6.002x CIRCUITS AND ELECTRONICS

Dependent Sources
Amplifiers





Review

- Nonlinear circuits — can use the node method
- Small signal trick resulted in linear response

Today

- Dependent sources
- Amplifiers

Reading: Chapter 7.1, 7.2

Dependent Sources

Elements we have seen previously

Resistor

Independent
Current source

2-terminal 1-port devices

Dependent sources

A new element for our toolchest; can be linear or nonlinear

E.g., Voltage Controlled Current Source
Current at output port is a function of voltage at the input port

Dependent source in a circuit

First, an Example with an independent source

Example 1: Find V

Dependent Sources: Example

Example 2: Find V

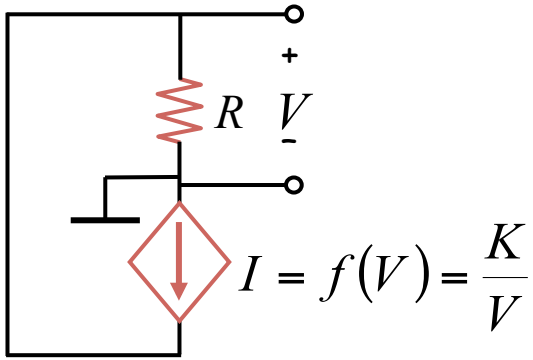
voltage
controled
current
source

Note that above is
abstracted view of:

Dependent Sources: Examples

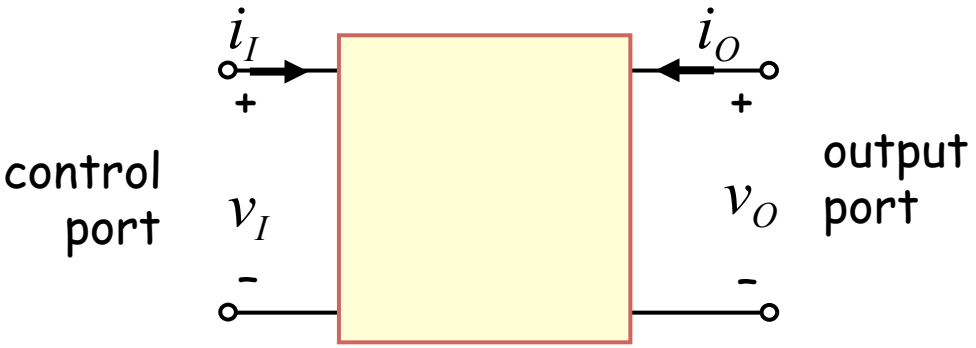
Example 2: Find V

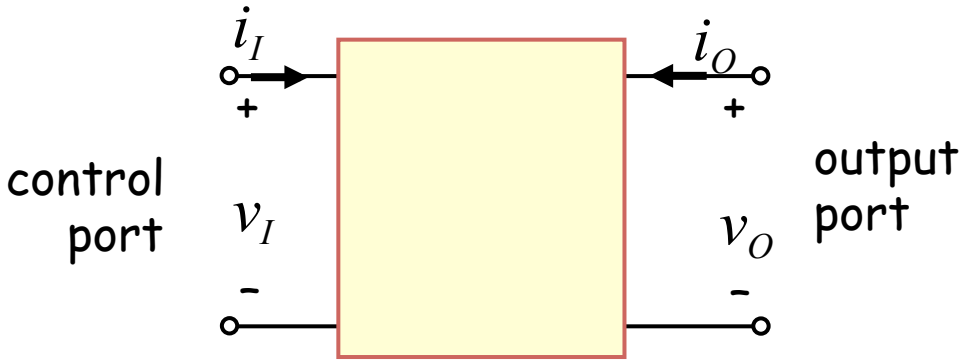
voltage
controled
current
source



e.g.
$K = 10^{-3}\ Amp \cdot Volt,$
$R = 1k\Omega$

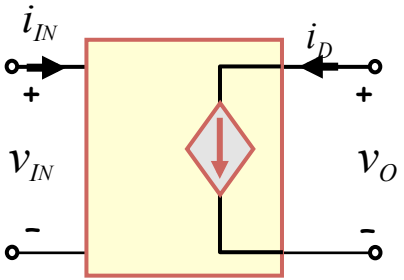
Other Types of Dependent Sources





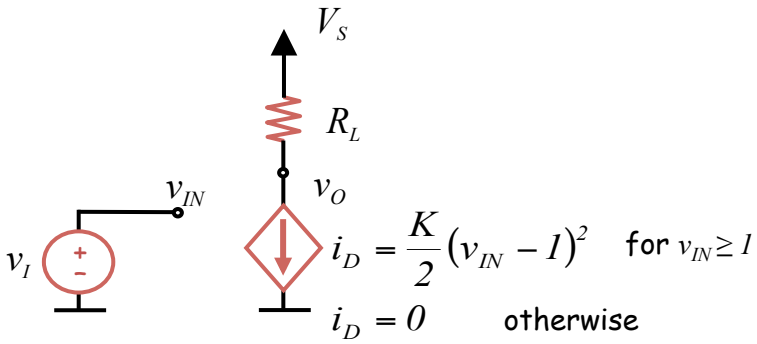
Similarly, CCVS, VCVS

Another dependent source example



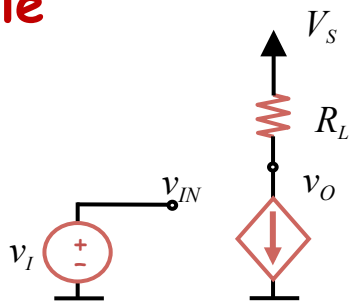
Simplify our Drawing

Solve



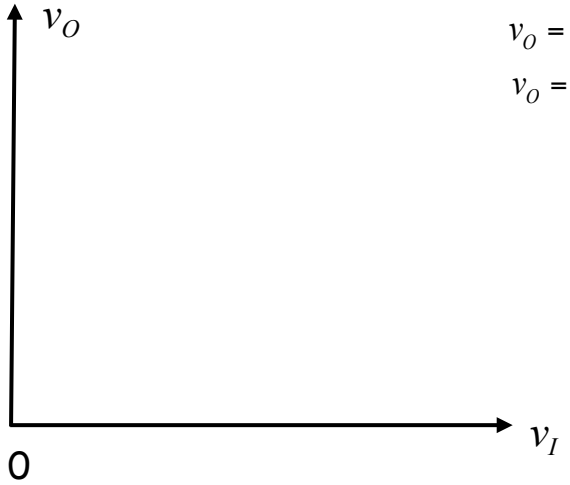
Hold that thought

Plot v_O versus v_I curve for our dependent source example



$$v_O = V_S - \frac{K}{2}(v_I - 1)^2 R_L \quad \text{for} \quad v_I \geq 1V$$

$$v_O = V_S \quad \text{for} \quad v_I < 1V$$



Superposition with Dependent Sources

One way

- leave all dependent sources in (note, dependent sources must be linear!)
- solve for one independent source at a time
- [section 3.5.1 of the text]

Next, Amplifiers

Why amplify?

Signal amplification key to both analog and digital processing.

Analog:

Besides the obvious advantages of being heard farther away, amplification is key to noise tolerance during communication

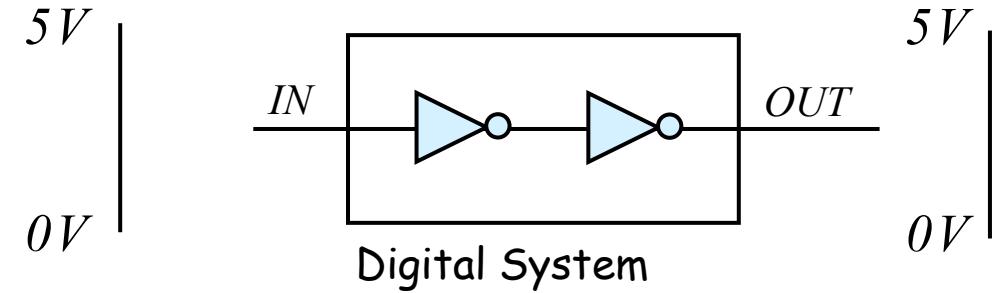
Why amplify?

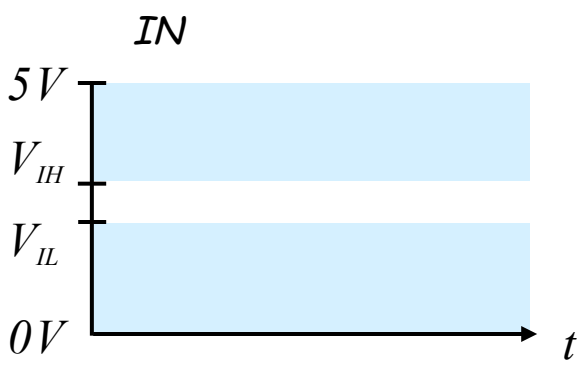
Amplification is key to noise tolerance during communication

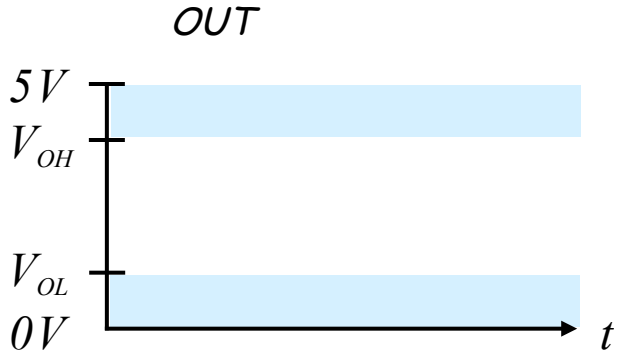
Try amplification

Why amplify?

Amplification if fundamental to the digital domain as well





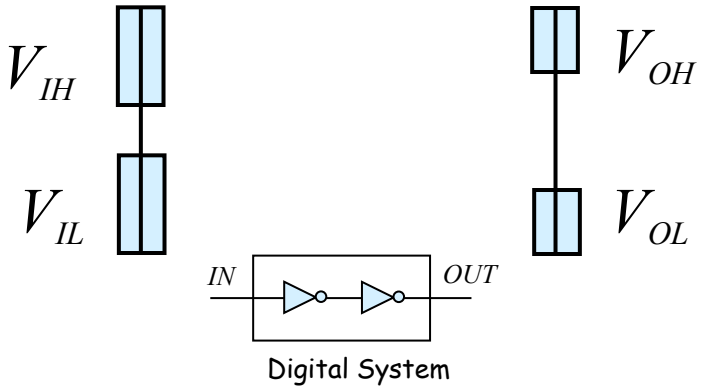


Why amplify?

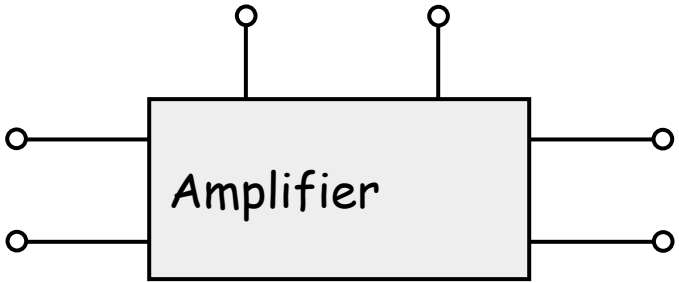
Digital domain:

Static discipline requires amplification!

Minimum amplification needed:



An amplifier is a 3-ported device, actually





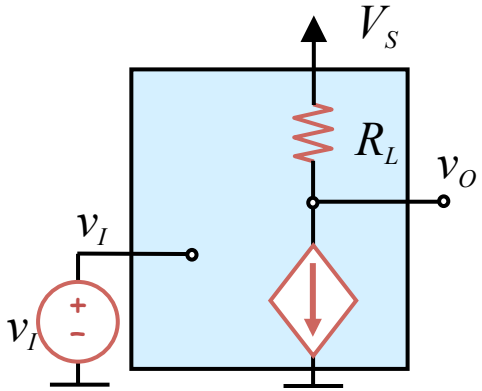
We often don't show the power port.

Also, for convenience we commonly observe "the common ground discipline."

In other words, all ports often share a common reference point called "ground."

How do we build one?

You already have! Remember…



Node method:

$$\frac{v_O - V_S}{R_L} + i_D = 0$$

$$v_O = V_S - i_D R_L$$



$$v_O = V_S - \frac{K}{2}(v_I - 1)^2 R_L \qquad \text{for } v_I \geq 1$$

$$i_D = \frac{K}{2}(v_{IN} - 1)^2 \quad \text{for } v_{IN} \geq 1$$

$$i_D = 0 \qquad \text{otherwise}$$

$$v_O = V_S \qquad \text{for } v_I < 1$$

Claim: This is an amplifier

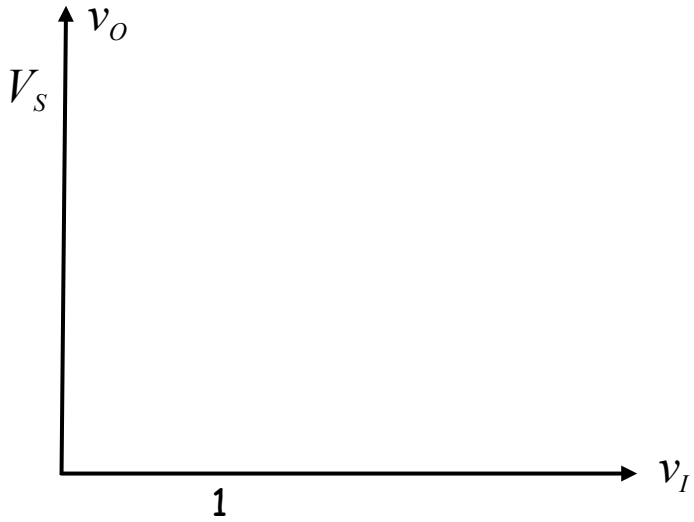
So, where's the amplification?

v_O versus v_I curve

e.g. $V_S = 10V, \quad K = 2\frac{mA}{V^2}, \quad R_L = 5k\Omega$

$$v_O = V_S - \frac{K}{2} R_L \left(v_I - 1\right)^2$$

$$v_O = 10 - 5\left(v_I - 1\right)^2$$



Plot v_O versus v_I

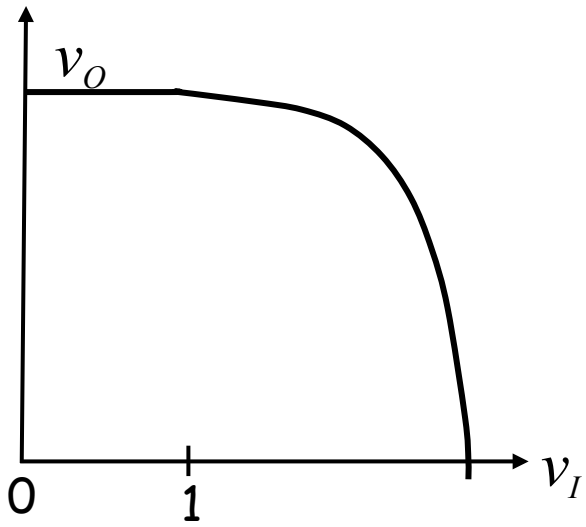
$$v_O = 10 - 5\left(v_I - 1\right)^2$$

v_I	v_O



Measure v_O.

One nit …



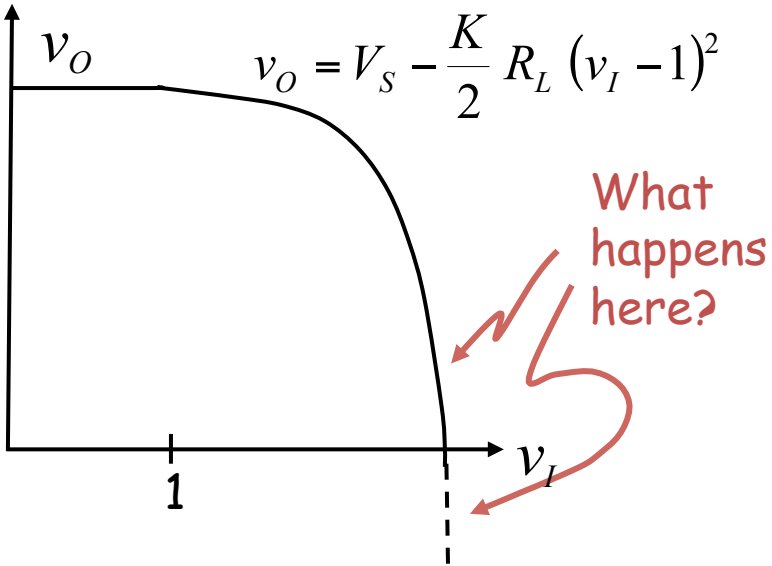
Mathematically,

$$v_O = V_S - \frac{K}{2} R_L \left(v_I - 1\right)^2$$

But, what happens Here with a practical device?

So this is mathematically predicted behavior in our amplifier built with an abstract dependent source

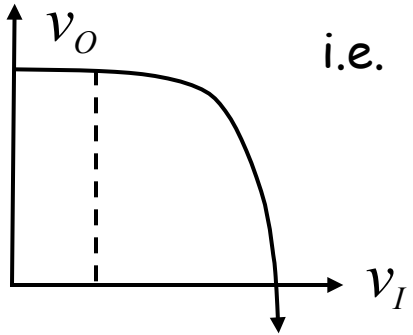
One nit …



However, looking at the circuit

If our VCCS is a device that can source (or supply) power

then the mathematically predicted behavior will be observed



i.e. $$v_O = V_S - \frac{K}{2} R_L \left(v_I - 1\right)^2$$

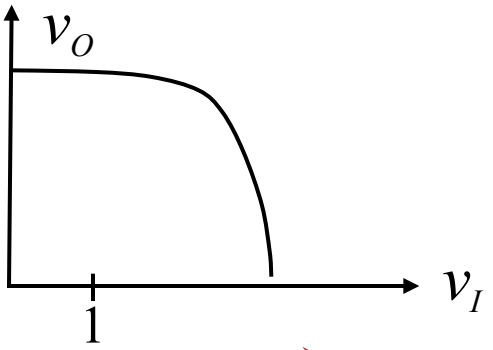
where v_O goes -ve

However, if our VCCS is a passive device

i.e., it does not provide power gain

Then it cannot source power, so v_O cannot go -ve.

e.g. i_D saturates (stops increasing) and we observe:



So, something must give!

Turns out, our model breaks down.

Commonly $$i_D = \frac{K}{2}(v_I - 1)^2$$

will no longer be valid when $v_O \leq 0$.



We will look at a practical device shortly…