\begin{align*}
\text{Assume the OP-AMP is ideal, and has no internal power loss.}
\end{align*}

- R_1 = 3 \text{ K ohms}
- R_2 = 39 \text{ K ohms}
- R_3 = 8 \text{ K ohms}
- V_1 = 14 \text{ volts}
- V_2 = 14 \text{ volts}
- V_{\text{in}} = 753 \text{ millivolts}

\begin{align*}
V_{ab} \text{ (volts)} & = \text{ ANSWER IS 0} \\
I_1 \text{ (milliamps)} & = \text{ ANSWER IS 0.251} \\
I_2 \text{ (milliamps)} & = \text{ ANSWER IS 0} \\
I_3 \text{ (milliamps)} & = \text{ ANSWER IS 0.251} \\
V_{ac} \text{ (volts)} & = \text{ ANSWER IS 9.789} \\
V_{cb} \text{ (volts)} & = \text{ ANSWER IS -9.789} \\
I_4 \text{ (milliamps)} & = \text{ ANSWER IS -1.224} \\
I_5 \text{ (milliamps)} & = \text{ ANSWER IS -1.475} \\
I_9 \text{ (milliamps)} & = \text{ ANSWER IS 0}
\end{align*}

\begin{align*}
V_{ab} = 0 \text{ FOR IDEAL OP-AMP} \\
I_2 = \frac{753V}{3K} = 0.251mA \\
I_3 = \frac{753V}{3K} = 0.251mA \\
V_{ac} = I_2 \times (25\text{mA}) / 3K = 9.789V \\
V_{cb} = -9.789V \text{ BY KVL} \\
I_4 = \frac{V}{R} = \frac{-9.789V}{8K} = -1.224mA \\
I_5 = I_4 - I_3 = -1.224mA - 0.251mA = -1.475mA \\
I_9 = 0 \text{ FOR IDEAL OP-AMP}
\end{align*}
Non-Inverting OP-AMP Circuit

Assume the OP-AMP is ideal, and has no internal power loss.

\[ \begin{align*}
R_1 &= 38 \text{ K ohms} \\
R_2 &= 684 \text{ K ohms} \\
R_3 &= 9 \text{ K ohms} \\
V_1 &= 14 \text{ volts} \\
V_2 &= 14 \text{ volts} \\
V_{\text{in}} &= 552 \text{ millivolts}
\end{align*} \]

\[ \begin{align*}
V_{\text{ad}} \text{ (volts)} &= \text{ANSWER IS } 0.552 \\
I_1 \text{ (milliamps)} &= \text{ANSWER IS } -0.01453 \\
I_2 \text{ (milliamps)} &= \text{ANSWER IS } 0 \\
I_3 \text{ (milliamps)} &= \text{ANSWER IS } -0.01453 \\
V_{\text{ac}} \text{ (volts)} &= \text{ANSWER IS } -9.936 \\
V_{\text{cd}} \text{ (volts)} &= \text{ANSWER IS } 10.49 \\
I_4 \text{ (milliamps)} &= \text{ANSWER IS } 1.165 \\
I_5 \text{ (milliamps)} &= \text{ANSWER IS } 1.18 \\
I_9 \text{ (milliamps)} &= \text{ANSWER IS } 0
\end{align*} \]

\[ \begin{align*}
V_{\text{ad}} &= \sqrt{552 V} \text{ V, by KVL} \\
I_1 &= \frac{-552 V}{38 \text{ K}\Omega} = -1.453 \text{ mA} \\
I_2 &= 0 \text{, for ideal OP-AMP} \\
I_3 &= I_2 = -1.453 \text{ mA} \\
V_{\text{ac}} &= I_2 R = (-1.453 \text{ mA}) (684 \text{ K}\Omega) = -993.6 \text{ V} \\
V_{\text{cd}} &= +1.552 V + 9.936 V = 10.49 \text{ V}
\end{align*} \]

\[ \begin{align*}
I_4 &= \frac{V}{R} = \frac{10.49 \text{ V}}{684 \text{ K}\Omega} = 0.0165 \text{ mA} \\
I_5 &= I_4 - I_3 = 0.0165 \text{ mA} - (-1.453 \text{ mA}) = 1.118 \text{ mA} \\
I_9 &= 0 \text{, for ideal OP-AMP}
\end{align*} \]
High Gain OP-AMP Circuit

Assume the OP-AMP is ideal, and has no internal power loss.

\[ R_1 = 18 \text{ K ohms} \]
\[ R_2 = 34 \text{ K ohms} \]
\[ R_3 = 30 \text{ K ohms} \]
\[ R_4 = 6 \text{ K ohms} \]
\[ R_5 = 0.75 \text{ K ohms} \]
\[ \text{Vin} = 50 \text{ millivolts} \]

\[ \text{Vab (volts) ? ANSWER IS 0} \]
\[ I_1 \text{ (milliamps) ? ANSWER IS 2.778E-03} \]
\[ \text{Vcb (millivolts) ? ANSWER IS -9.444 mV} \]
\[ I_3 \text{ (milliamps) ? ANSWER IS -0.1259 mA} \]
\[ I_2 \text{ (milliamps) ? ANSWER IS 0.1287 mA} \]
\[ \text{Vod (volts) ? ANSWER IS 3.861 V} \]
\[ \text{Vdb (volts) ? ANSWER IS -3.956 V} \]

\[ \text{Vab} = \frac{6V}{2}, \text{ for ideal OP-AMP} \]
\[ I_1 = \frac{V}{R} = \frac{0.5V}{18K} = 0.002778 mA \]
\[ V_{cb} = I_1 R = (0.002778 mA)(34K) = -94.44 mV \]
\[ I_3 = \frac{V}{R} = \frac{-94.44 mV}{7.5K} = -0.1259 mA \]
\[ I_2 = I_1 - I_3 = 0.002778 mA - (-0.1259 mA) = 0.1287 mA \]
\[ V_{od} = I_2 R = (0.1287 mA)(34K) = 3.861 V \]
\[ V_{db} = 0V - (-94.44 mV) - 3.861 V = -3.956 V \]
Inverting Summing Amplifier

R1 = 4.4 k ohms
R2 = 2.1 k ohms
R3 = 5.7 k ohms
R4 = 5 k ohms
V1 = .13 volts
V2 = .5 volts

I1 (mA) = \frac{.13V}{4.4k\Omega} = 0.02955 \text{ mA}
I2 (mA) = \frac{.5V}{2.1k\Omega} = 0.238 \text{ mA}
I3 = I1 + I2 = .02955 + .238 = 0.2676 \text{ mA}
Vc = 0V - IR3 = (.2676 \text{ mA})(5.7k\Omega) = -1.526V
I4 = \frac{Vc}{R4} = \frac{-1.526V}{5k\Omega} = -0.305 \text{ mA}
Differential Amplifier with Two Input Voltages

R1 = 3 k ohm
R2 = 11 k ohm
R3 = 9 k ohm
V1 = .21 volts
V2 = -.34 volts

I1 (mA)? ANSWER IS .015
Va (volts)? ANSWER IS .165
I2 (mA)? ANSWER IS -.1683
V3 (volts)? ANSWER IS 2.017

\[ I_1 = \frac{V}{R} = \frac{.21V}{3k\Omega + 11k\Omega} = 0.015 mA \]
\[ V_a = I_1 R = (0.015 mA)(11k\Omega) = 1.65V \]
\[ V_a = I_1 R = (0.015 mA)(11k\Omega) = 1.65V \]
\[ V_3 = V_a + I_2 (1683 mA)(11k\Omega) = 1.8517V \]
\[ V_3 = V_a + I_2 (1683 mA)(11k\Omega) = 1.8517V \]
Differential Amplifier with a Differential Input Voltage

\[ R_1 = 3 \text{ k ohm} \]
\[ R_2 = 11 \text{ k ohm} \]
\[ R_3 = 3 \text{ k ohm} \]
\[ V_1 = 0.21 \text{ volts} \]

\[ I_1 \text{ (mA)}? \text{ ANSWER IS 0.035} \]
\[ V_a \text{ (volts)? ANSWER IS 0.385} \]
\[ V_3 \text{ (volts)? ANSWER IS 0.77} \]

The two \( R_1 \)'s are in series:

\[ I_1 = \frac{V_1}{R_1 + R_2} = \frac{0.21V}{3k\Omega + 3k\Omega} = 0.035 \text{ mA} \]

\[ V_a = I_1 R_1 = (0.035 \text{ mA})(11k\Omega) = 0.385V \]

\[ V_{cb} = I_1 R_2 = (0.035 \text{ mA})(11k\Omega) = 0.385V \]

\[ V_3 = V_a + 0V + 0.385V = 0.770V \text{ (by KVL)} \]