Dependent Voltage and Current Sources

A linear dependent source is a voltage or current source that depends linearly on some other circuit current or voltage.

Example: you watch a certain voltmeter $V_1$ and manually adjust a voltage source $V_s$ to be 2.5 times this value.
**Dependent Voltage Source Example**

The voltage $V_s$ source depends linearly on $V_1$ (because you set it to 2.5 times $V_1$, no matter what $V_1$ is).

If you and the voltmeter are placed inside a box, the box functions as a voltage-dependent voltage source.

Note that the red box has two wires in (to read the input voltage) and two wires out (to deliver the output voltage).

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**Dependent Voltage and Current Sources**

- A linear dependent source is a voltage or current source that depends linearly on some other circuit current or voltage.
- We can have voltage or current sources depending on voltages or currents elsewhere in the circuit.

Here the voltage $V$ is proportional to the voltage across the element c-d.

$$V = A_v \times V_{cd}$$

A diamond-shaped symbol is used for dependent sources, just as a reminder that it's a dependent source.

Circuit analysis is performed just as with independent sources.
**The 4 Basic Linear Dependent Sources**

<table>
<thead>
<tr>
<th>Constant of proportionality</th>
<th>Parameter being sensed</th>
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</table>

- **Voltage-controlled voltage source** … \[ V = A_v V_{cd} \]
- **Current-controlled voltage source** … \[ V = R_m I_c \]
- **Current-controlled current source** … \[ I = A_i I_c \]
- **Voltage-controlled current source** … \[ I = G_m V_{cd} \]

**WHY DEPENDENT SOURCES?**

**EXAMPLE: MODEL FOR AN AMPLIFIER**

**AMPLIFIER SYMBOL**

- Differential Amplifier
  - \[ V_0 \text{ depends only on input } (V_+ - V_-) \]

**EXAMPLE:** \( A = 20 \) Then if input \((V_+ - V_-) = 10\text{mV}\); \( V_0 = 200\text{mV} \).

An actual amplifier has dozens (to hundreds) of devices (transistors) in it. But the dependent source allows us to model it with a very simple element.
Example: Dependent Source In an Amplifier

\[ V_0 = A(V_+ - V_-) \]

See the utility of this: this Model when used correctly mimics the behavior of an amplifier but omits the complication of the many many transistors and other components.

OP-AMP AND USE OF FEEDBACK

A very high-gain differential amplifier can function in an extremely linear fashion as an operational amplifier by using negative feedback.

Negative feedback \( \Rightarrow \text{Stabilizes the output} \)

We can show that that for \( A \to \infty \) and \( R_i \to \infty \),

\[ V_0 \approx V_{IN} \cdot \frac{R_1 + R_2}{R_1} \]

Stable, finite, and independent of the properties of the OP AMP!

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IDEAL OP-AMPS ANALYSIS TECHNIQUE

Assumption 1: The potential between the op-amp input terminals, \( v_+ - v_- \), equals zero.

Assumption 2: The currents flowing into the op-amp’s two input terminals both equal zero.

\[ \frac{v_{in}}{R_1} + \frac{v_{in} - v_{out}}{R_2} = 0 \]

\[ v_{out} = \frac{R_1 + R_2}{R_1} v_{in} \]

Non-inverting Amplifier
IDEAL OP-AMPS ANALYSIS EXAMPLE #2

\[
\frac{V_R - V_{IN}}{R_1} + \frac{V_R - V_{OUT}}{R_2} = 0
\]

\[
V_{OUT} = V_R - \frac{R_2}{R_1}(V_{in} - V_R)
\]

Inverting Amplifier with reference voltage

THE RAILS

The output voltage of an amplifier is of course limited by whatever voltages are supplied (the “power supplies”). Sometimes we show them explicitly on the amplifier diagram, but often they are left off.

Differential Amplifier

If the supplies are 2V and 0V, the output cannot swing beyond these values. (You should try this experiment in the lab.) So in this case we have upper rail = 2V, lower rail = 0V.

The rails cannot be larger than the supply voltages. For simplicity we will use the supply voltages as the rails.