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

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'

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
  - Let's 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 ____________

Digital Voltage Noise Margins
- Consider one digital gate feeding another

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

**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?

**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' = _______

**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
Arduino Limits

- Arduino outputs can sink (suck up) and source (produce) around a maximum of 20 mA on a pin
- 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...

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
**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

**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

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

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

Two active devices, both trying to output a signal, collide here.

Output of gate is floating until µC program makes Pxx a zero.