A. Passive Sign Convention:

We choose voltage drop reference direction (VDRD) to be the same as current flow reference direction (CFRD). \( V \) & \( i \) could be both positive or both positive or one positive the other negative.

**Example 1:** Ohm's Law: The voltage drop for an ideal resistor, the voltage drop across the resistor is proportional to the current flow through the resistor provided we use passive sign convention.

\[ V_{AB} = \frac{V_A - V_B}{R} \]

Or simply

\[ V_R = \frac{V_A - V_B}{R} \]

Another way to say this: Voltage drop between two terminals is proportional to the current and is in the same direction as current flow.

If we do not use passive sign convention Ohm's law becomes \( V = -RI \).
**Example 2**

Capacitor

$V_c$ could be positive or negative.

Time Interval

$I$ $II$ $III$ $IV$

$\omega V_m$ ($V_m \sin \omega t$) $V_c$ $i_c$ $P_{d\rightarrow c}$

<table>
<thead>
<tr>
<th>Interval</th>
<th>$V_c$</th>
<th>$i_c$</th>
<th>$P_{d\rightarrow c}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>II</td>
<td>+</td>
<td>-</td>
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<tr>
<td>III</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>IV</td>
<td>-</td>
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</tbody>
</table>

We have chosen Passive Sign Convention

$V_c = \frac{1}{\omega} \sin \omega t$ $\Rightarrow \frac{d}{dt}$

$V_c = V_m \sin \omega t$ $\Rightarrow i_c = V_m \omega \cos \omega t$

$T = \frac{2\pi}{\omega}$

$P_{d\rightarrow c} = \text{Power delivered to Capacitor}$

$P_{d\rightarrow c} > 0 \Rightarrow$ Capacitor absorbs energy from power supply Voltage Source

$P < 0 \Rightarrow$ Capacitor delivers power to the Voltage Source

\[ \text{direction of voltage drops sometimes opposite the Current} \]
B. Ideal Amplifiers: 4 types

1. Voltage Amplifier
2. Current Amplifier
3. Transconductance Amplifier
4. Transresistance Amplifier

\[ V_i \rightarrow V_o \]

Voltage Amp

\[ I_i \rightarrow I_o \]

Current Amp

\[ A_{\text{Vo}} = \text{open circuit gain} \]

\[ I_{\text{out}} = A_{\text{Vo}} I_i \]

Since there is no load to draw current through \( R_o \),

\[ A_{\text{isc}} = \text{short circuit current gain} \]

Because if you short circuit the output all the current goes through the short.

\[ I_{\text{sc}} = A_{\text{isc}} I_i \]
3. \( G_{\text{msc}} \) is Short Circuit Current gain.
   
   \( G_{\text{msc}} \) has units of \( \frac{1}{\Omega} = \text{Siemens} \)

4. \( R_{\text{moc}} \) = Open Circuit Gain.
   
   \( V_{\text{out}} = R_{\text{moc}} i_{\text{in}} \) with no load at the output.
source for \( V_{\text{in}} \)

source for \( I_{\text{in}} \)

Now we use the appropriate

1. Voltage Amplifier

\[
V_{\text{in}} = \frac{R_{\text{in}}}{R_{\text{in}} + R_s} \cdot V_s \quad \Rightarrow \quad V_{\text{out}} = \frac{R_L}{R_L + R_o} \cdot A_{\text{vo}} \cdot V_s
\]

\[
\therefore V_{\text{out}} = \left( \frac{R_{\text{in}}}{R_{\text{in}} + R_s} \right) \left( \frac{R_L}{R_L + R_o} \right) A_{\text{vo}} V_s \quad \Rightarrow \quad \text{we should choose larger } R_{\text{in}} \text{ and small } R_o
\]

Power supplied by source

\[
\frac{V_s^2}{R_s + R_{\text{in}}}
\]

Power delivered to load

\[
\frac{V_{\text{out}}^2}{R_L + R_o}
\]

\[
\Rightarrow \quad P_d \to P_l \quad \Rightarrow \quad P_d \text{ by source}
\]
2. Current Amplifier

\[ i_{in} = \frac{R_s}{R_s + R_{in}} i_s \]

Current divider rule

\[ i_0 = \frac{R_o}{R_L + R_o} A_{isc} i_{in} < A_{isc} i_{in} \]

\[ i_0 = \left( \frac{R_s}{R_s + R_{in}} \right) \left( \frac{R_o}{R_L + R_o} \right) A_{isc} i_s \]

To make the loading effect as small as possible we need to make the ratio as close to 1 as possible.

\[ \Rightarrow \text{We must have } R_{in} \ll R_s \text{ and } R_o \gg R_L \]
3. Transconductance Amplifier

\[ V_{in} = \frac{R_{in}}{R_{in} + R_s} V_s \]
\[ I_o = \frac{R_o}{R + R_L} G_{msc} V_{in} \]

\[ I_o = \left( \frac{R_{in}}{R_{in} + R_s} \right) \left( \frac{R_o}{R_0 + R_L} \right) G_{msc} V_s \]

We should choose \( R_{in} \) very large

so that \( \frac{R_{in}}{R_{in} + R_s} \approx \frac{R_{in}}{R_{in}} = 1 \)

Similarly \( R_0 \gg R_L \) so that \( \frac{R_0}{R_0 + R_L} \approx \frac{R_0}{R_0} = 1 \)

Large \( R_{in} \), Large \( R_0 \)
**Summary**

Voltage Amp

\[ V_o = \frac{R_{in}}{R + R_s} \frac{R_L A_{vo}}{R + R_L} \]

Require \( R_{in} \) very large, \( R_o \) very small.

Current Amp

\[ I_o = \frac{R_{s}}{R + R_{in}} \frac{R_o A_{vo}}{R + R_L} \]

\( R_{in} \) very small, \( R_o \) very large.

Trans Conduction

\[ V_o = \frac{R_{s}}{R_{s} + R_{in}} \frac{R_o}{R + R_L} \]

Require \( R_{in} \) very small, \( R_o \) very small.

Trans Conductance

\[ I_o = \left( \frac{R_{in}}{R_{in} + R_s} \right) \left( \frac{R_o}{R + R_L} \right) G_{msc} V_s \]

\( R_{in} \) large, \( R_o \) large.

\( G_{msc} \) V_s
4. Transresistance ( = Transimpedance) with source and load

\[ i_{\text{in}} = \left( \frac{R_s}{R_{\text{in}} + R_s} \right) i_s < i_s \]

\[ V_{\text{out}} = R_{\text{moc}} \left( \frac{R_L}{R_L + R_o} \right) i_{\text{in}} < R_{\text{moc}} i_{\text{in}} \]

\[ V_{\text{out}} = \left( \frac{R_s}{R_{\text{in}} + R_s} \right) \left( \frac{R_L}{R_L + R_o} \right) R_{\text{moc}} i_s \]

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We should choose \( R_{\text{in}} \) as small as possible and \( R_o \) as small as possible.
Cascading

\[ V_{\text{out}} = A_{v_0} V_{\text{in}} \left( \frac{R_L}{R_L + R_0} \right) \]

\[ V_{\text{in}}' = A_{v_0} V_{\text{in}} \left( \frac{R_{\text{in}}'}{R_{\text{in}}'} \right) \]

\[ V_{\text{in}} = \frac{R_{\text{in}}}{R_{\text{in}} + R_s} V_3 \]

\[ V_{\text{out}} = A_{v_0}' A_{v_0} \left( \frac{R_{\text{in}}}{R_{\text{in}} + R_s} \right) \left( \frac{R_{\text{in}}'}{R_{\text{in}}'} \right) \left( \frac{R_L}{R_{\text{in}} + R_0} \right) V_3 \]

If we reverse the two amplifiers we get (exchanging primed and unprimed)

\[ V_{\text{out}} = A_{v_0} A_{v_0}' \left( \frac{R_{\text{in}}}{R_{\text{in}} + R_s} \right) \left( \frac{R_{\text{in}}'}{R_{\text{in}}'} \right) \left( \frac{R_L}{R_{\text{in}} + R_0} \right) V_3 \]

In general \( V_{\text{out}} \neq V_{\text{out}}' \), i.e., cascading in two different ways does not give the same result.