MORE NODAL ANALYSIS

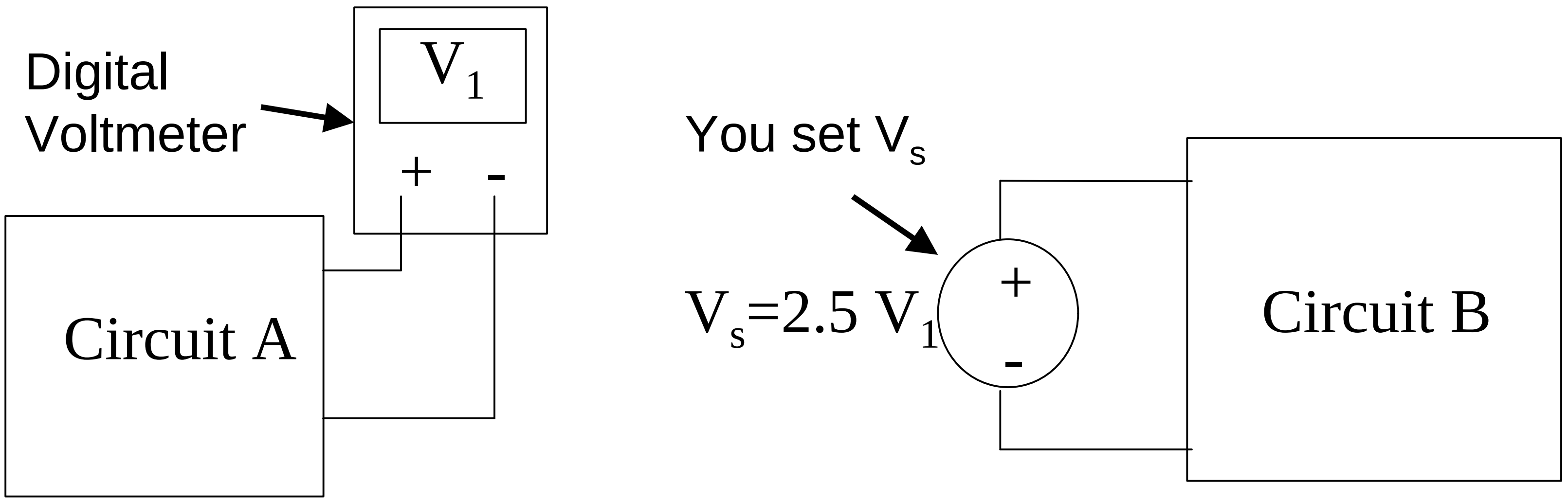
Today:

- Dependent Sources
- Examples

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.

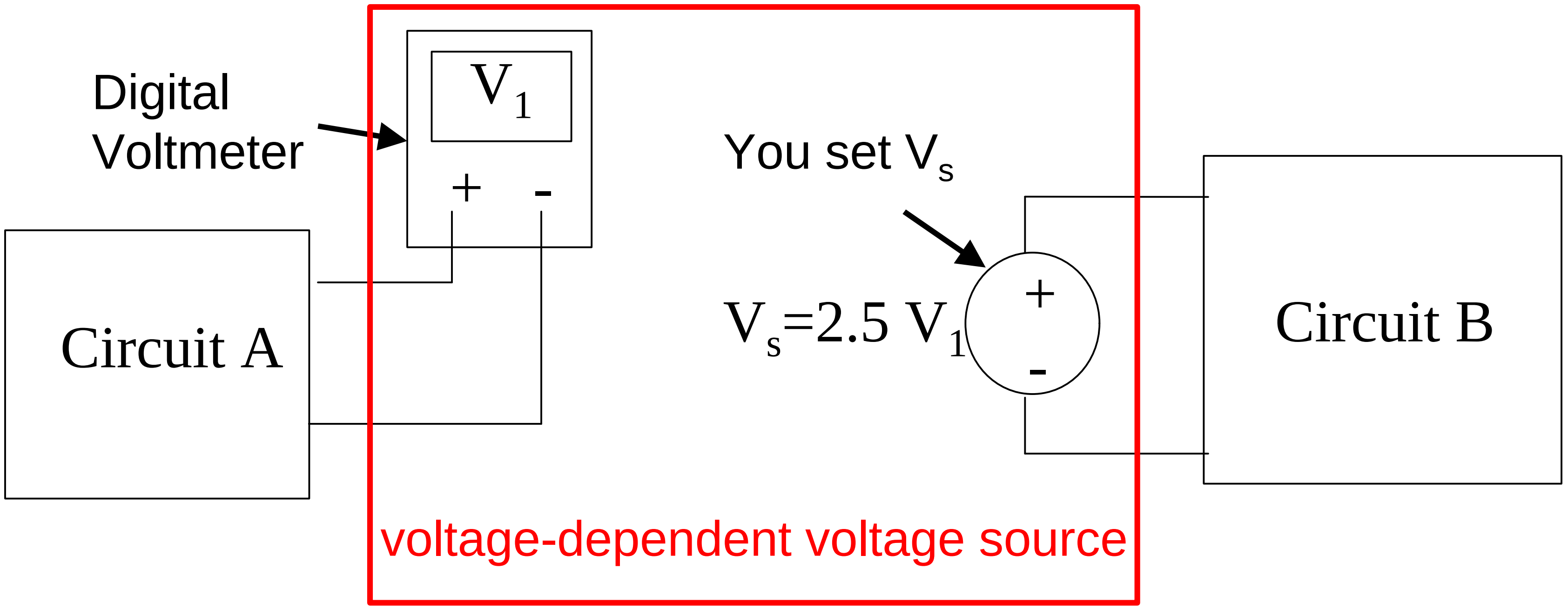
Example: you watch a certain voltmeter V_1 and manually adjust a voltage source V_s to be 2.5 times this value.



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.



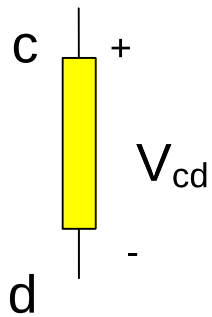
Note that the red box has two wires in (to read the input voltage) and two wires out (to deliver the output voltage).

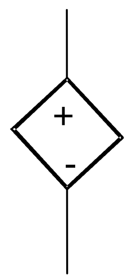
Dependent Voltage and Current Sources

• 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 .





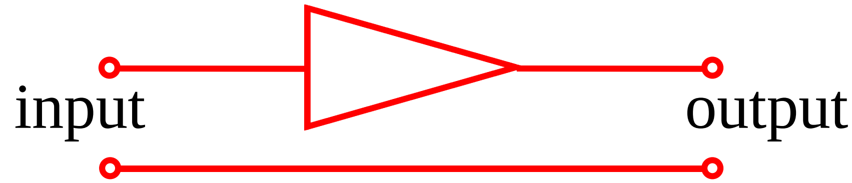
$V = A_v \times V_{cd}$

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

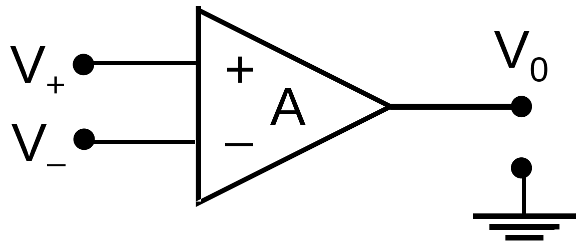
Circuit analysis is performed just as with independent sources.

WHY DEPENDENT SOURCES?
EXAMPLE: MODEL FOR AN AMPLIFIER

AMPLIFIER SYMBOL



Differential Amplifier



$$V_0 = A(V_+ - V_-)$$

V_0 depends only on input ($V_+ - V_-$)

EXAMPLE: A =20 Then if input (V_+-V_-) = 10mV; V_o = 200mV.

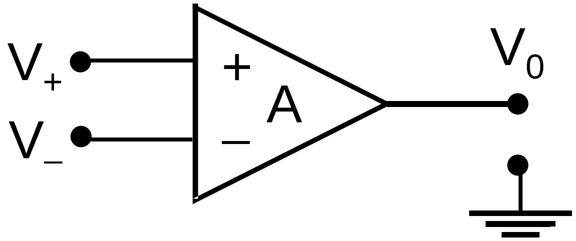
An actual amplifier has dozens (to hundreds) of devices (transistors) in it. But the dependent source allows us to model it with a very simple element.

EXAMPLE OF THE USE OF DEPENDENT SOURCE IN THE MODEL FOR AN AMPLIFIER

AMPLIFIER SYMBOL

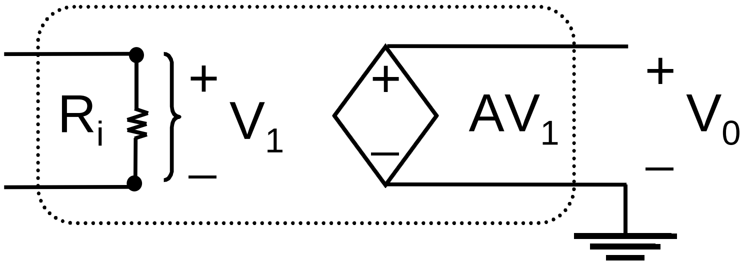
Differential Amplifier

$$V_0 = A(V_+ - V_-)$$



AMPLIFIER MODEL

Circuit Model *in linear region*



V_0 depends only on input $(V_+ - V_-)$

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.

The 4 Basic Linear Dependent Sources

Constant of proportionality

Parameter being sensed

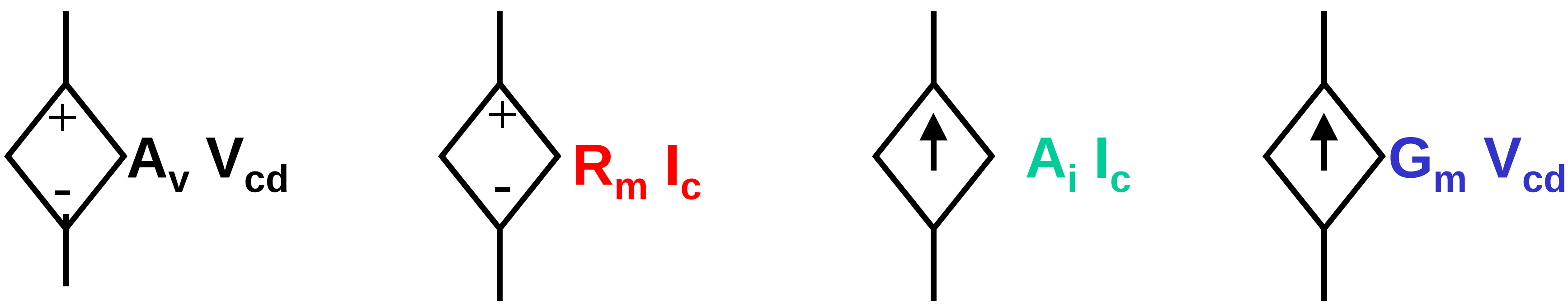
Output

Voltage-controlled voltage source … $V = A_v\ V_{cd}$

Current-controlled voltage source … $V = R_m\ I_c$

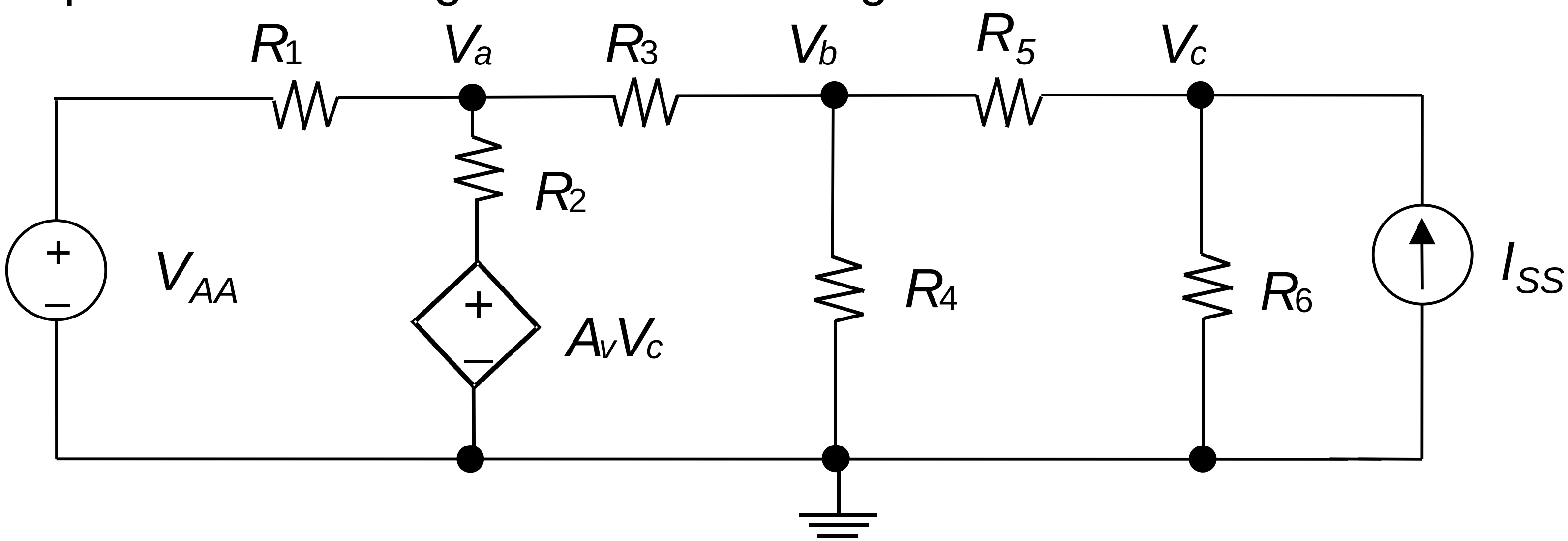
Current-controlled current source … $I = A_i\ I_c$

Voltage-controlled current source … $I = G_m\ V_{cd}$



NODAL ANALYSIS WITH DEPENDENT SOURCES

Example circuit: Voltage controlled voltage source in a branch



Write down node equations for nodes a, b, and c.

(Note that the voltage at the bottom of R_2 is "known" so current flowing down from node a is $(V_a – A_vV_c)/R_2$.)

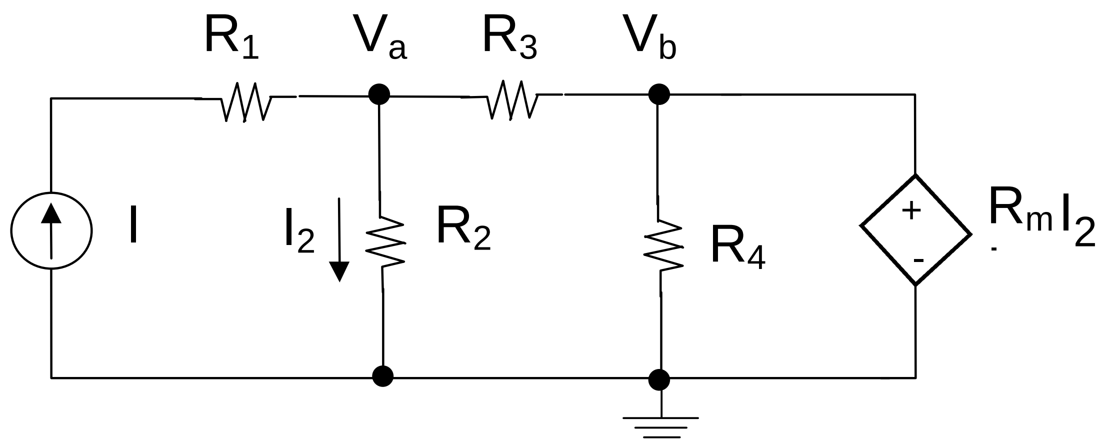
$$\frac{V_a - V_{AA}}{R_1} + \frac{V_a - A_v V_c}{R_2} + \frac{V_a - V_b}{R_3} = 0$$

$$\frac{V_b - V_a}{R_3} + \frac{V_b}{R_4} + \frac{V_b - V_c}{R_5} = 0 \qquad \frac{V_c - V_b}{R_5} + \frac{V_c}{R_6} = I_{SS}$$

CONCLUSION:

Standard nodal analysis works

ANOTHER EXAMPLE OF NODAL ANALYSIS WITH DEPENDENT SOURCES



Standard technique, except an additional equation is needed if the dependent variable is an unknown current as here. Note Vb is redundant.

$I = V_a / R_2 + (V_a - R_m I_2)/ R_3$ and $I_2 = V_a / R_2$

Solving: $I = V_a (1/R_2 + 1/R_3 - R_m /R_2 R_3)$

So $V_a = I R_2 R_3 /(R_2 + R_3 - R_m)$

NODAL ANALYSIS WITH DEPENDENT SOURCES

Finding Thévenin Equivalent Circuits with Dependent Sources Present

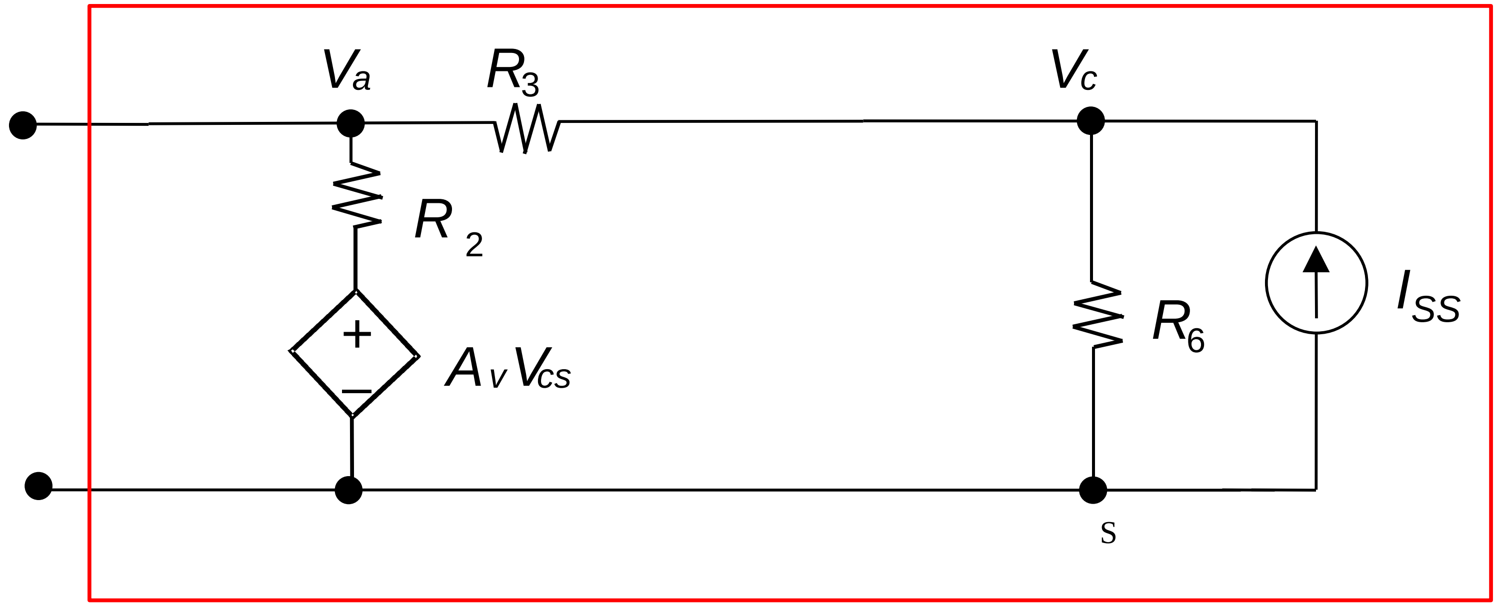
Method 1: Use V_{oc} and I_{sc} as usual to find V_T and R_T (and I_N as well)

Method 2: To find R_T by the "ohmmeter method" turn off only the *independent* sources; let the dependent sources just do their thing.

See examples in text (such as Example 4.3) and on blackboard

NODAL ANALYSIS WITH DEPENDENT SOURCES

Example : Find Thévenin equivalent of stuff in red box.



With method 2 we first find open circuit voltage (V_T) and then we "measure" input resistance with source I_{SS} turned off.

See blackboard for solution.