Today

- Simplification
  - Practical use of DeMorgan's Theorem
  - Methodology
- Logic Gates
  - Equivalencies, Cost, and Notation
  - Multiple Input Semantics
- Effective DesignWorksing

DeMorgan and "Break the Bar"

- Motivation: Inversion of Entire Functions
- Heuristic: When simplifying, eliminate multivariable negations 1st
- Example: Simplify the following equation:

$$f(a,b) = \overline{a}\overline{b}$$

$$f(a,b) = \overline{a} + \overline{b}$$ DeMorgan's Law

"Break the Bar" Example 1

- Simplify the following equation:

$$f(x,y,z) = \overline{xy + \bar{x}z}$$

$$f(x,y,z) = \bar{x}\bar{y} \bullet \bar{\bar{x}}\bar{z} \qquad \text{DeMorgan's Law}$$

$$f(x,y,z) = (\bar{x} + \bar{y})(\bar{\bar{x}} + \bar{z}) \qquad \text{DeMorgan's Law}$$

$$f(x,y,z) = (\bar{x} + \bar{y})(x + \bar{z}) \qquad \text{Involution}$$

"Break the Bar" Example 2

- Simplify the following equation:

$$f(x,y,z) = \overline{\bar{x}\bar{y} + z} + x\bar{y}z + x\bar{y}\bar{z}$$

$$f(x,y,z) = \bar{\bar{x}}\bar{\bar{y}} \bullet \bar{z} + x\bar{y}z + x(\bar{y} + \bar{z}) \qquad \text{DeMorgan's Law}$$

$$f(x,y,z) = xy\bar{z} + x\bar{y}z + x(\bar{y} + \bar{z}) \qquad \text{Involution}$$

$$f(x,y,z) = xy\bar{z} + x\bar{y}z + x\bar{y} + x\bar{z} \qquad \text{Distributive}$$

Minimization "Cost"

- Dependant on target technology (CMOS)
- Possible Metrics: delay, integration, power, size, noise, $$, and driving capability
- Issues
  - "How do I minimize automatically?"
  - "How do I know something is minimized?"
- Better Algorithms
  - Boolean Cubes
  - Karnaugh Maps
  - Quine-McKlusky Algorithm

Logic Gates

- Equivalencies and Notation
  - Understanding vs. Technology Mapping
  - Converting to NAND (or NOR) only circuits

$$f(a,b,c) = \overline{ab} + c$$

- Multiple Inputs
  - "Fan-in" (vs. "Fan-out")
  - Syntax and Semantics (AND, OR, XOR)

Waveforms and Behavior

- Propagation Delay
  - Analog World
  - Scoped to many levels
- Highly Variable
  - Don t count on any particular behavior
  - Published Upper and Lower Bounds

Effective DesignWorksing

- Draw a schematic for the following in DesignWorks:
  - Standard Wiring
  - Self-imposed regular structures

$$f(x, y, z) = \overline{x}\,\overline{y} + xy + x\,\overline{y}$$