# Electronic Circuits

## Operational Amplifier

### Lecture 4

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# Op-Amp Applications

## Linear Applications

1- The Inverting Amplifier

2-The Noninverting Amplifier

3- Summing Amplifier

4- Subtractor

5- Voltage Follower

6- Controlled Sources

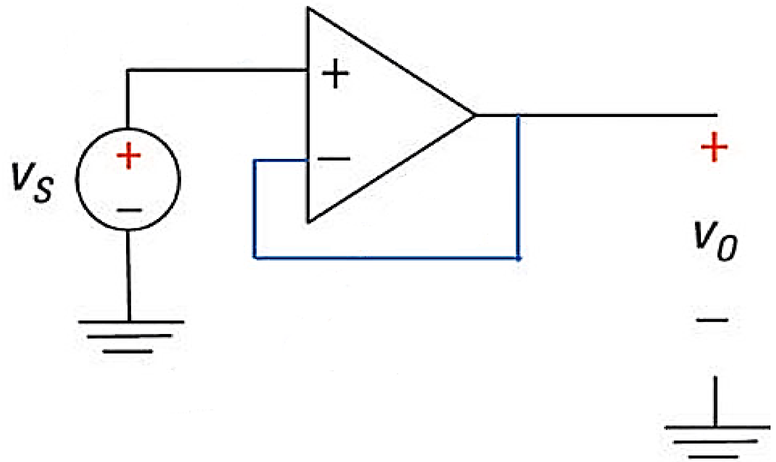
7- Integrator

8- Differentiator

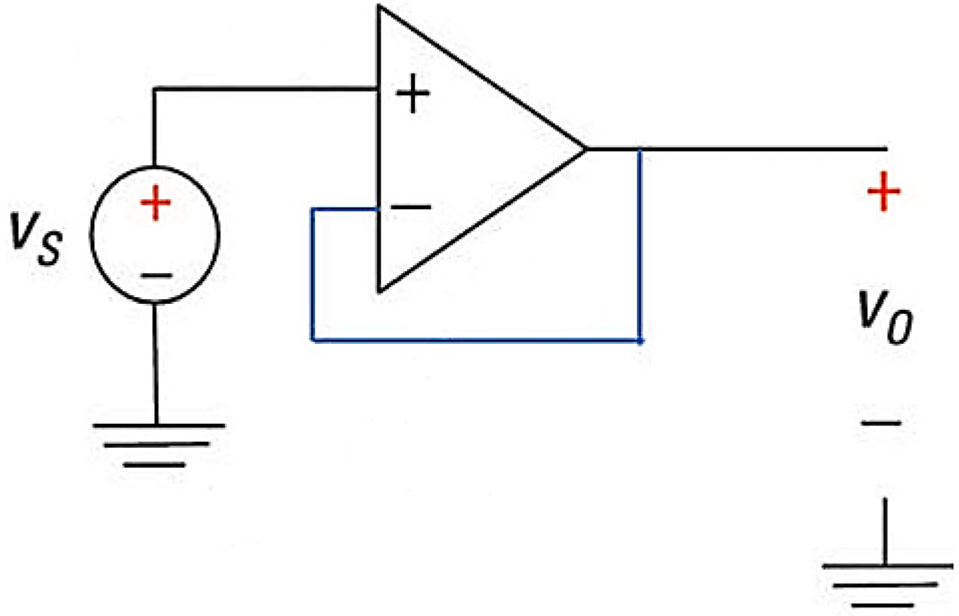
# 5- Voltage Follower (Buffer)

- The voltage follower (or buffer) is an op-amp circuit that has its inverting input connected directly to the output without a feedback resistor. Since the input always equals the output, the gain of a voltage follower equals one.

- The benefit of using a voltage follower is the high input impedance and low output impedance of the op-amp that allows almost all of the voltage from a previous source to be dropped across it. The op-amp can, in turn, feed the rest of the circuit with the higher desired voltage. See the section on input/output impedance for clarification.



# 5- Voltage Follower (Buffer)




- Again, V+ = V-, and in this case V+ also equals the voltage source (Vs). Furthermore, the output (Vout) is equal to V-.
- V- = Vout, and V+ = Vs, therefore, Vs = Vout

$$A\ (\text{Gain}) = \frac{V_{out}}{V_s} = 1$$

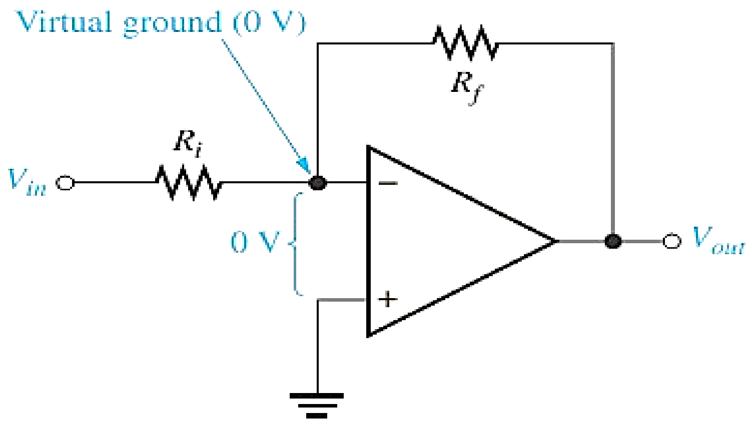
# 6- Controlled Voltage and Current Sources

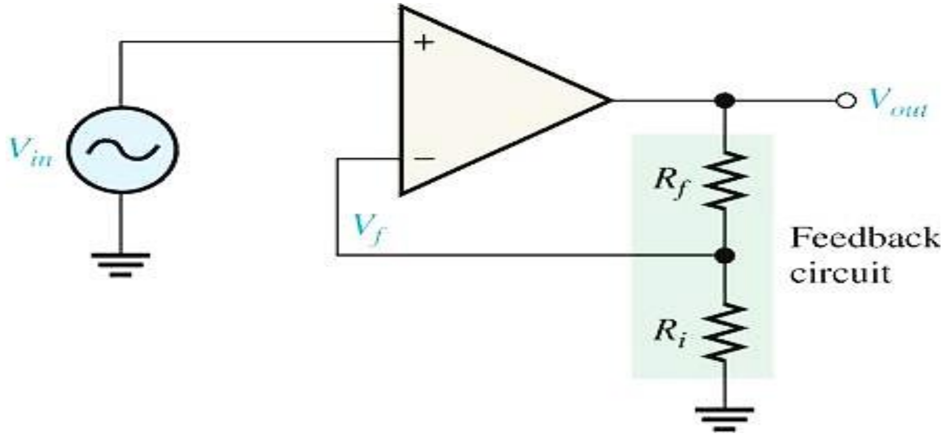
A controlled source is one whose output voltage or current is determined by magnitude of another, independent voltage or current.

- Voltage-Controlled Voltage Source (VCVS)
- Voltage-Controlled Current Source (VCCS)
- Current-Controlled Voltage Source (CCVS)
- Current-Controlled Current Source (CCCS)

# 6.1- Voltage-Controlled Voltage Source (Voltage Amplifier)

- An ideal, voltage-controlled voltage source is one whose output voltage Vo equals a fixed constant (k) times the value of another.
- controlling voltage: Vo = kVi; and is independent of the current drawn from it, the constant k is dimensionless.
- Both the inverting and noninverting configurations of an ideal operational amplifier meet the two criteria. In each case, the output voltage equals a fixed constant (the closed-loop gain, determined by external resistors) times an input voltage. Also, since the output resistance is (ideally) 0, there is no voltage division at the output and the voltage is independent of load.



# 6.2- Voltage-Controlled Current Source ( Voltage to Current Converter )

- An ideal, voltage-controlled current source is one that supplies a current whose magnitude equals a fixed constant (k) times the value of an independent controlling voltage: $I_o = kV_i$; and is independent of the load to which the current is supplied.

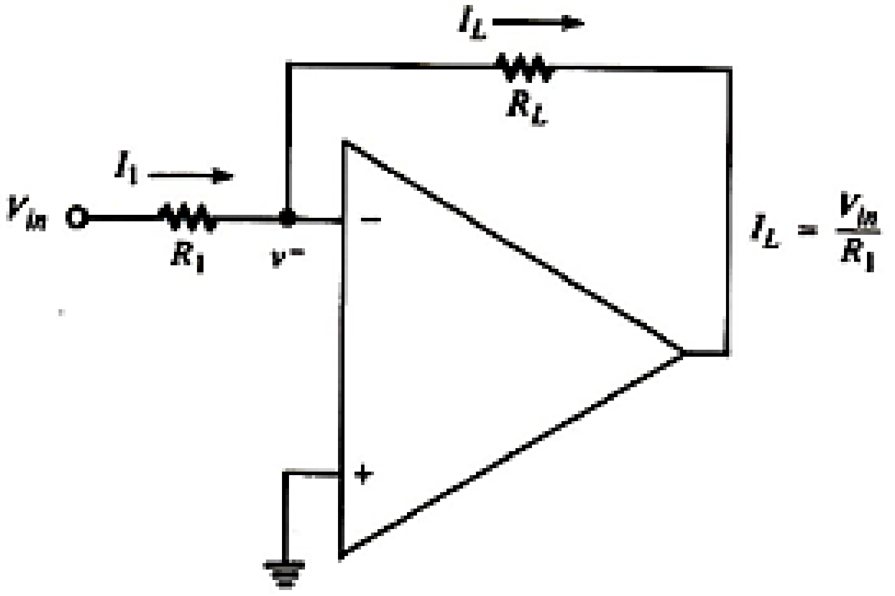
- The constant k has the dimensions of conductance. Since it relates output current to input voltage, it is called the transconductance, gm, of the source.

- This is done for inverting and noninverting amplifiers.

# 6.2- Voltage-Controlled Current Source ( Voltage to Current Converter )

- Inverting amplifier:

$$I_L = V_{in}/R_1 = g_m V_{in}$$

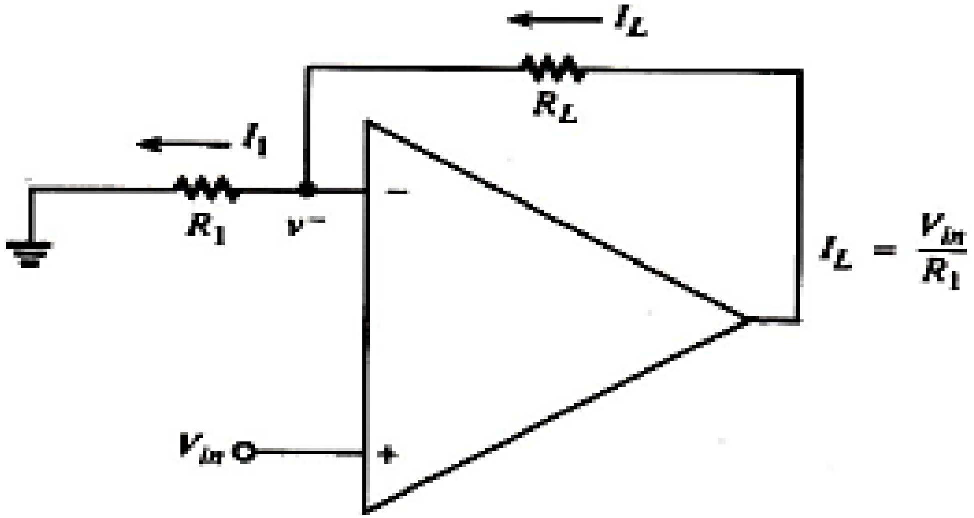



- v− is virtual ground, so I1 = Vin/R1. Since no current flows into the inverting terminal of the ideal amplifier, IL = I1, or The transconductance gm = 1/R1.
- Since RL does not appear in the equation, so the load current is independent of load resistance. This version of a controlled current source is said to have a **floating load**, because neither side of RL can be grounded.

# 6.2 Voltage-Controlled Current Source ( Voltage to Current Converter )

- Noninverting amplifier:
- v − = Vin, so I1 = Vin/R1. Once again, no current flows into the inverting terminal, so IL = I1. As in the inverting configuration, the load current is independent of RL and the transconductance is 1/R1. The load is also **floating** in this version.

$$I_L = V_{in}/R_1 = g_m V_{in}$$



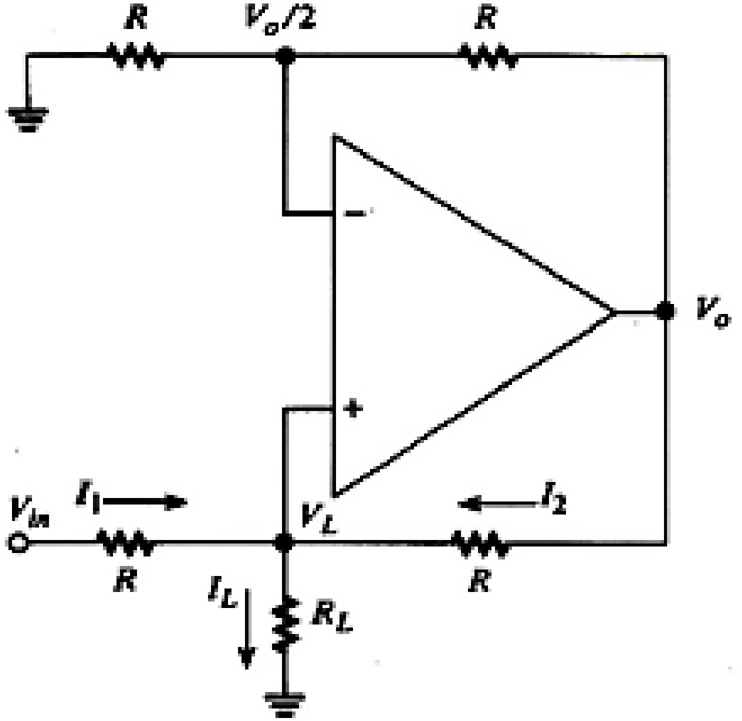
# 6.2 Voltage-Controlled Current Source ( Voltage to Current Converter )

Voltage-controlled current source that can be operated with a **grounded load**. Since there is (ideally) zero current into the + input, Kirchhoff's current law at the node where RL is connected to the + input gives

$$V_L = v^+ = v^- = \frac{RV_o}{R+R} = \frac{V_o}{2} \quad \text{and}$$

$$I_L = I_1 + I_2 = \frac{V_{in}-V_L}{R} + \frac{V_o-V_L}{R} = \frac{V_{in}}{R} - \frac{V_o}{2R} + \frac{V_o}{R} - \frac{V_o}{2R}$$

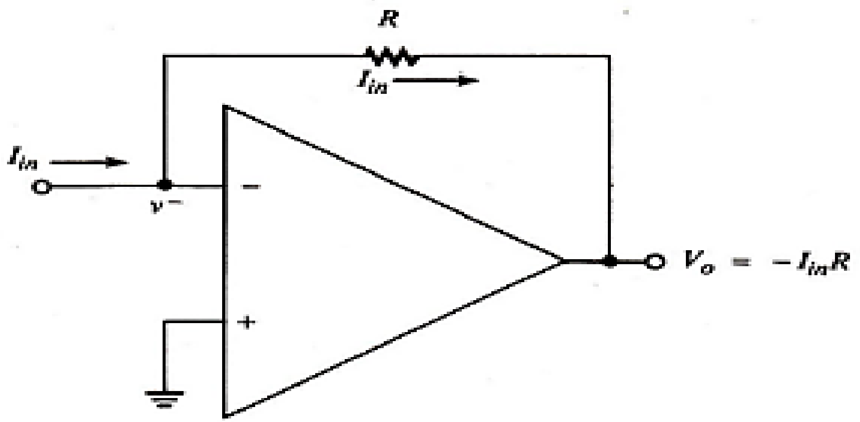
$$I_L = V_{in}/R = g_m V_{in}$$




- This equation shows that the load current is controlled by Vin, and that it is independent of RL.

# 6.3 Current-Controlled Voltage Source ( Current to Voltage Converter )

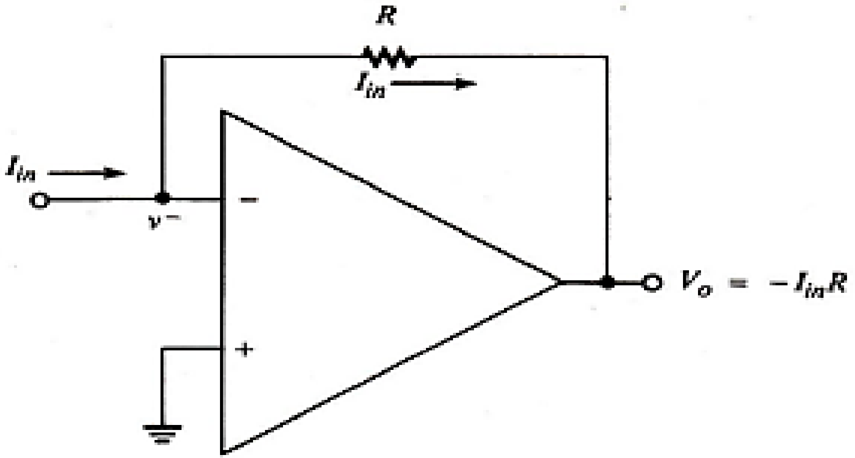
- An ideal current-controlled voltage source has an output voltage that is equal to a constant (k) times the magnitude of an independent current: Vo = kIi ; and is independent of the load connected to it. Here, the constant k has the units of ohms.
- A current controlled voltage source can be thought of as a current-to-voltage converter, since output voltage is proportional to input current. It is useful in applications where current measurements are required, because it is generally more convenient to measure voltages.



# 6.3- Current-Controlled Voltage Source ( Current to Voltage Converter )

- Since no current flows into the − input, the controlling current Iin, is the same as the current in feedback resistor R. Since v − is virtual ground

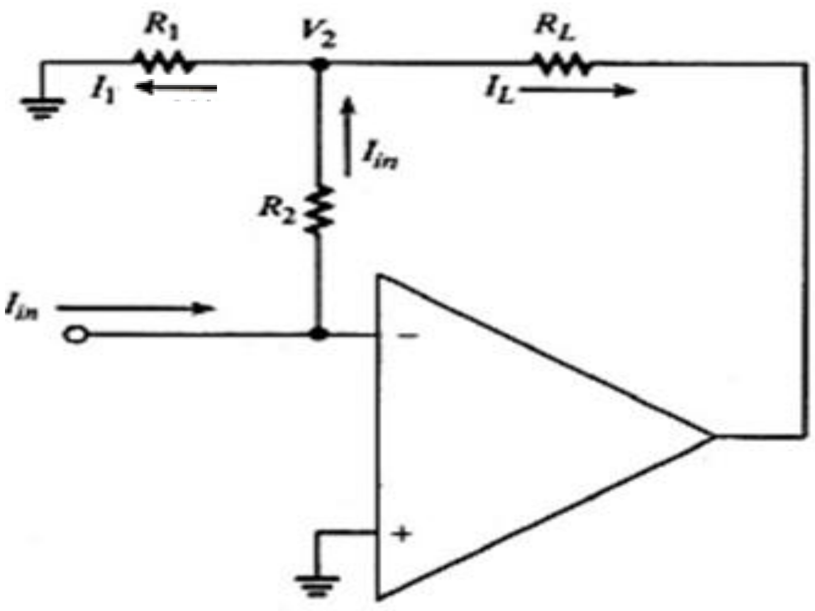
$$V_o = -I_{in}R$$




- Once again, the fact that the amplifier has zero output resistance implies that the output voltage will be independent of load.

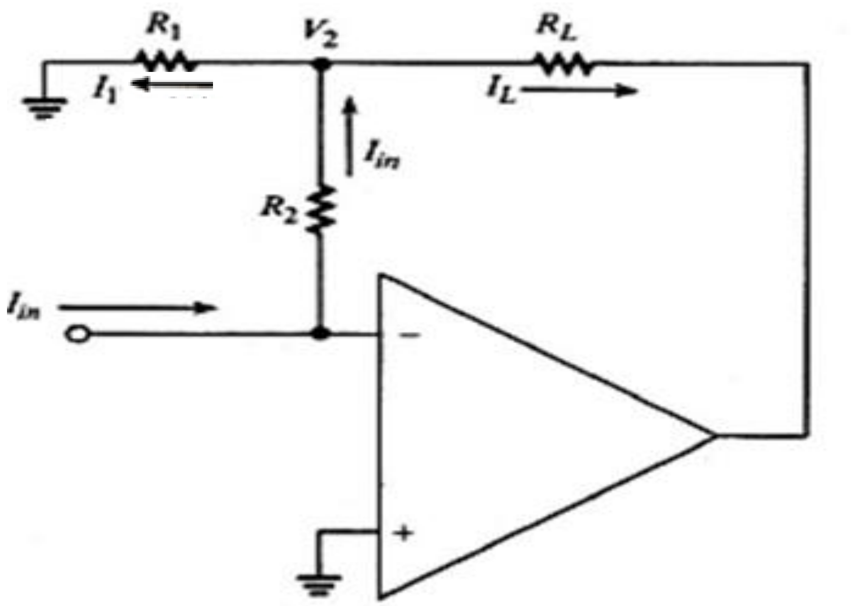
# 6.4 Current-Controlled Current Source(Current Amplifier )

- An ideal current-controlled current source is one that supplies a current whose magnitude equals a fixed constant (k) times the values of an independent controlling current: Io = kIi; and is independent of the load to which the current is supplied. The constant k is dimensionless, since it is the ratio of two currents.



# 6.4 Current-Controlled Current Source(Current Amplifier )

- Since no current flows into the − input, the current in R2 must equal Iin. Since v− is at virtual ground,



$$I_L = \left(\frac{R_2}{R_1} + 1\right) I_{in}$$

- This equation shows that the load current equals the constant (l + R2/R1) times the controlling current and that IL is independent of RL.

$$k = I_L/I_{in} = 1 + R_2/R_1$$