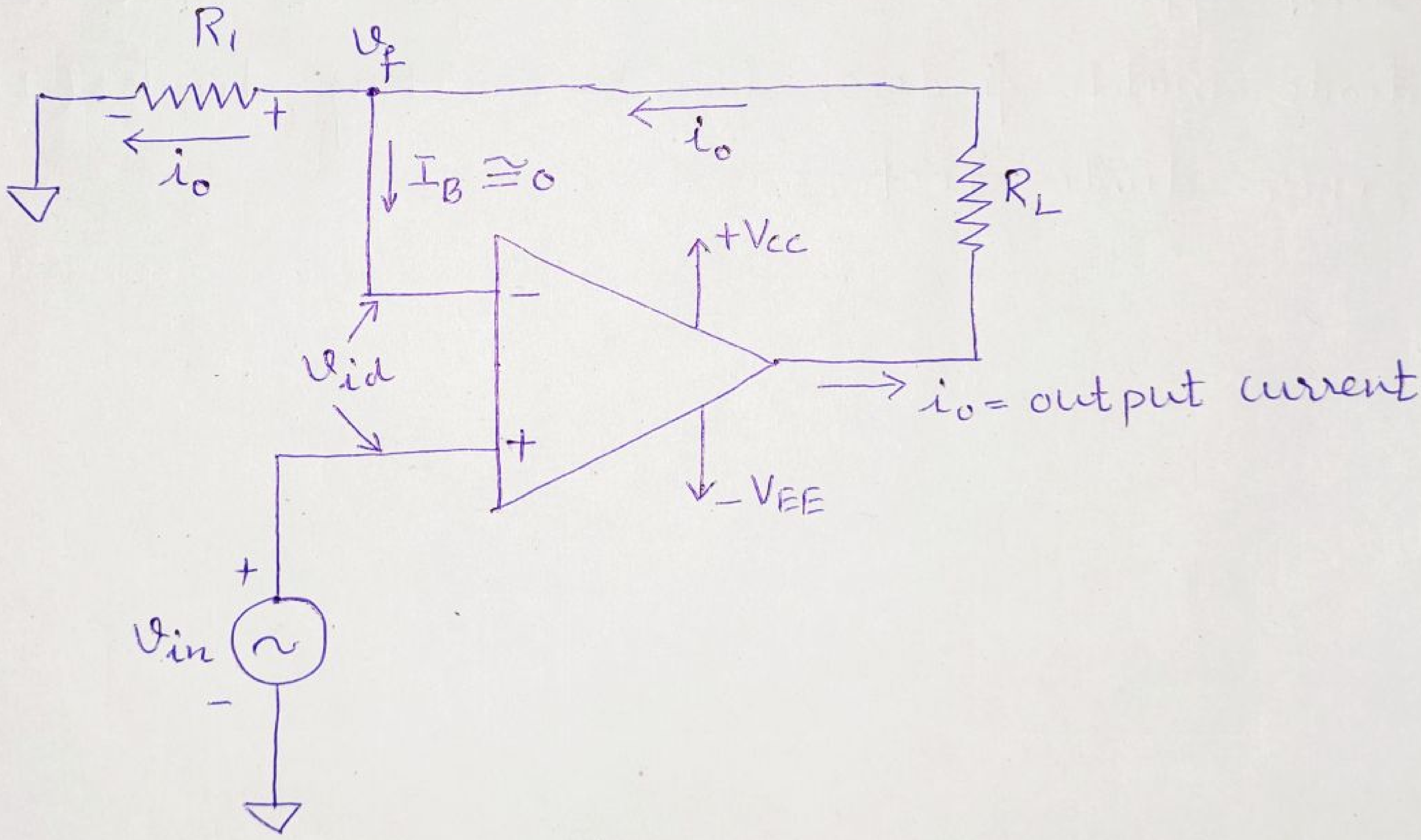

Figure 1. Voltage to current converter with floating load.

Writing Kirchhoff's voltage equation for the input loop,

$$v_{in} = v_{id} + v_f$$

But $v_{id} \cong 0V$, since A is very large; therefore

$$v_{in} = v_f$$

$$v_{in} = R_1 i_o$$

or

$$i_o = \frac{v_{in}}{R_1}$$

This means that in the circuit of Figure 1, an input voltage v_{in} is converted into an output current of $\frac{v_{in}}{R_1}$.

In other words, input voltage v_{in} appears across R_1. If R_1 is a precision resistor, the output current i_o will be precisely fixed.

The voltage-to-current converter can be used in such applications as low voltage dc and ac voltmeters, diode match finders, light-emitting diodes (LEDs) and Zener diode testers.