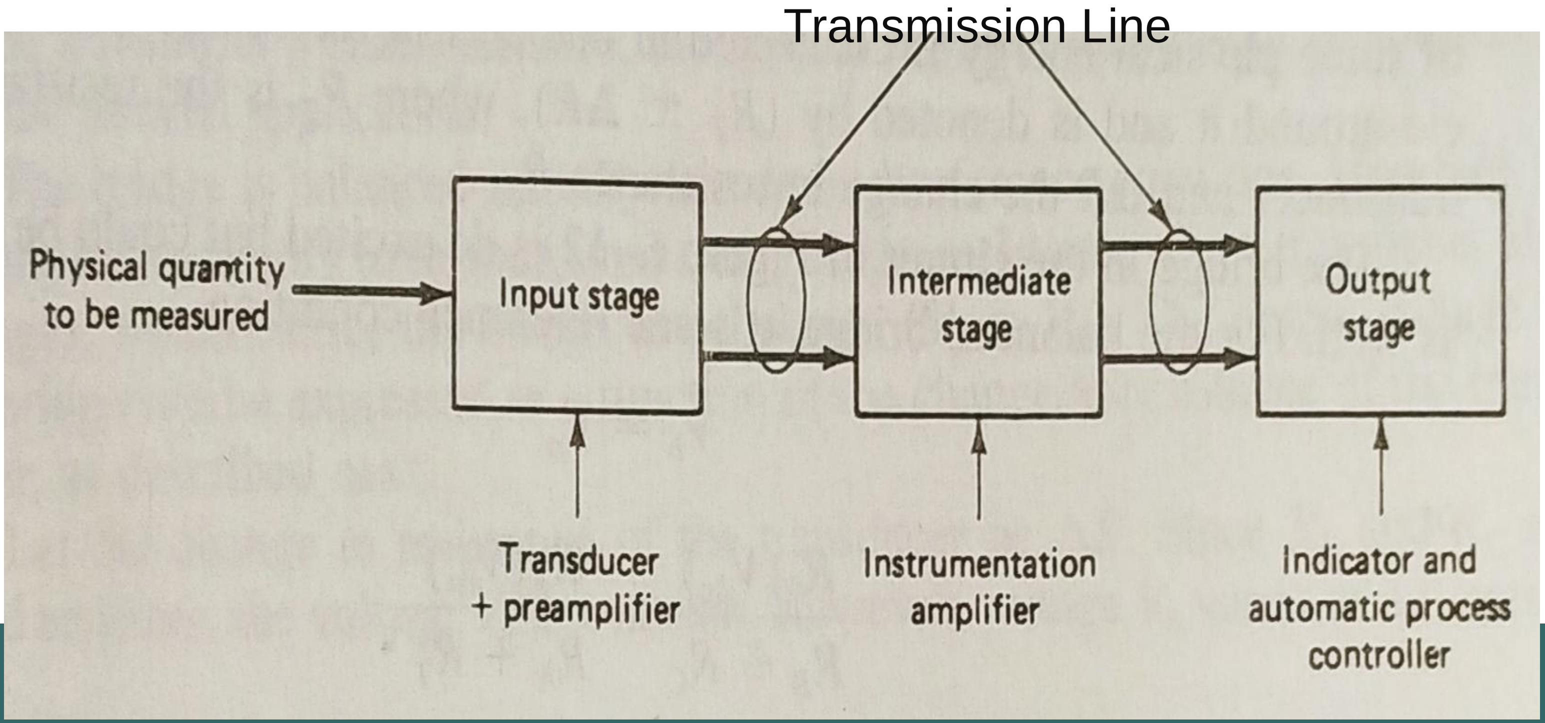
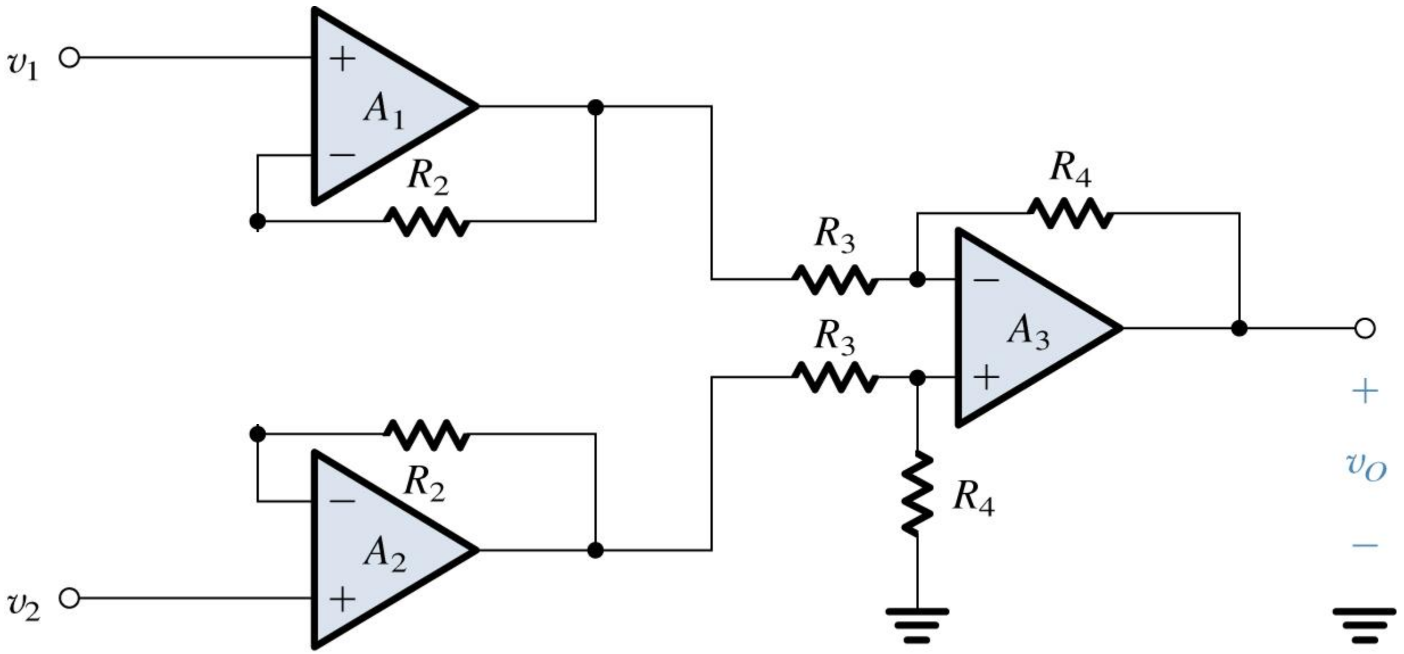
Instrumentation Amplifiers



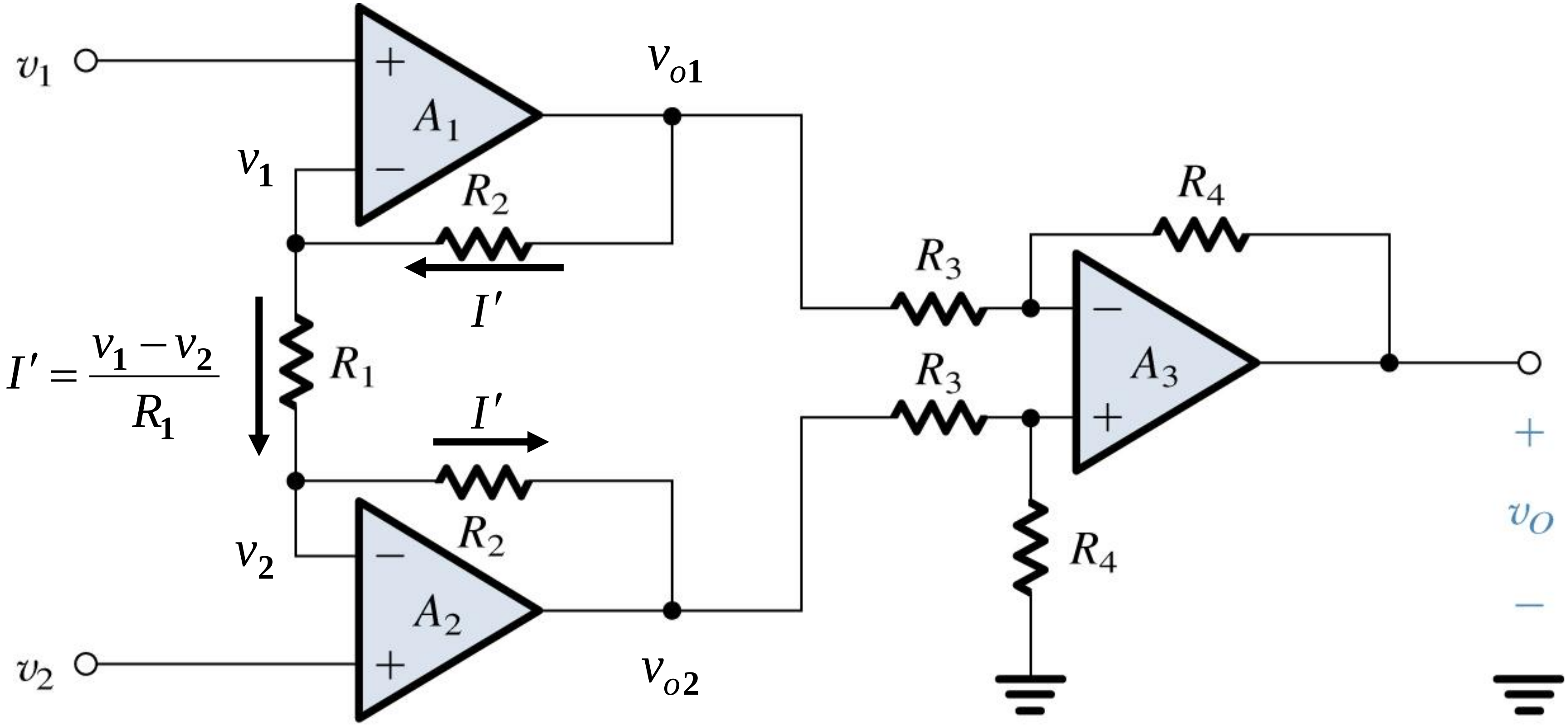
Improving the input resistance of amplifiers



Add buffer amplifiers to the inputs

R_{in} = infinity at both V_1 and V_2

Instrumentation Amplifier



The Buffer Amplifier

$$v_{o1} - v_{o2} = \frac{v_1 - v_2}{R_1} R_2 + v_1 - v_2 + \frac{v_1 - v_2}{R_1} R_2$$

$$= (v_1 - v_2)\left[\frac{R_2}{R_1} + 1 + \frac{R_2}{R_1}\right]$$

$$= (v_1 - v_2)\left[1 + \frac{2R_2}{R_1}\right]$$

The Difference Amplifier

- Using superposition, the output is due to an inverting amplifier and non-inverting amplifier.

The Difference Amplifier

- The inverting amplifier produces

$$v_{oi} = -v_{o1}\left[\frac{R_4}{R_3}\right]$$

- The non-inverting amplifier produces

$$v_{on} = v_{o2}\left[\frac{R_4}{R_3 + R_4}\right]\left[1 + \frac{R_4}{R_3}\right]$$

- The output is the sum of the outputs produced by each input.

$$v_{out} = v_{oi} + v_{on} = v_{o2}\left[\frac{R_4}{R_3 + R_4}\right]\left[1 + \frac{R_4}{R_3}\right] - v_{o1}\left[\frac{R_4}{R_3}\right]$$

$$= v_{o2}\left[\frac{R_4}{R_3 + R_4}\right]\left[\frac{R_3}{R_3} + \frac{R_4}{R_3}\right] - v_{o1}\left[\frac{R_4}{R_3}\right]$$

$$v_{out} = v_{o2}\left[\frac{R_4}{R_3+R_4}\right]\left[\frac{R_3+R_4}{R_3}\right] - v_{o1}\left[\frac{R_4}{R_3}\right]$$

$$= v_{o2}\left[\frac{R_4}{R_3}\right] - v_{o1}\left[\frac{R_4}{R_3}\right] = \left(v_{o2} - v_{o1}\right)\left[\frac{R_4}{R_3}\right]$$

$$= -\left(v_1 - v_2\right)\left[1+\frac{2R_2}{R_1}\right]\left[\frac{R_4}{R_3}\right] = \left(v_2 - v_1\right)\left[1+\frac{2R_2}{R_1}\right]\left[\frac{R_4}{R_3}\right]$$

- For $R_2 = R_3 = R_4$,

$$v_{out} = (v_2 - v_1)\left[1 + \frac{2R_2}{R_1}\right]$$

- Quite often, R_1 is a variable resistor that is used to set the gain and is denoted as R_g.

*The **INA326** is an instrumentation amplifier made by Texas Instruments.*

The main purpose of using an in-amp is to take the difference of two signals and gain the resulting signal. One important part of getting the best resolution is to reject signals common to both signals (common-mode rejection).

Excellent long-term stability and very low 1/f noise assure low offset voltage and drift throughout the life of the product.

CMRR (Min) = (dB)100

Current to voltage Converter

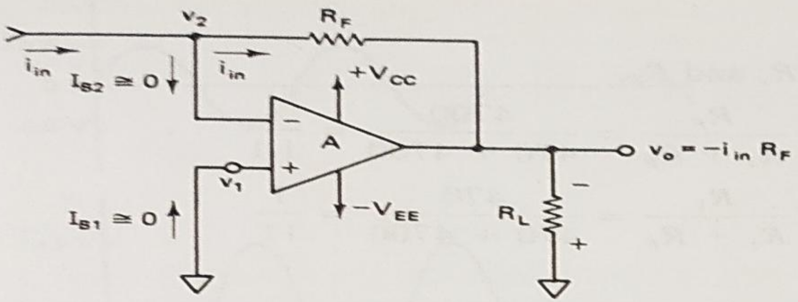


FIGURE 3–12 Current-to-voltage converter.

Therefore,

$$v_o = -\left(\frac{v_{\text{in}}}{R_1}\right)R_F$$

However, since $v_1 = 0$ V and $v_1 = v_2$.

$$\frac{v_{\text{in}}}{R_1} = i_{\text{in}}$$

and

$$v_o = -i_{\text{in}}R_F \qquad \textbf{(3–23)}$$

This means that if we replace the v_{in} and R_1 combination by a current source i_{in} as shown in Figure 3–12, the output voltage v_o becomes proportional to the input current i_{in}. In other words, the circuit of Figure 3–12 *converts* the input current into a proportional output voltage.

One of the most common uses of the current-to-voltage converter is in sensing current from photodetectors and in digital-to-analog converter applications,

voltage to Current Converter with Floating Load

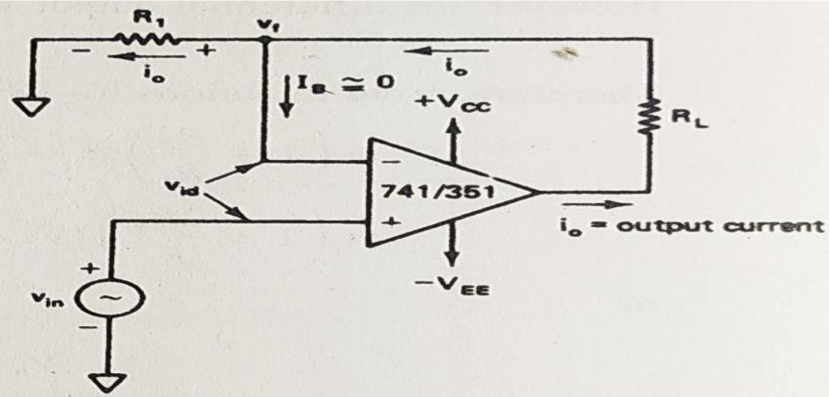


FIGURE 6–15 Voltage-to-current converter with floating load.

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}.

Writing Kirchhoff's voltage equation for the input loop,

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

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

$$v_{in} = v_f$$

$$v_{in} = R_1 i_o$$

or

$$i_o = \frac{v_{in}}{R_1} \qquad (6\text{–}19)$$

This means that in the circuit of Figure 6–15 an input voltage v_{in} is converted into an output current of 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 ($i_o = v_{in}/R_1$) will be precisely fixed.

The voltage-to-current converter can be used in such

voltage to Current Converter with Grounded Load

Writing Kirchhoff's current equation at node V_1,

$$I_1 + I_2 = I_L$$

$$\frac{V_{in} - V_1}{R} + \frac{V_o - V_1}{R} = I_L$$

$$V_{in} + V_o - 2V_1 = I_L R$$

Therefore,

$$V_1 = \frac{V_{in} + V_o - I_L R}{2} \tag{6–21a}$$

Since the op-amp is connected in the noninverting mode, the gain of the circuit in Figure 6–19 is $1 + R/R = 2$. Then the output voltage is

$$\begin{aligned} V_o &= 2V_1 \\ &= V_{in} + V_o - I_L R \end{aligned}$$

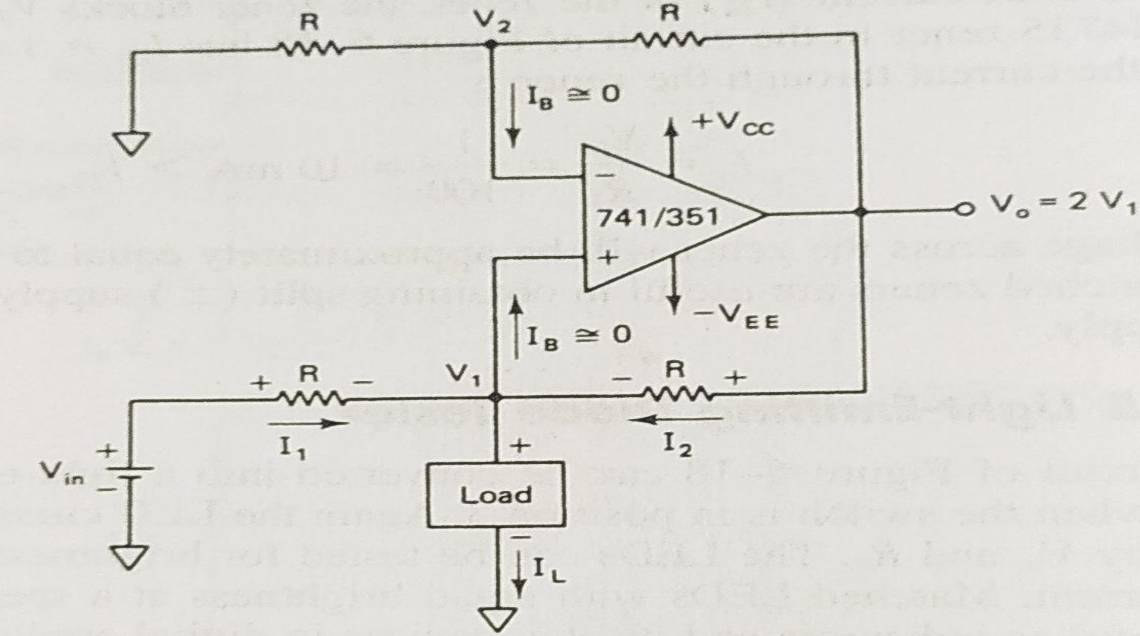


FIGURE 6–19 Voltage-to-current converter with grounded load.

That is,

$$V_{\text{in}} = I_L R$$

or

$$I_L = \frac{V_{\text{in}}}{R}$$