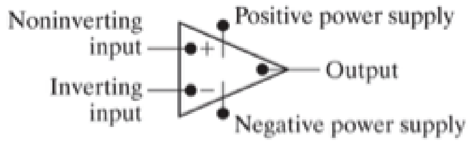
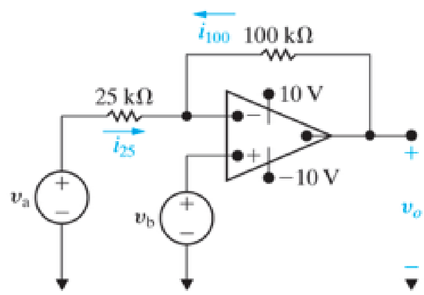
General Information



The purpose of an operational amplifier is to amplify the incoming input voltage by some linear amount. The amplifier possesses a saturation point at which the voltage is no longer amplified. This is based on the voltage of the power supply that is connected to the device. Since there is an attached power supply, the device is considered non-passive and it explains the limits of the linear behavior of the device which spans from $-V_{cc}$ to V_{cc}.

For an ideal op-amp, the inverting and non-inverting voltage will be equal since the resistance within the amplifier is, ideally infinite, no current will flow through the actual device, $v_n = v_p$.



This example circuit can be analyzed to find the output voltage and thus the amplification that the device provides. Using $v_a = 1\ V$ and $v_b = 2\ V$, node equations can be written for the inverting node and the output node to determine the value of v_0. Since $v_n = v_p$, and the voltage at non-inverting input is simply v_b, the voltage at the node of the inverting input will also be equal to the voltage v_b. The first node equation therefore will be,

$$\frac{v_b - v_a}{25000} + \frac{v_b - v_0}{100000} = 0$$

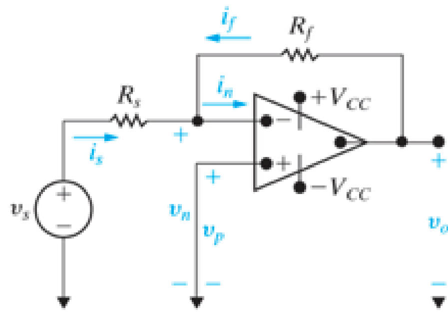
Solving this equation by plugging in the values for v_a and v_b, the value of v_0 is found to be $6\ V$. Since V_{cc} ranges from $-10\ V$ to $10\ V$, and the value of v_0 was found to be $6\ V$, this amplifier is operating within its linear region.

We can also determine the range for which this amplifier can operate within its linear region by substituting the constraint values of V_{cc} in for v_0 and solving for v_b. Arranging the equation to solve for v_b,

$$v_b = 20000\left(\frac{v_a}{25000} + \frac{v_0}{100000}\right) = \frac{4}{5}v_a + \frac{1}{5}v_0$$

Now, plugging in $10\ V$ for v_0, the upper bound for v_b is $2.8\ V$ and the lower bound, from plugging in $-10\ V$, equals $-1.2\ V$, therefore, the linear operating range for this particular amplifier must respect, $-1.2\ V \leq v_b \leq 2.8\ V$.

The Inverting-Amplifier

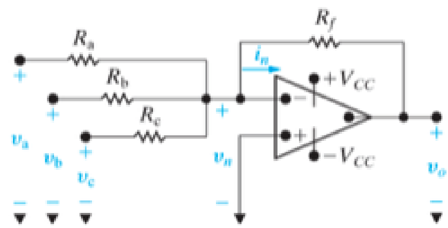


This is circuit for the inverting amplifier and it is called such due to the source voltage being connected to the inverting input node of the device. The resulting behavior is that the output voltage is negative for any positive input voltage. Using the node equations once again as done with all of these circuits, here the voltage of the left node is zero since the non-inverting input is connected directly to ground, $v_n = 0$ and since $v_p = v_n$, $v_p = 0$. Solving the node equations as done previously, an expression for v_0 can be written,

$$v_0 = -\frac{R_f}{R_s} v_s$$

The amount of amplification received here will be equal to the fractional term, $\frac{R_f}{R_s}$. To find the range of values for v_s that will satisfy the linear behavior of the device, the same method can be employed as before, plugging in V_{cc} for v_0 and solving for v_s.

The Summing Amplifier



The circuit for the summing amplifier is shown and consists of multiple input sources, dampened by resistors, and all connected to the inverting input of the op-amp.

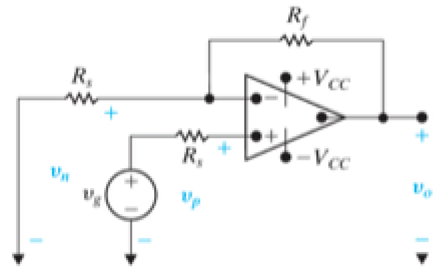
The equation for the output voltage for this configuration is given by,

$$v_0 = -\left(\frac{R_f}{R_a} v_a + \frac{R_f}{R_b} v_b + \frac{R_f}{R_c} v_c\right)$$

If the input resistors are all equivalent, $R_a = R_b = R_c$, the equation can be written simply as the functional resistance over the source resistance, R_s,

$$v_0 = -\frac{R_f}{R_s}(v_a + v_b + v_c)$$

The Non-Inverting Amplifier



For this circuit it can be seen that the input voltage is connected to the non-inverting input of the op-amp therefore, this is a non-inverting amplifier. Functioning very similarly to the inverting amplifier, the equation can be found to be very similar as well.

$$v_0 = \frac{R_s + R_f}{R_s} v_g$$

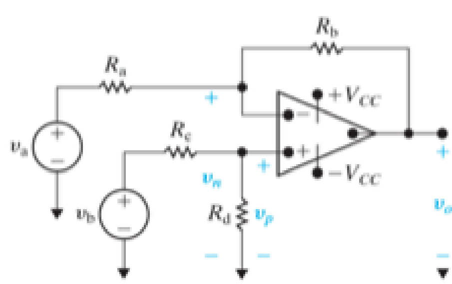
or,

$$v_0 = \left(1 + \frac{R_f}{R_s}\right) v_g$$

Using one of these equations will yield the value of v_0 and the amount of amplification that the amplifier provides. It also gives the region of linearity with the expression,

$$\left(1 + \frac{R_f}{R_s}\right) < \mid \frac{V_{cc}}{v_g} \mid$$

The Difference Amplifier



The last iteration of the operational amplifier and it is difference amplifier. This will take in two sources at both inputs as well as a path to ground which is connected to the non-inverting side of the amplifier. To find the equation of the output voltage in this case requires the same procedure as the others, the node equations an be written for the two nodes. In some cases however, if the resistor connected to the non-inverting input is not directly connected to the node, the voltage source v_b, may be converted to a Thevenin's equivalent circuit, which then gives a source in series with a resistor, and the equations can be written and solved.

$$v_0 = \frac{R_d(R_a + R_b)}{R_a(R_c + R_d)} v_b - \frac{R_b}{R_a} v_a$$

This equation can be simplified drastically however, it requires a few conditions to hold true in order to do so. If $\frac{R_a}{R_b} = \frac{R_c}{R_d}$, the equation can be written as,

$$v_0 = \frac{R_b}{R_a}(v_b - v_a)$$

With all the resistors given along with the two input sources, the output voltage can be determined and with that, as can be the range of the input voltage for the linear operation of the amplifier.