LECTURE #3: Mixed Logic
EEL 3701: Digital Logic and Computer Systems
Based on lecture notes by Dr. Eric M. Schwartz

DeMorgan’s Law:
\[ A + B = \overline{AB} \quad \overline{AB} = A + B \]
(Show Venn Diagram.)

Activation Levels:
Definition: The activation level of a signal is the voltage level at which the signal is considered to be true.

Voltage Levels:
- High (H), +5V
- Low (L), 0V (ground)

Active-high is true when the voltage is high.
- Notation: X(H), X.H, or X_H
Active-low is true when the voltage is low.
- Notation: X(L), X.L, or X_L

Level Shifters:
- Change the activation level from high to low or low to high.

- Electrically – A level shifter complements.
- Logically – A level shifter does nothing to a signal.
(Note: The complement of a complement is itself: \(/(/A) = A)\)

“Bubbles:”
- A bubble represents active-low
- Lack of a bubble represents active-high
- Matching bubble to bubble or no bubble to no bubble changes nothing
- Mismatched bubbles represent a complement: A(H) = /A(L), B(L) = /B(H)

Remember: The voltage on a wire does not change due to a mismatched bubble on the end, but the logical interpretation does.
Gates: Mixed-Logic Style
1) Level Shifter, 74’04

2) AND, 74’08 (and Mixed-Logic OR version)

3) NAND, 74’00 (and Mixed-Logic OR version)

4) OR, 74’32 (and Mixed-Logic AND version)

5) NOR, 74’02 (and Mixed-Logic AND version)

Logical Equivalence
Remember: Bubbles have no effect logically.

The following OR shaped gates are logically equivalent:

The following AND shaped gates are logically equivalent:

Remember: These are not equivalent electrically.
The Basic Rule of Mixed Logic:
A mismatch creates an implied complement.
- No Bubble to Bubble => Complement
- Bubble to No Bubble => Complement
- Bubble to Bubble => NO complement
- No Bubble to No Bubble => NO complement

Remember: No Bubble means Active-High, Bubble means Active-Low

Procedure for Creating Mixed-Logic Circuits:
1) Draw Gates (with signals for inputs and outputs)
2) Add level shifters to address I/O activation mismatches
   - Externally, signal activation levels must be specified as active-high or -low
   - Internally, match circuit input and output activation levels
     - Then forget about activation levels!
3) Fill in internal bubbles and/or level shifters to deal with complements

Remember: Logically – A bubble has no effect (it only affects activation level).

Examples:
See Schwartz’s lecture “04 Mixed Logic.”

Note: Both NAND and NOR gates can be used to make any other type of gate.

Important Mixed-Logic Concepts:
1) Voltage and Logic – You gotta keep ‘em separated!
   - Electrically, bubbles represent activation levels.
     - Active-low is the same as a bubble.
     - Active-high is the same as no bubble.
     - Logically, a mismatch of bubbles complements.

2) Designing Circuits
   1st – Draw the basic gates.
   2nd – Add level shifters to match I/O activation levels.
     - Then forget about activation levels!
   3rd – Handle complements (with internal bubbles or level shifters).