Unit 20

Physical Design Constraints & Issues

20.1

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

20.2

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.)

20.3

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 _______.

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

Digital Voltage Noise Margins

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 __________:

Digital Voltage Noise Margins

- Consider one digital gate feeding another
- 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 99th person (i.e. output result)… _______!
  - If you are the 101st person… _______!

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
Class Activity

• Do an internet search for "74LS00 datasheet" (this is a chip with 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

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 ___________

Fanout

• Fanout refers to 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)

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

<table>
<thead>
<tr>
<th>Dev.</th>
<th>VOH</th>
<th>VIH</th>
<th>VOL</th>
<th>VIL</th>
<th>IOH</th>
<th>IIH</th>
<th>IOL</th>
<th>IIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.4V</td>
<td>3.3V</td>
<td>0.5V</td>
<td>1.0V</td>
<td>-4 mA</td>
<td>-1 mA</td>
<td>10 mA</td>
<td>2 mA</td>
</tr>
<tr>
<td>B</td>
<td>3.2V</td>
<td>3.0V</td>
<td>0.6V</td>
<td>0.7V</td>
<td>-2 mA</td>
<td>-1 mA</td>
<td>6 mA</td>
<td>2 mA</td>
</tr>
</tbody>
</table>

Voltage requirement 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 = a_1F_1 + a_2F_1^2 + a_3F_0
• Important: Rarely want F_1 > __________

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 need an _________________…