Unit 40 The noninverting amplifier

- The gain of a noninverting amplifier is given by:

$$A_V = 1 + \frac{R_1}{R_2}$$

- The input resistance of a noninverting amplifier is of the order of 100 MΩ.

The general form of the circuit used as a noninverting amplifier is shown in Figure 40.1.

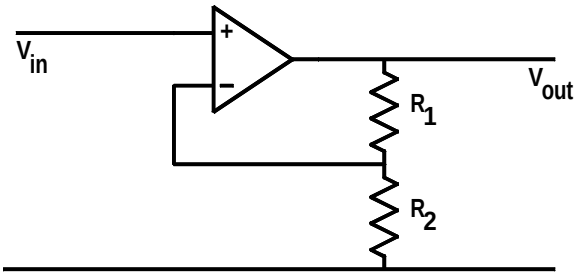

Figure 40.1: The noninverting amplifier circuit.

A fraction of the output voltage, determined by the potential divider at the output of the op-amp, is applied to the inverting input of the op-amp. We then use the first rule for op-amps from Unit 39 to get the result that the voltages at the two inputs to the op-amp are effectively equal. This gives:

$$V_{in} = V_{in+} = V_{in-} = V_{out} \times \frac{R_2}{R_1 + R_2}$$

which is easily simplified to get:

$$A_V = \frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2} = 1 + \frac{R_1}{R_2}$$

The input resistance of the noninverting amplifier is high because the resistance between the two input terminals is about 1 MΩ. However, when

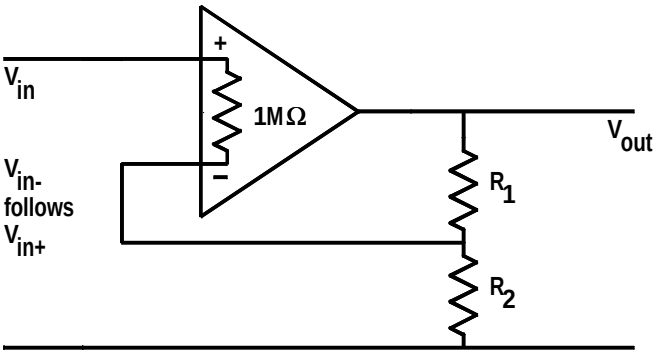

Figure 40.2: Calculating the input resistance.

an input is applied to the noninverting input, the full input voltage does not appear across the 1 MΩ since the output voltage is fed back to the other end of the 1 MΩ, at the inverting input, so as to cause it to follow closely the voltage at the noninverting input. We saw in Unit 39 that the maximum difference between the two inputs is about 100 μV. The result is that the amplifier input resistance is much greater than the op-amp input resistance because of the feedback signal. The maximum input current is:

$$I_{in(max)} = \frac{100\,\mu\text{V}}{1\,\text{M}\Omega} = 10^{-10}\,\text{A}$$

which gives a minimum amplifier input resistance of about $10^9\,\Omega$. Various current leakage paths on the printed circuit board due to moisture films, dirt etc., will usually reduce the amplifier input resistance to about 100 MΩ unless special precautions are taken to minimize current leakage paths. In most cases an input resistance of 100 MΩ is fully adequate and special precautions are unnecessary.

40.1 Example

40.1 The circuit for a noninverting amplifier is shown in Figure 40.3. The power supply voltages are ±15 V. Calculate the gain of this amplifier and plot a graph of the output voltage as V_{in} is varied from −1 V to +1 V.

The gain of the amplifier is given by:

$$A_V = 1 + \frac{R_1}{R_2} = 1 + \frac{5000}{200} = 1 + 25 = 26$$

We now calculate a number of representative values for the output voltage using $V_{out} = 26 \times V_{in}$.

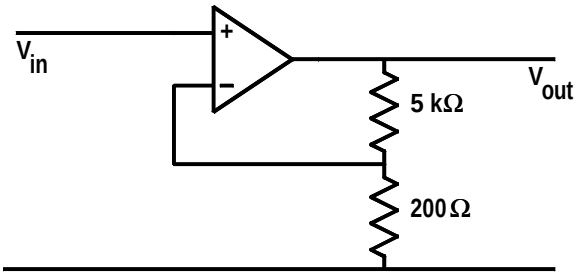

Figure 4 0.3: Example 4 0.1.

V_{in}	Calculated V_{out}	Actual V_{out}
−2 V	−52 V	−13 V
−1 V	−26 V	−13 V
−0.4 V	−10.4 V	−10.4 V
−0.1 V	−2.6 V	−2.6 V
0 V	0 V	0 V
0.1 V	2.6 V	2.6 V
0.4 V	10.4 V	10.4 V
1 V	26 V	13 V
2 V	52 V	13 V

These results are plotted in Figure 40.4. Again, as in the case of the inverting amplifier, it should be noted that the output voltage does not move outside the limits of ±13 V when the supply voltage is ±15 V so that the output voltage saturates for large values of the input voltage. The region of amplifier linear response within which $V_{out} = 26 \times V_{in}$ is indicated on the diagram.

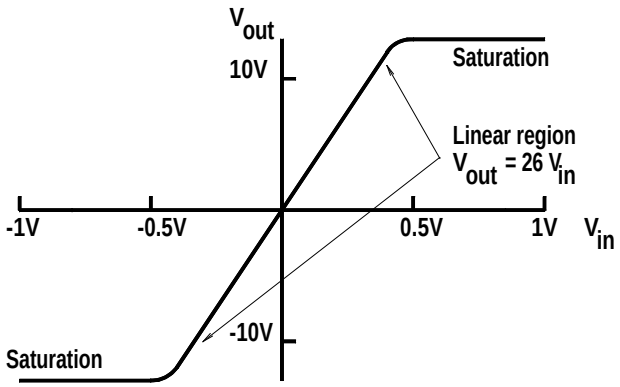

Figure 40.4: V_{out} as a function of V_{in} for Example 40.1.

40.2 Problems

40.1 Calculate the voltage gain for the amplifier shown in Figure 40.5 and plot the output voltage for input voltages from $-1\,\mathrm{V}$ to $+1\,\mathrm{V}$. The power supply voltages for the op-amp are $\pm 10\,\mathrm{V}$.

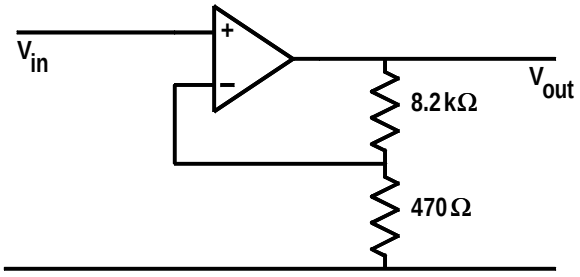

Figure 40.5: Problem 40.1.

40.2 Design a noninverting amplifier which has a gain which can be varied from $+9$ to $+60$. The circuit shown in Figure 40.6 is suggested. Calculate suitable values for the fixed resistors and for the potentiometer resistance, R_V. What other arrangements of resistors could be used in the potential divider?

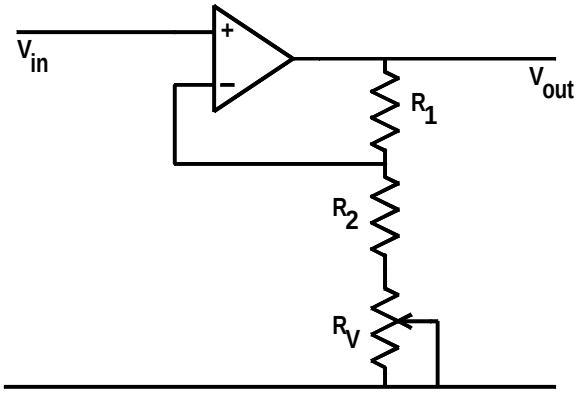

Figure 40.6: Problem 40.2.

40.3 Design a noninverting amplifier which has a gain of $+43$. Draw the full circuit diagram for the amplifier including the power supply connections. The amplifier is to be powered by two PP9, 9 V batteries. Show where the batteries should be connected.