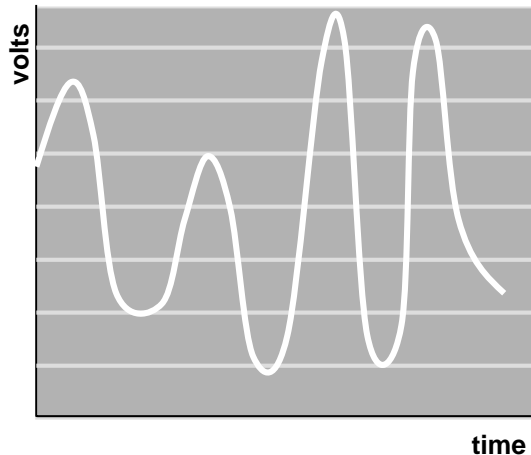


# Unit 19

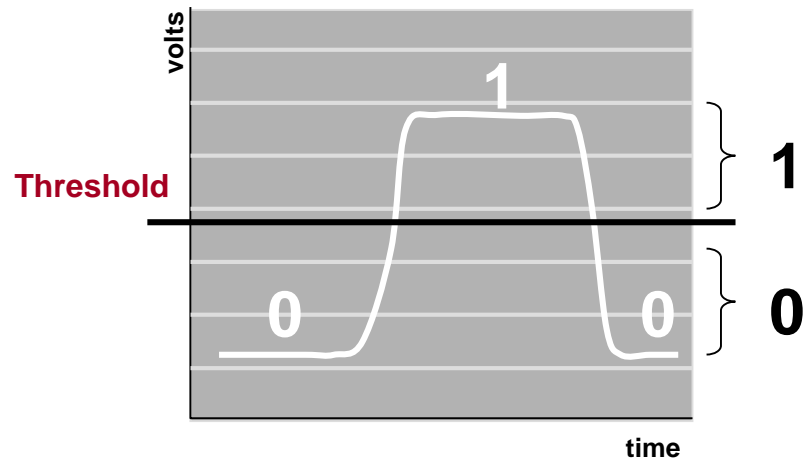
## Physical Design Constraints & Issues

# Signal Types

- Recall even digital signals are *just voltages*...
- Analog signal
  - Continuous time signal where each voltage level has a unique meaning
- Digital signal
  - Continuous signal where voltage levels are mapped into 2 ranges meaning 0 or 1

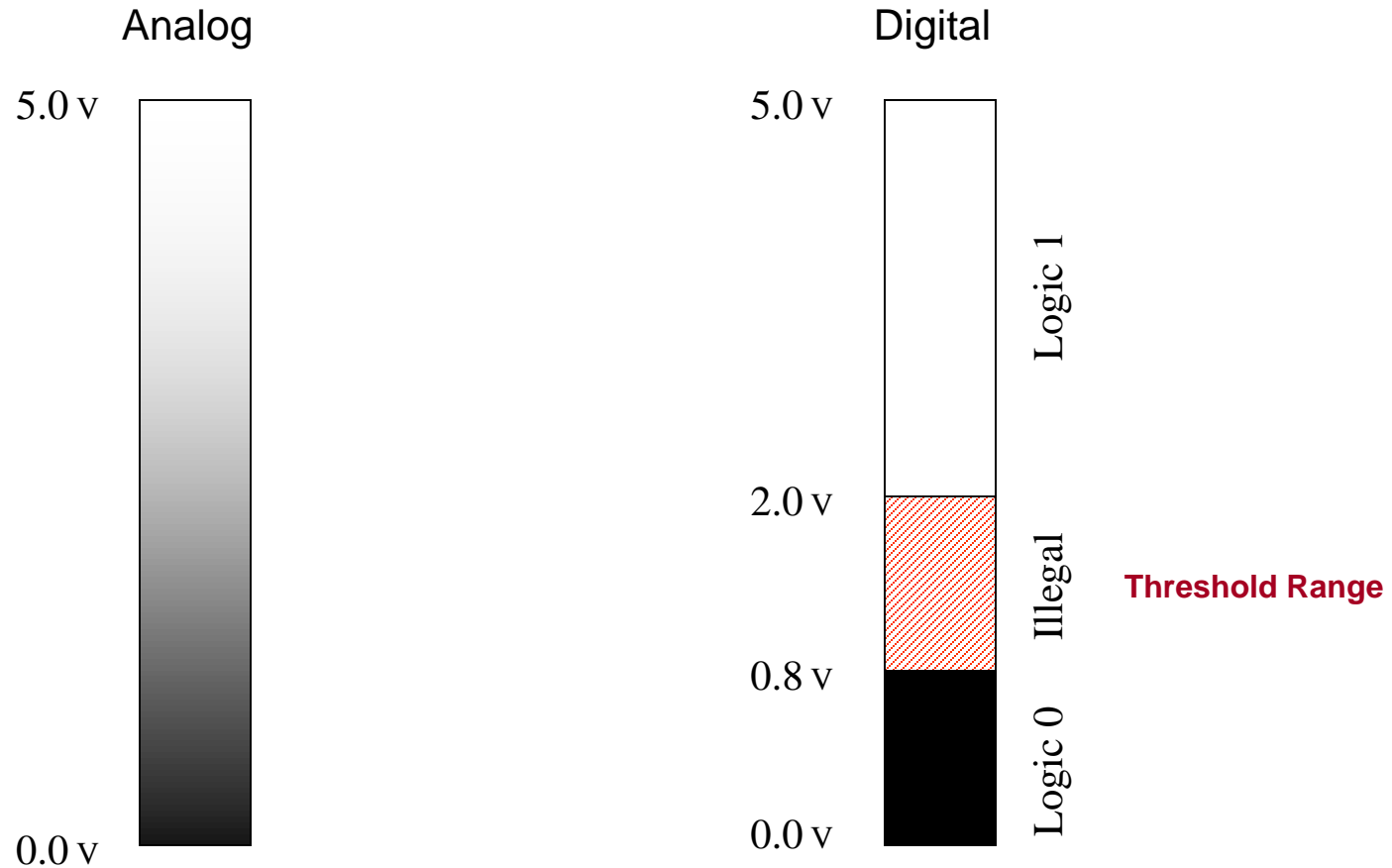


**Analog**



**Digital**

# Signals and Meaning



Each voltage value has unique meaning

Each voltage maps to '0' or '1'  
 (There is a small illegal range where meaning is undefined since threshold can vary based on temperature, small variations in manufacturing, etc.)

# **NOISE MARGINS, LEVEL SHIFTERS, & DRIVE STRENGTH**

# A Motivating Example

## Example 1

- You connect an output port to an LED (light emitting diode) and connect everything **correctly**. The light should turn on when you set your output bit to a high voltage (logic '1').
- When you turn the system on the LED does not glow. You measure the voltage at the gate output with a voltmeter and find it is not 5V but 1.8V? Why isn't it a logic 1?
- The \_\_\_\_\_ output ability from the output port is not \_\_\_\_\_ enough to adequately \_\_\_\_\_ the LED which then drags the voltage \_\_\_\_\_.

## Example 2

- You buy two digital chips (say a microprocessor and GPS reader)
- You correctly wire them together and write software to turn 'on' a pin on the microprocessor to a '1' to enable the GPS reader
- When the software runs the GPS unit does not turn on. Why?
- Different circuit implementation techniques use different voltage \_\_\_\_\_ to indicate \_\_\_\_\_ and may be \_\_\_\_\_

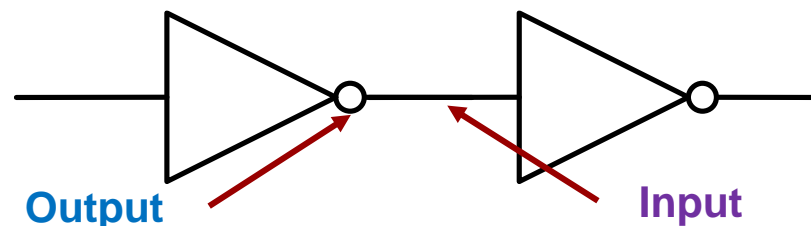
*Lesson To Be Learned: Not all 1's or 0's are created equal!*

# The Digital Abstraction

- Digital is a nice abstraction of voltage and current
  - Lets us just think 'on' or 'off' but not really worry about the voltages and currents underneath
- \_\_\_\_\_
- Not all 1's and 0's are created equal
  - A '1' can be any 'HIGH' voltage (maybe in the range \_\_\_\_\_)
  - A '0' can be any 'LOW' voltage (maybe in the range \_\_\_\_\_)
  - So 3V and 5V both mean \_\_\_\_\_ but they aren't equal
- Similarly certain outputs of a chip may connect to other devices that require more \_\_\_\_\_ than the output can \_\_\_\_\_
  - Think of connecting a \_\_\_\_\_ to your garden spigot
  - Or even worse your garden hose to a fire \_\_\_\_\_... would shred it
  - In the same way, inputs and outputs of different devices must be matched to the \_\_\_\_\_ of what they connect to

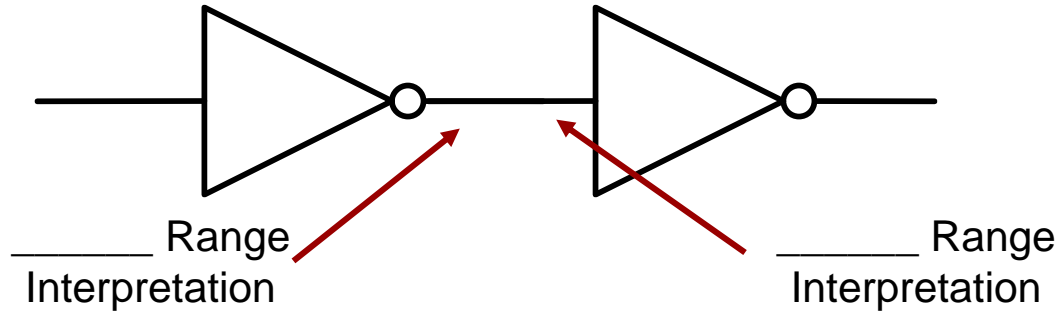
# Digital Voltage Noise Margins

- Consider the **output** of one digital circuit feeding the **input** of another
  - Assume the devices are from different vendors (families of devices)
- There may be different \_\_\_\_\_ and requirements of the two devices
  - Example: The output may produce 3V to mean logic '1' while the next device's **input requires 5V** to be used as logic '1'
- Analogy 1: Grades. Suppose the **cutoff for an A is 90%** (i.e. \_\_\_\_\_ input)
  - If you get a 91% (i.e. output result)... \_\_\_\_\_!
  - If you get an 89%...(\_\_\_\_\_ for this class! But \_\_\_\_\_ from the cutoff's perspective.)
- Analogy 2: Tickets. Suppose there are **100 available tickets to an event** (i.e. input limit)
  - If you are the 99<sup>th</sup> person (i.e. output result)... \_\_\_\_\_!
  - If you are the 101<sup>st</sup> person... \_\_\_\_\_!

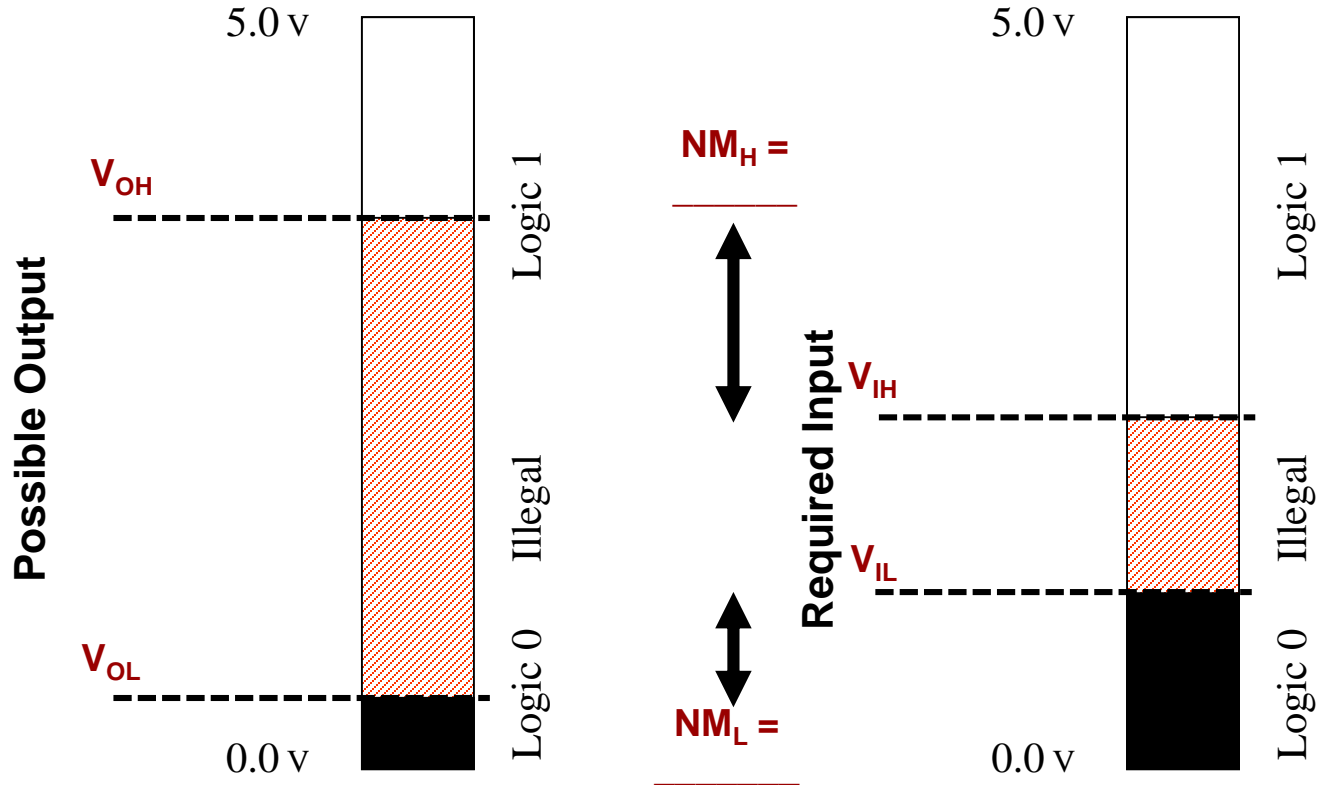


# Digital Voltage Noise Margins

- Consider one digital gate feeding another



OH = Output High  
 OL = Output Low  
 IH = Input High  
 IL = Input Low  
 NM = Noise Margin



As long as \_\_\_\_\_ and \_\_\_\_\_ we are in good shape...  
 Electromagnetic interference & power spikes can cause this to break down



# Class Activity

- Do an internet search for "74LS00 datasheet" (this is a chip w/ some 2-input NAND gates) and try to find any PDF and open it
- Skim the PDF and try to find:
  - V<sub>OH</sub>, V<sub>IH</sub>, V<sub>OL</sub>, V<sub>IL</sub>

# Fanout Analogy

- Can the output of one logic gate be connected to 5 or 10 or 100 gate inputs?
- Consider a sprinkler system...what will happen if you add 100 new sprinklers to your backyard?
- Pressure (voltage) will go \_\_\_\_\_ and \_\_\_\_\_ water (current) flow coming out of each

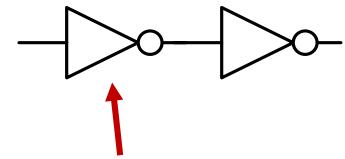


# Fanout

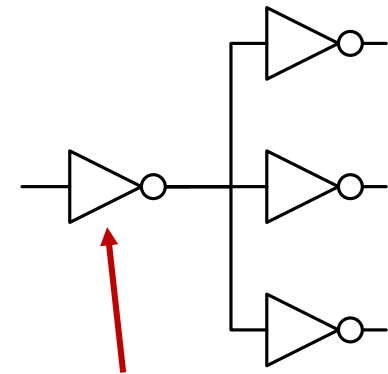
- Fanout refers the number of gates (aka "loads") an output connects to
- As the fanout increases delay

- 
- In addition, if fanout is too high the circuit may stop

- 
- Due to current limitations (see next slide)



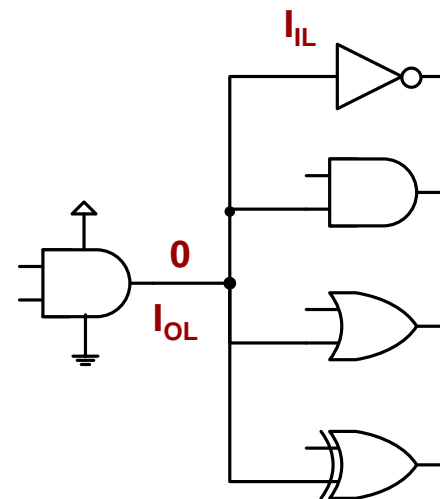
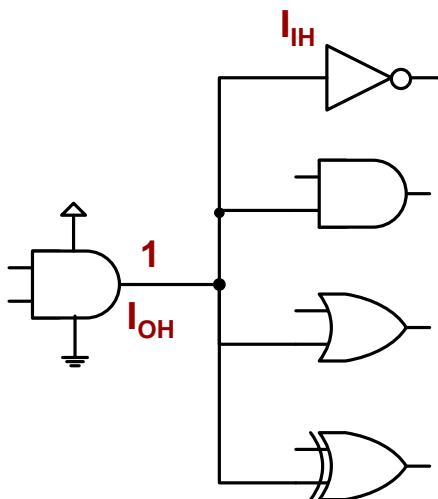
This inverter has a fanout (# of loads) = 1



This inverter has a fanout (# of loads) = 3

# Fanout & Current Limitations

- When a circuit outputs a 'HIGH' ('1') it can only supply ( \_\_\_\_\_ ) so much current (think of your garden hose spigot) =  $I_{OH}$
- When a circuit outputs a 'LOW' ('0') it can only suck up ( \_\_\_\_\_ ) so much current =  $I_{OL}$
- When a circuit receives a 'HIGH' signal on the input side it may need a certain amount of current to recognize the input as 'HIGH' =  $I_{IH}$
- When a circuit receives a 'LOW' signal on the input side it may need a certain amount of current to recognize the input as 'LOW' =  $I_{IL}$



# Example

- Consider the example where device A's output connects to device B's input
  - Are the voltage requirements compatible?
  - How many device B inputs can a single device A output drive?
    - Always use worst case of \_\_\_\_\_ output drive capability

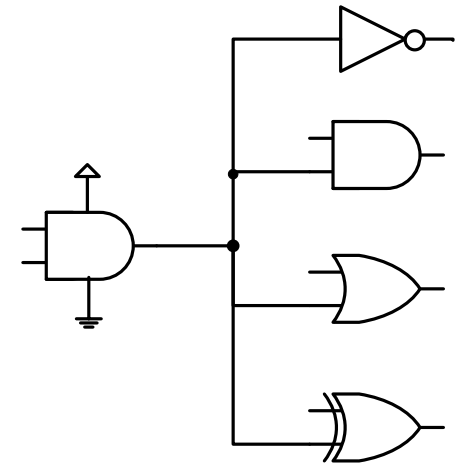
Dev.	VOH	VIH	VOL	VIL	IOH	IIH	IOL	IIL
A	3.4V	3.3V	0.5V	1.0V	-4 mA	-1 mA	10 mA	2 mA
B	3.2V	3.0V	0.6V	0.7V	-2 mA	-1 mA	6 mA	2 mA

Voltage requirements are \_\_\_\_\_  
 Dev. A VOH \_\_\_ Dev. B VIH  
AND  
 Dev. A VOL \_\_\_ Dev. B VIL

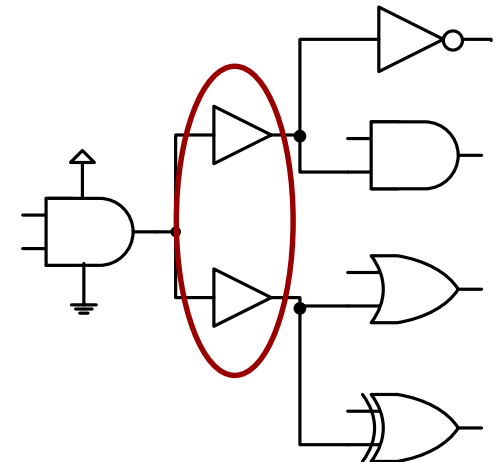
Dev. A's output can drive 4 Dev. B inputs  
 When outputting '1':  
 - (Dev. A IOH / Dev. B IIH) = (\_\_\_\_\_) = \_\_\_\_  
 When outputting '0':  
 - (Dev. A IOL / Dev. B IIL) = (\_\_\_\_\_) = \_\_\_\_  
 Drive capability = \_\_\_\_\_

# Consideration

- If we attach too many gates to one output it may not be enough to drive those gates
- Need to make sure the current requirements and capabilities match
- Let's say we connect one of the NAND gates on the 74LS00 chip to an input of N other NAND gates...
- Can it produce/suck up the required current...
- ...if  $N = 6$ ?
- ...if  $N = 12$ ?



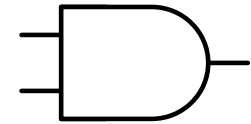
If  $I_{OH}$  or  $I_{OL}$  is too low we can split the loads by place intermediate buffers



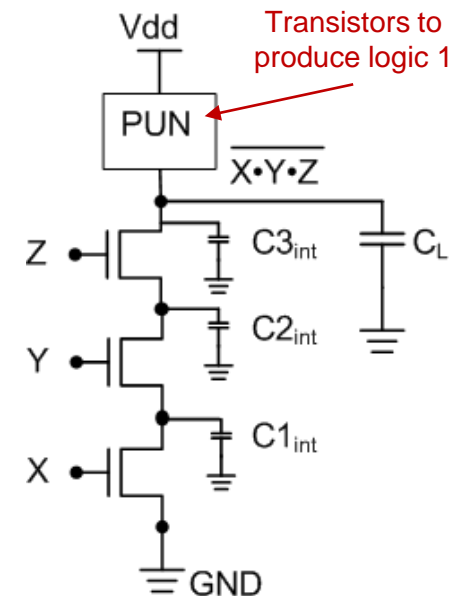
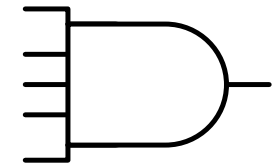
# Fan-in

- Fan-in refers to the number of \_\_\_\_\_ to a gate
- Each input adds additional resistance and \_\_\_\_\_ to the circuit and does so in such a way to cause the delay to grow \_\_\_\_\_
- This means delay grows quadratically with fan-in but linearly with fanout
  - Delay  $\approx a_1FI + a_2FI^2 + a_3FO$
- Important: Rarely want  $FI > \underline{\hspace{2cm}}$

Fanin = 2

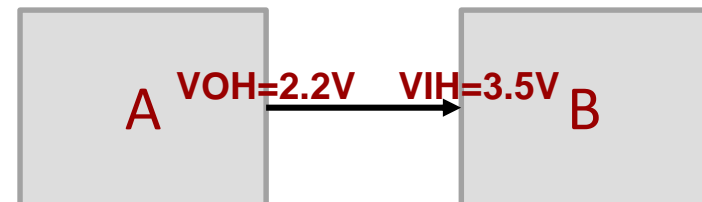


Fanin = 5



# All In the Family

- There are many families of circuit devices that talk different language (Each has a different  $V_{OH}$ ,  $V_{IH}$ ,  $V_{OL}$ ,  $V_{IL}$ ,  $I_{OL}$ ,  $I_{IL}$ , etc.)
- Examples:
  - \_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
- Must make sure if you interface two different devices that they are \_\_\_\_\_ (i.e.  $V_{OH}$  of device A is greater than  $V_{IH}$  of device B) or use a buffer/amplifier/level shifter circuit to help them talk to each other
  - <http://www.ti.com/lit/ds/symlink/cd4504b-ep.pdf>



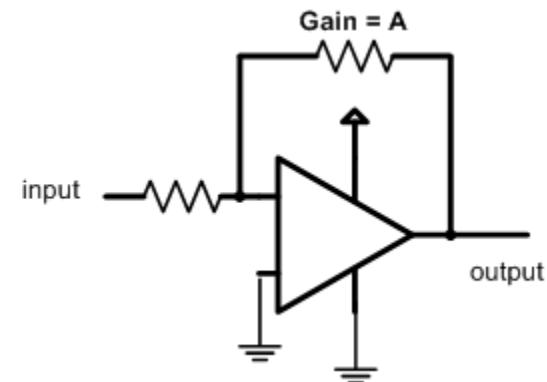


# Arduino Limits

- Arduino outputs can sink (suck up) and source (produce) around a maximum of 20 mA on a pin
  - [http://www.atmel.com/Images/Atmel-8271-8-bit-AVR-Microcontroller-ATmega48A-48PA-88A-88PA-168A-168PA-328-328P\\_datasheet.pdf](http://www.atmel.com/Images/Atmel-8271-8-bit-AVR-Microcontroller-ATmega48A-48PA-88A-88PA-168A-168PA-328-328P_datasheet.pdf)
- Do an internet search for "Standard Servo Motor Datasheet" and find the maximum current it may need
- It doesn't seem like the Arduino would be able to drive the servo motor.

How is it working?

- Remember the 3-pin interface: R = Power, B = Ground, W = Signal
- The signal is \_\_\_\_\_ from the power
- The power source is used to amplify the signal



# Another Example

- Now consider a speaker system where the power and signal are provide together
  - Given our Arduino use 5V = Vcc and its current limitations per pin, how much power can we supply to the speaker?
  - 5V \* \_\_\_\_\_ = \_\_\_\_\_
  - You need an \_\_\_\_\_...

