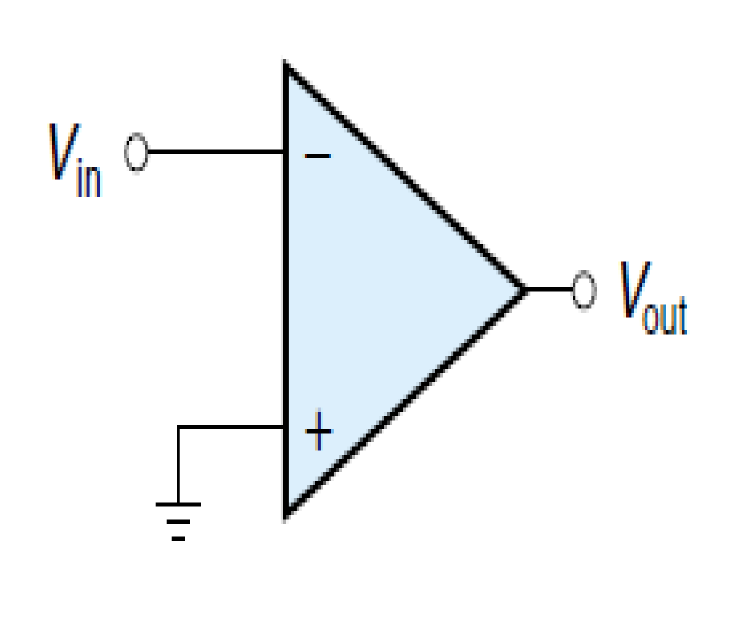
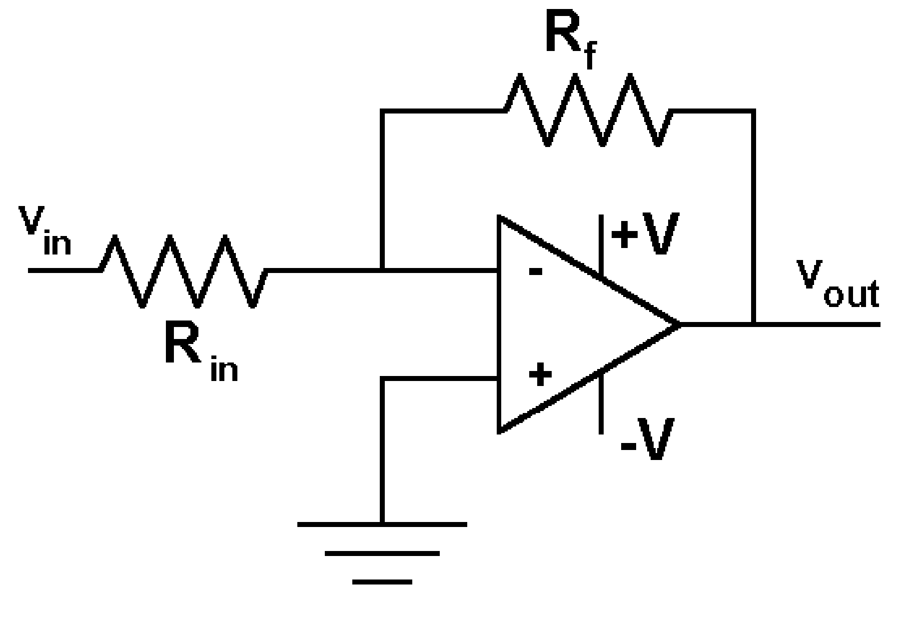
# OP-AMP BASED SIGNAL CONDITIONING CIRCUITS

# Op-Amp Circuits

- Op-Amps circuits can perform mathematical operations on input signals:
  - Addition and subtraction
  - Multiplication and Division
  - Differentiation and integration
- Other common uses include:
  - Impedance buffering
  - Active filters
  - Active controllers
  - Analog-digital interfacing
  - Rectifiers

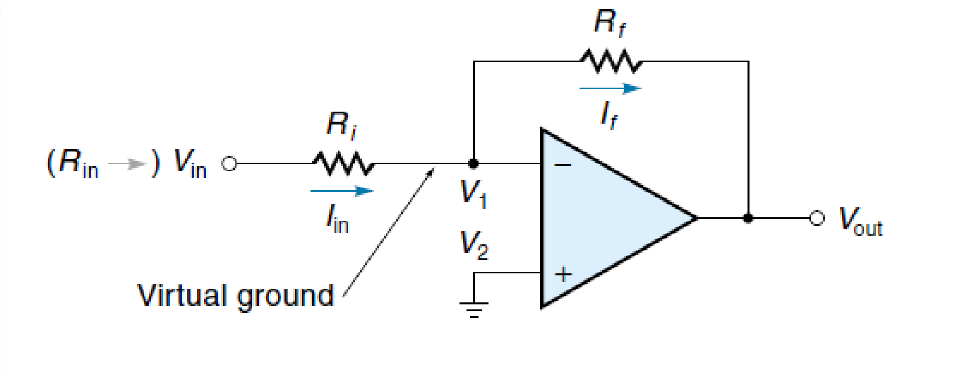
# Inverting Amplifier




$$V_{out} = -\frac{R_f}{R_{in}} V_{in} \qquad A = -\frac{R_f}{R_{in}}$$

# Contd..




- Most op-amp circuits incorporate **negative feedback.** This means that a portion of the output signal is fed back and subtracted from the input.
- Negative feedback results in a very stable and predictable operation at the expense of lowered gain.
- From the Ohm's law

$$I_{in} = \frac{V_{in}}{R_i}$$

$$I_{in} = I_f = \frac{0 - V_{out}}{R_f}$$

$$A_V = \frac{-R_f}{R_i}$$

$$\frac{V_{in}}{R_i} = \frac{0 - V_{out}}{R_f}$$

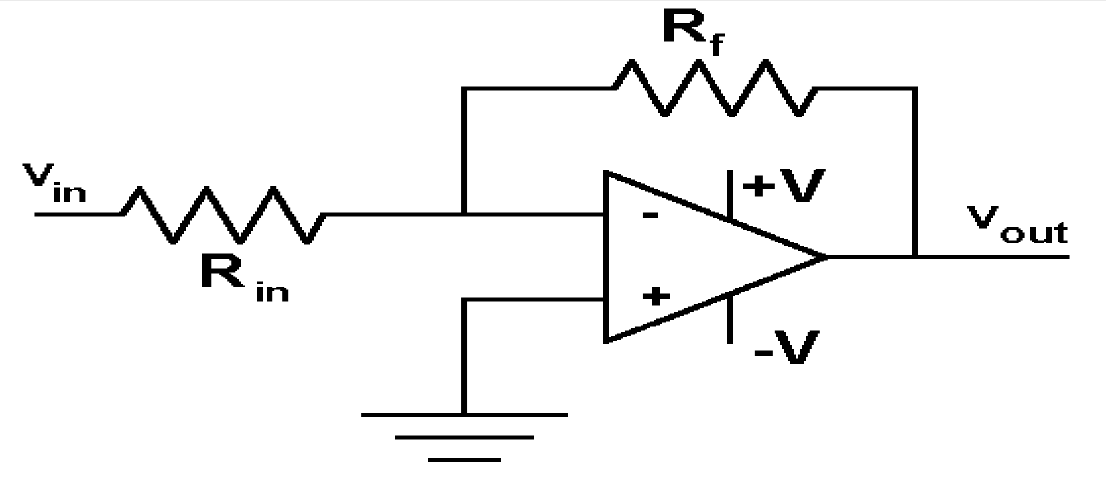
$$\frac{V_{out}}{V_{in}} = \frac{-R_f}{R_i}$$

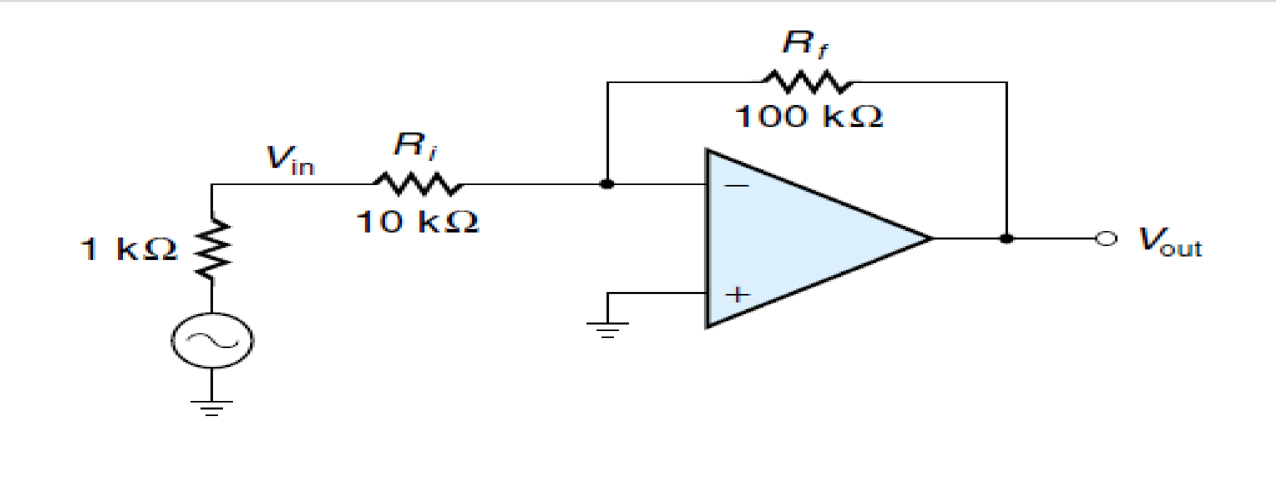
- This result shows us that the voltage gain of the inverting amp is simply the ratio of the two resistors *Rf* and *Ri*.
- The minus sign indicates that the output is inverted.
- The gain derived is called the **closed-loop gain** and is always lower than the (open-loop) gain of the op-amp by itself.

An inverting amp is to have a gain of 10. The signal source is a sensor with an output impedance of 1 kΩ ($R_{in}$=10Kohm). Draw a circuit diagram of the completed amplifier.

$R_i = 10\ \text{k}\Omega.$

$$\begin{aligned} R_f &= -AR_i \\ &= -(-10) \times 10\ \text{k}\Omega = 100\ \text{k}\Omega \end{aligned}$$



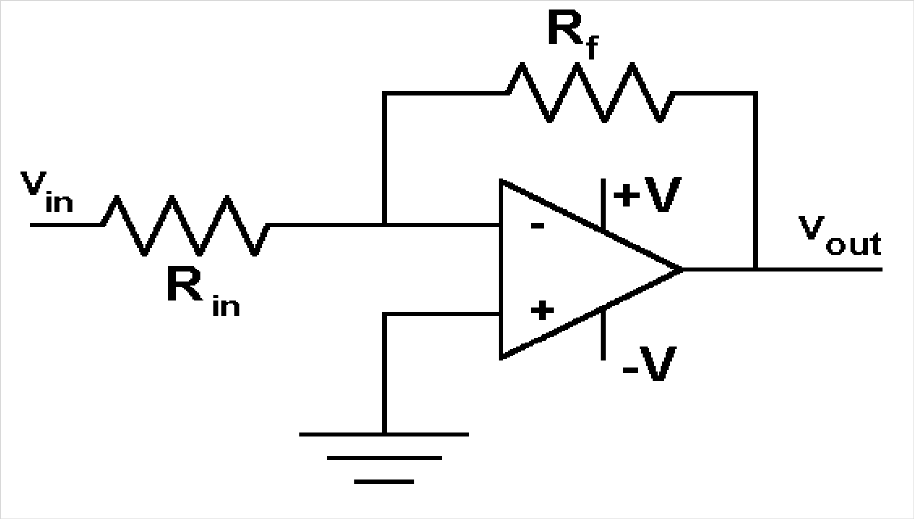



# Unity Gain Inverter

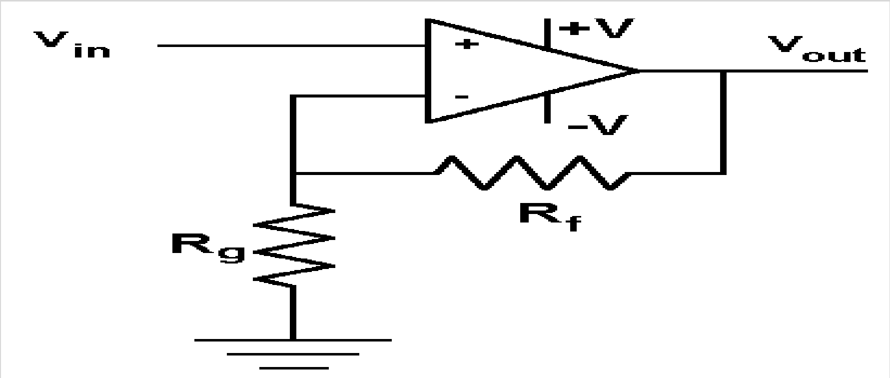
- If the two resistors are of equal value, $R_{in} = R_f$ then the gain of the amplifier will be -1 producing a complementary form of the input voltage at its output as $V_{out} = -V_{in}$.
- This type of inverting amplifier configuration is generally called a Unity Gain Inverter of simply an *Inverting Buffer*.

$$A_V = \frac{-R_f}{R_i}$$

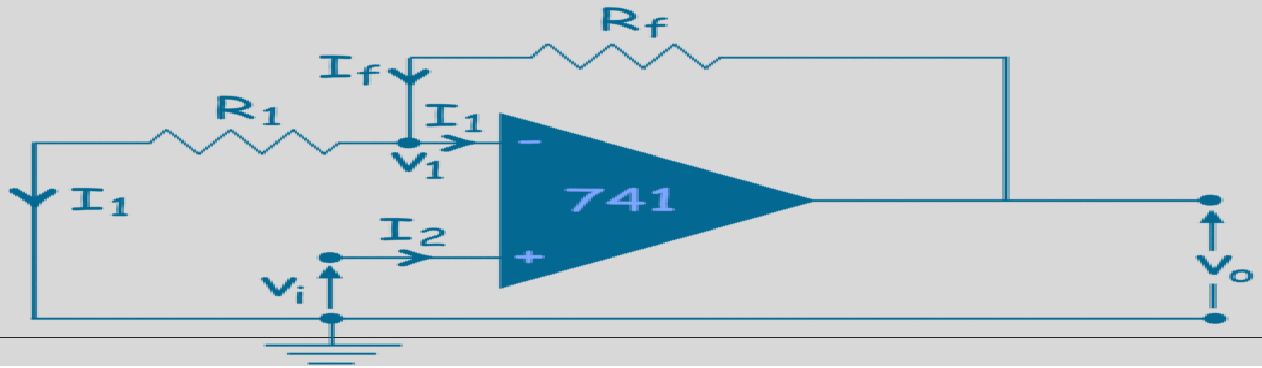
$$\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{-R_f}{R_i}$$



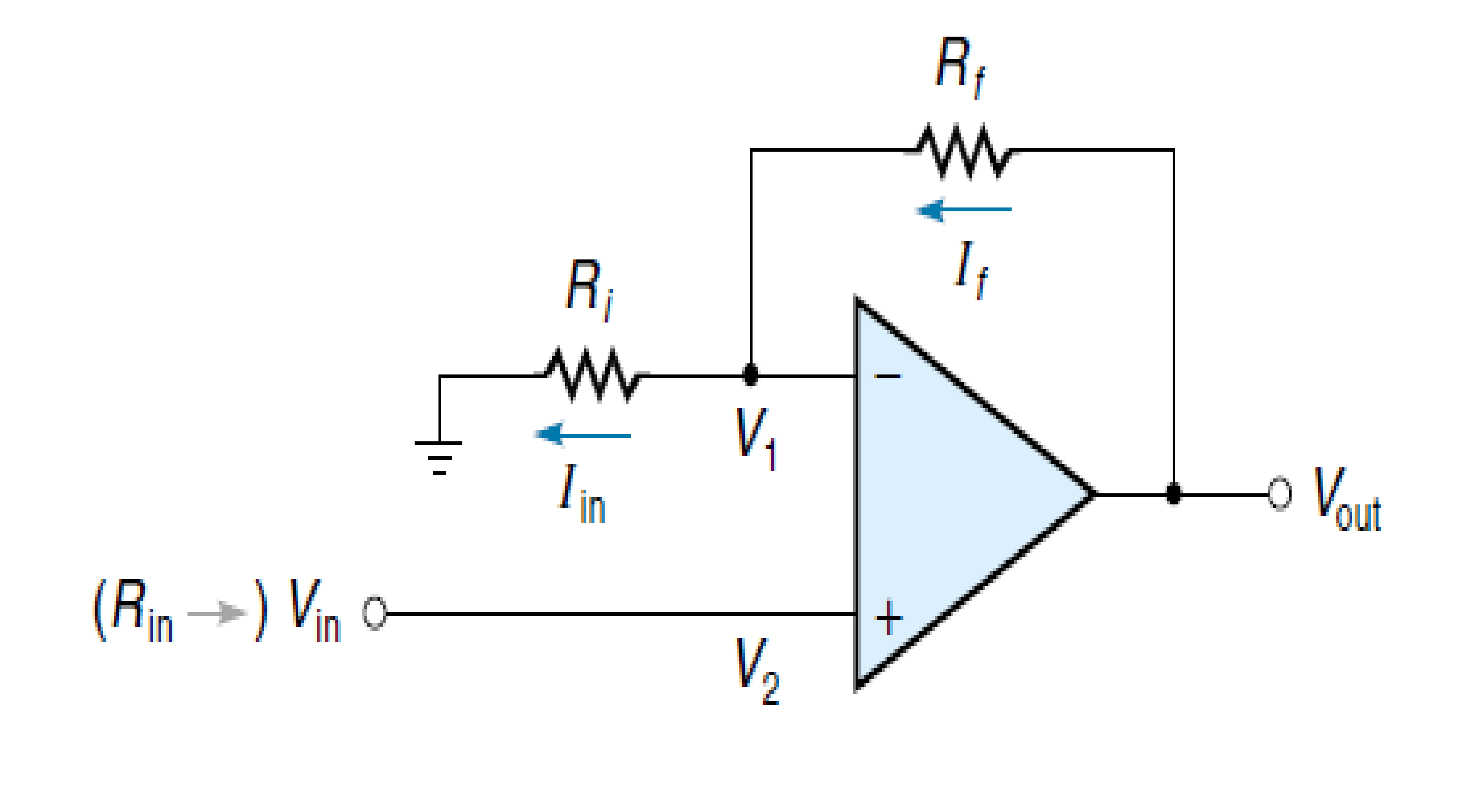
# Non-inverting Amplifier



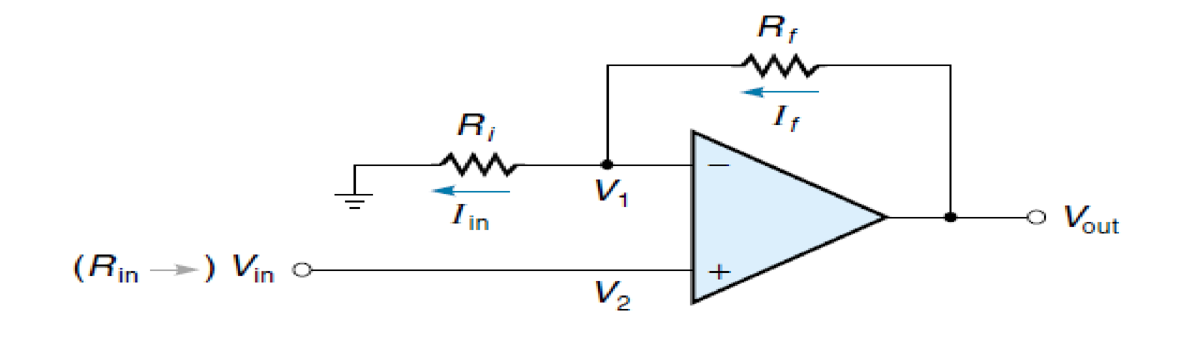

- A non-inverting Op-Amp circuit is one whose output is in phase with the input.
- The inverting terminal is connected through a resistor R1/Rg to the ground.
- Rf is the feedback resistor. Many applications requires only amplification that does not invert the output.
- The output of a thermocouple might be such that as the temperature goes up, the voltage goes up. In such applications there is no requirement of phase shift.
- It is similar to the inverting amp except the input signal Vin now goes directly to the noninverting input and *Ri* is grounded.
- Notice that the noninverting amp has an almost infinite input impedance (*Ri*) because Vin connects only to the opamp input.



# CIRCUIT DIAGRAM



# Contd..




- If $V1$ is virtually the same as $V2$, then the voltage input ($Vin$) appears across $Ri$. Applying Ohm's law to $Ri$,

$$I_{in} = \frac{V_{in} - 0}{R_i}$$

- The current in $Rf$ can also be calculated using Ohm's law. We know the voltage across $Rf$ is the difference between $Vin$ and $Vout$. Therefore,

$$I_f = \frac{V_{out} - V_{in}}{R_f}$$

$$I_{in} = I_f$$

$$I_{in} = I_f = \frac{V_{in} - 0}{R_i} = \frac{V_{out} - V_{in}}{R_f}$$

# Contd..

$$V_{out} - V_{in} = \frac{R_f V_{in}}{R_i}$$

$$V_{out} = \frac{R_f V_{in}}{R_i} + V_{in} = V_{in}\left(\frac{R_f}{R_i} + 1\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{R_f}{R_i} + 1$$

$$A_V = \frac{R_f}{R_i} + 1$$

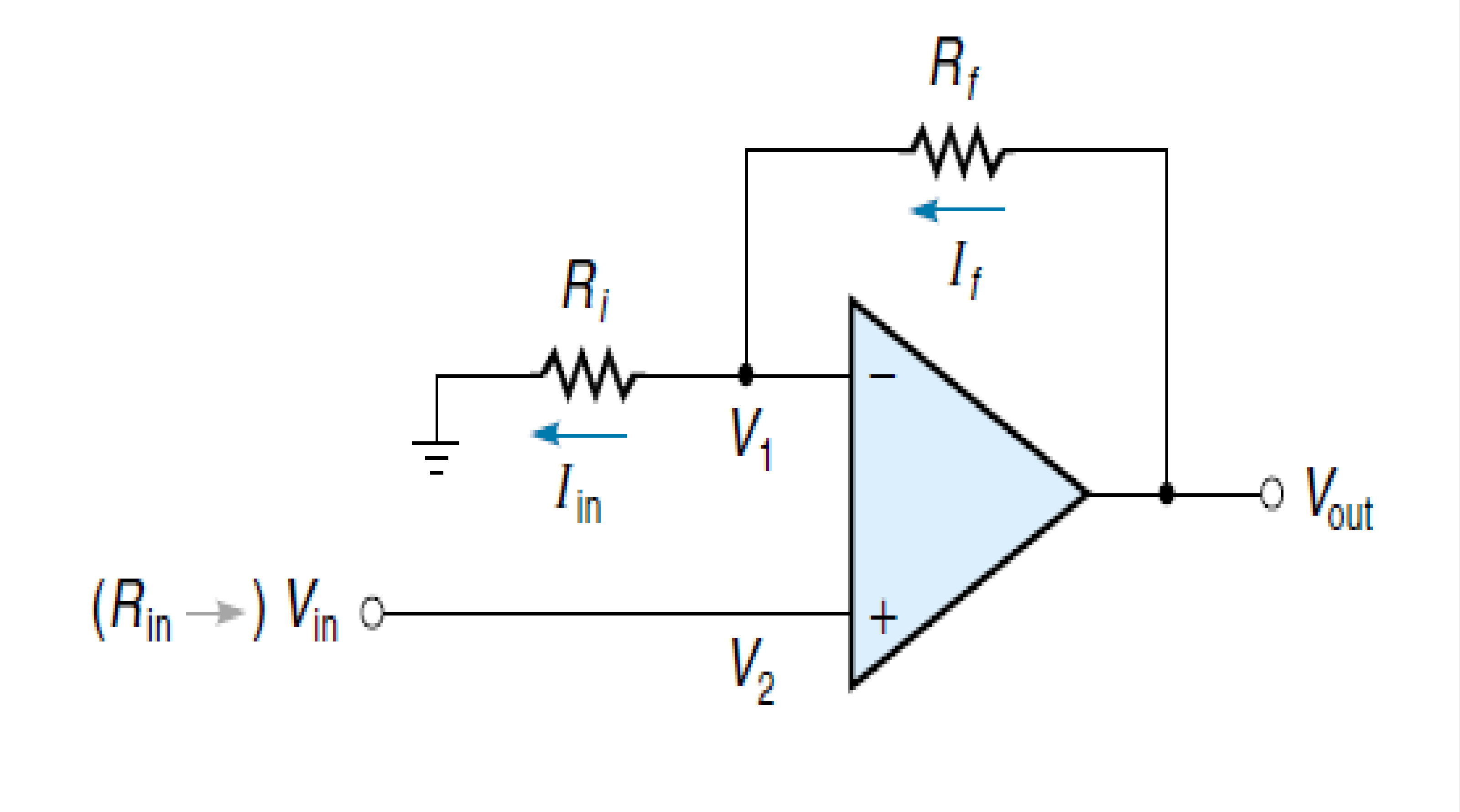
where

$A_V$ = voltage gain for the noninverting amp

$R_f$ = value of the feedback resistor

$R_i$ = value of the input resistor

Draw the circuit diagram of a noninverting amp with a gain of 20 ($R_i$=2 KΩ).

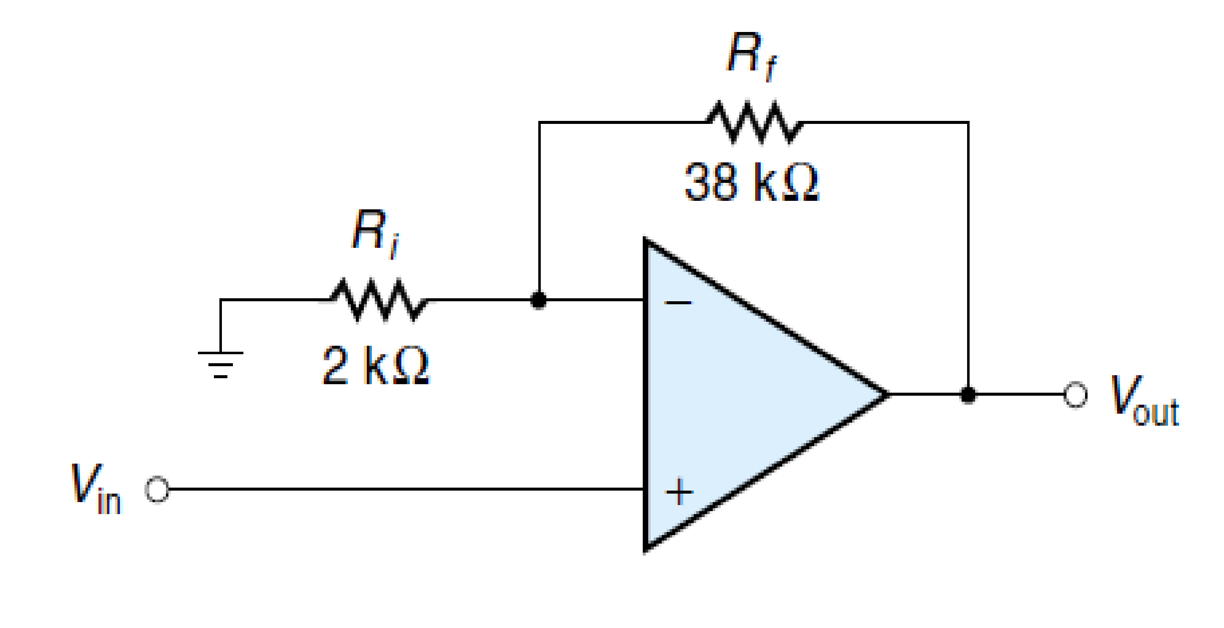


# Solution

$$A_V = 20 = \frac{R_f}{R_i} + 1$$

$$\frac{R_f}{R_i} = 19 \quad \text{or} \quad R_f = 19 \times R_i$$

$$R_f = 19 \times R_i = 19 \times 2\ \text{k}\Omega = 38\ \text{k}\Omega$$



# Steps in Analyzing Op-Amp Circuits

1) Remove the op-amp from the circuit and draw two circuits (one for the + and one for the – input terminals of the op amp).
2) Write equations for the two circuits.
3) Simplify the equations using the rules for op amp analysis and solve for $V_{out}/V_{in}$

- **Rule 1: $V_A = V_B$**
  - The output attempts to do whatever is necessary to make the voltage difference between the inputs zero.
  - The op-amp "looks" at its input terminals and swings its output terminal around so that the external feedback network brings the input differential to zero.
- **Rule 2: $I_A = I_B = 0$**
  - The inputs draw no current
  - The inputs are connected to what is essentially an open circuit

# References


- *Coughlin, R.F., Operational Amplifiers and Linear Integrated Circuits, Pearson Education (2006).*
- *Gayakwad, R.A., Op-Amp and Linear Integrated Circuits, Pearson Education (2002).*
- Franco, S., Design with Operational Amplifier and Analog Integrated circuit, McGraw Hill (2016).
- *Terrell, D., Op Amps Design Application and Troubleshooting, Newness (1996).*