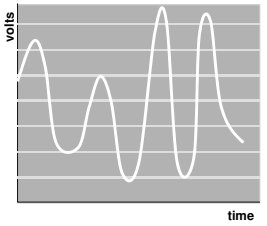
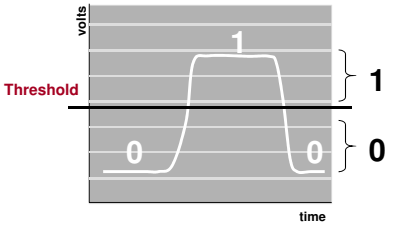
EE 109 Unit 18 – Noise Margins, Interfacing, and Tri-States

Signal Types

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

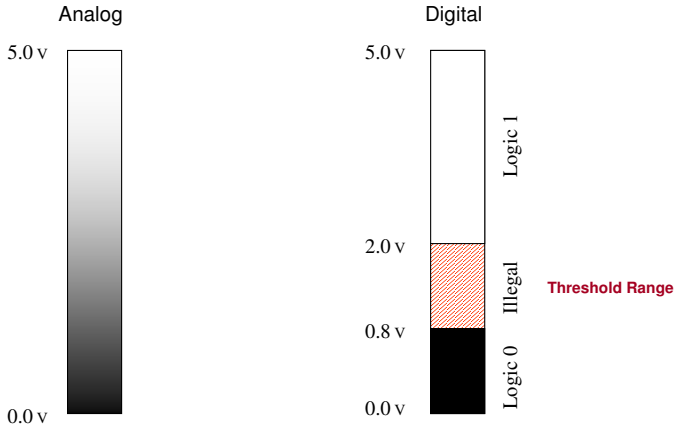


Analog



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 2.3V? 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 have correctly built a circuit using chips provided by your instructor and verified its outputs
- You then attempt to interface it to a specific microprocessor
- When you connect them the microprocessor indicates that it never senses your circuit producing logic '1'. Why?
- Different circuit implementation techniques use different _____ _____ to indicate '1' or '0' and may be _____

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

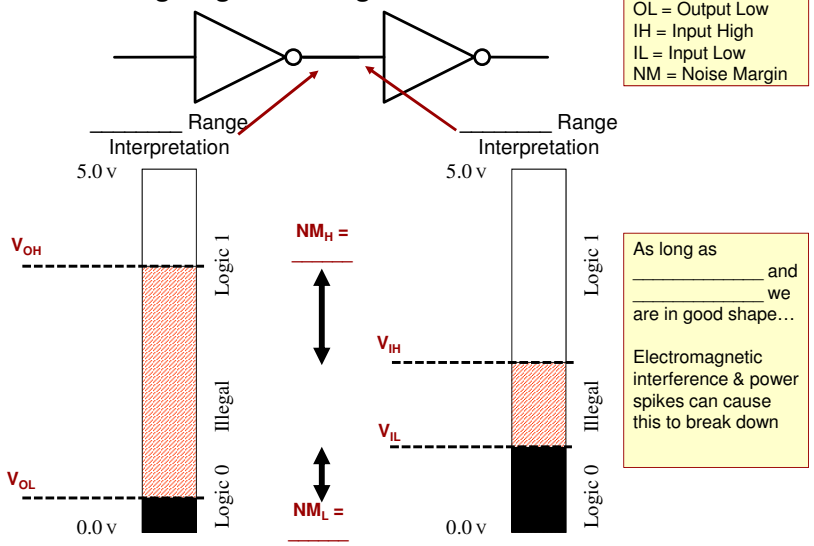
The Digital Abstraction

- 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 _____
  - 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 fire hose to your _____
  - Or even worse your _____ to a fire hydrant…it would _____ 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 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

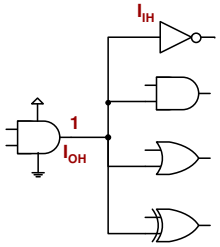
- Do an internet search for "74LS00 datasheet" (this is a chip w/ some 2-input NAND gates) and try to find any PDF and open it
- Skim the PDF and try to find:
  - VOH, VIH, VOL, VIL

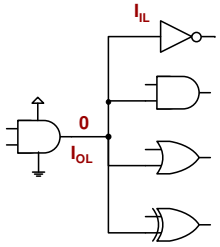
Analogy

- 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

Current Limitations

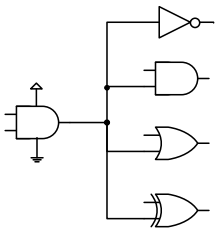
- When a circuit outputs a 'HIGH' ('1') it can only supply (_____) so much current (think of your garden hose spigot) = _____
- When a circuit outputs a 'LOW' ('0') it can only suck up (_____) so much current = _____
- When a circuit receives a 'HIGH' signal on the input side it may need a certain amount of current to recognize the input as 'HIGH' = _____
- 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' = _____



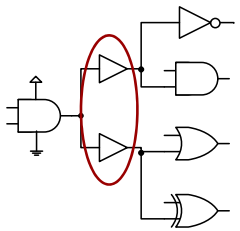


Consideration

- 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?

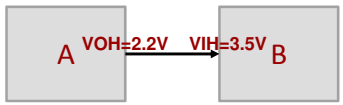


If I_{OH} or I_{OL} is too _____ we can split the loads by place intermediate buffers



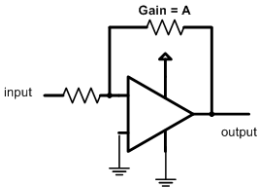
All In the Family

- There are many families of circuit devices that talk different language (Each has a different VOH, VIH, VOL, VIL, IOL, IIL, etc.)
- Examples:
  - _____
  - _____
  - _____
- Must make sure if you interface two different devices that they are _____ (i.e. VOH of device A is greater than VIH 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



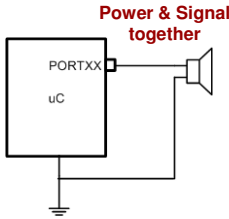
Arduino Limits

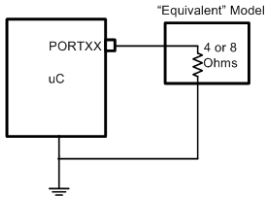
- Arduino outputs can sink (suck up) and source (produce) around a maximum of 20 mA on a pin
  - http://www.atmel.com/Images/Atmel-8271-8-bit-AVR-Microcontroller-ATmega48A-48PA-88A-88PA-168A-168PA-328-328P_datasheet.pdf
- Do an internet search for "Standard Servo Motor Datasheet" and find the maximum 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 _____ an amplifier…





TRI-STATE GATES

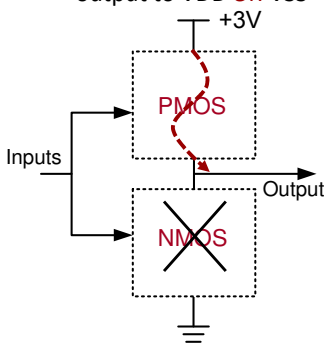
Typical Logic Gate

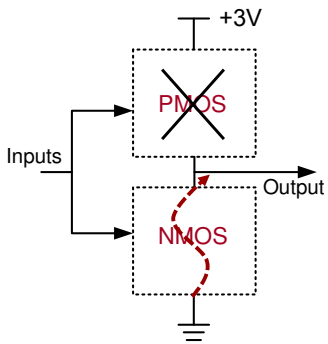
- Gates can output two values: 0 & 1
  - Logic '1' (Vdd = 3V or 5V), or Logic '0' (Vss = GND)
  - But they are ALWAYS outputting something!!!
- Analogy: a sink faucet
  - 2 possibilities: Hot ('1') or Cold ('0')
- In a real circuit, inputs cause *EITHER* a pathway from output to VDD *OR* VSS

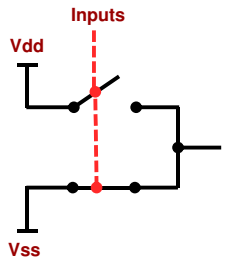
Hot Water = Logic 1

Cold Water = Logic 0

(Strapped together so always one type of water coming out)

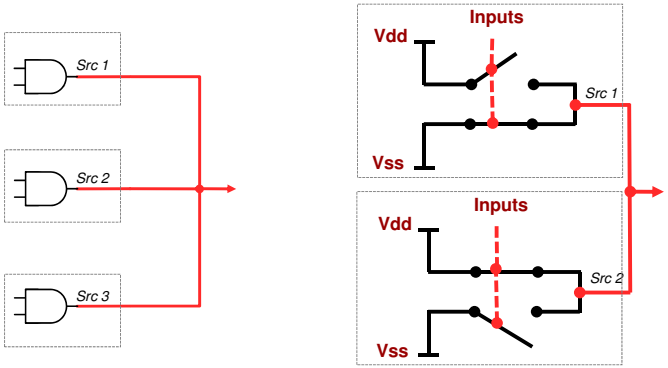






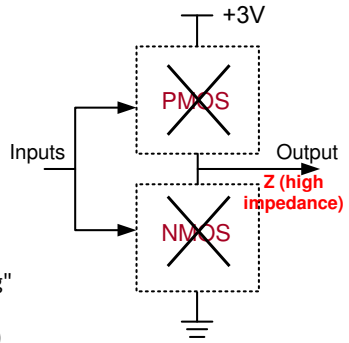
Output Connections

- Can we connect the output of two logic gates together?
- _____! Possible _____ (static, low-resistance pathway from Vdd to GND)
- We call this situation _____



Tri-State Buffers

- Normal digital gates can output two values: 0 & 1
  1. Logic 0 = 0 volts
  2. Logic 1 = 5 volts
- Tristate buffers can output a third value:
  3. __ = _____ = "Floating" (no connection to any voltage source..._____ resistance)
- Analogy: a sink faucet
  - 3 possibilities:
    1.) Hot water,
    2.) Cold water,
    3.) _____ water



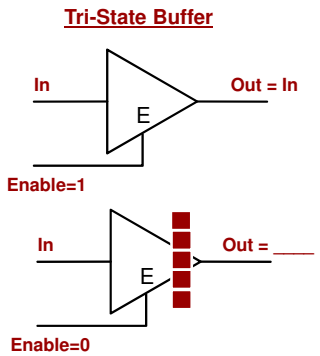
Hot Water = Logic 1

Cold Water = Logic 0

___ Water = Z (High-Impedance)

Tri-State Buffers

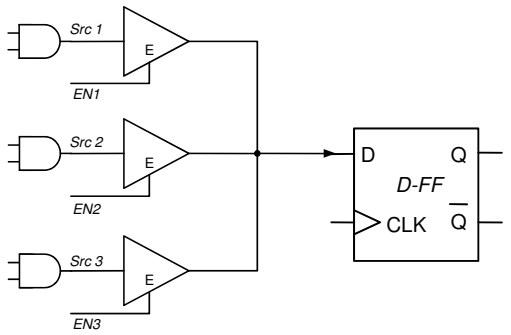
- Tri-state buffers have an extra enable input
- When disabled, output is said to be at high impedance (a.k.a. Z)
  - High Impedance is equivalent to no connection (i.e. floating output) or an infinite resistance
  - It's like a brick wall between the output and any connection to source
- When enabled, normal buffer



En	In	Out
0	-	Z
1	0	0
1	1	1

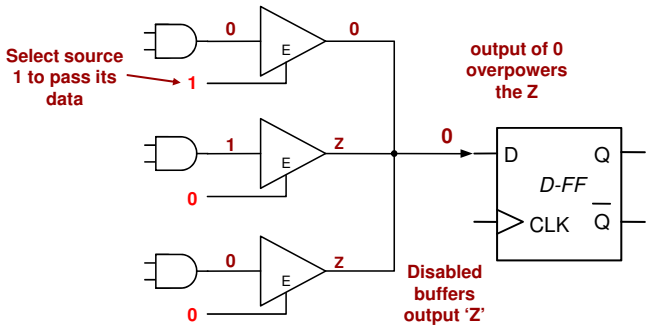
Tri-State Buffers

- We use tri-state buffers to _____ one output amongst several sources
- Rule: Only _____ at a time



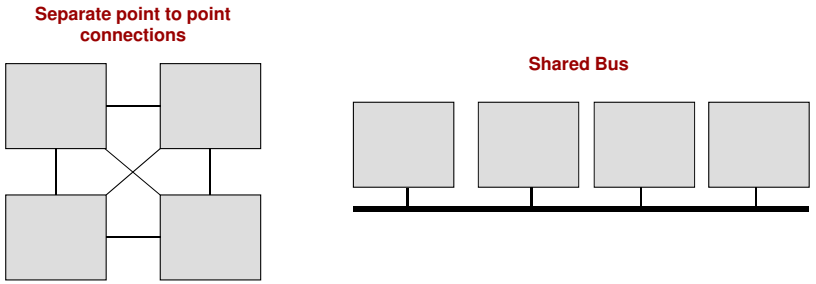
Tri-State Buffers

- We use tri-state buffers to share one output amongst several sources
- Rule: Only 1 buffer enabled at a time
- When 1 buffer enabled, its output overpowers the Z's (no connection) from the other gates



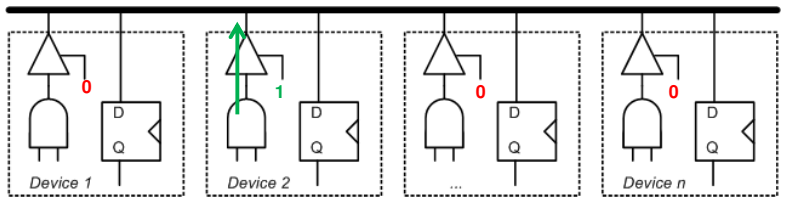
Communication Connections

- Multiple entities need to communicate
- We could use
  - Point-to-point connections
  - A _____



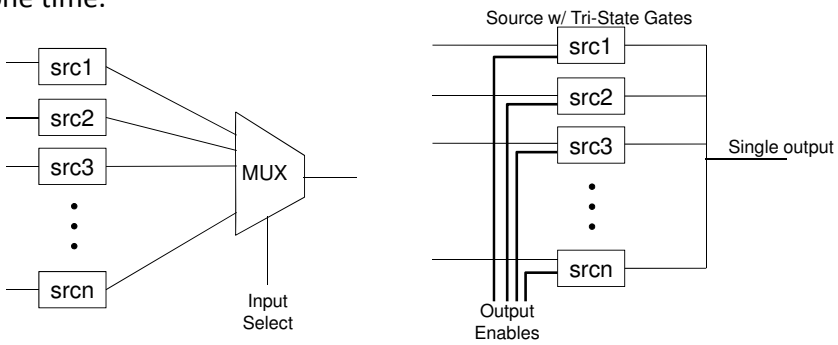
Bidirectional Bus

- _____ transmitter (otherwise bus contention)
- N receivers
- Each device can send (though 1 at a time) or receive



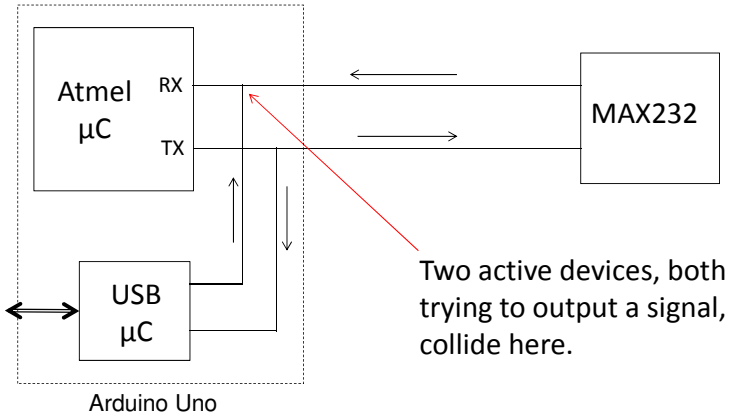
Tri-State Gates

- Big advantage: don't have to know in advance how many devices will be connected together
  - Tri-State gates give us the option of connecting together the outputs of many devices without requiring a circuit to multiplex many signals into one
- Just have to make sure only one is enabled (output active) at any one time.



Tri-State Gates

Problem: How can you use the serial I/O lines of the Arduino, which are also used for programming it?



Tri-State Gates

Solution: Use a Tri-State gate to isolate the MAX232 received data from the µC until programming is over.