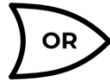


# CSE 390B Midterm Reference Sheet

## Basic Combinational Logic Gates



a	b	out
0	0	0
0	1	0
1	0	0
1	1	1



a	b	out
0	0	0
0	1	1
1	0	1
1	1	1



in	out
0	1
1	0



a	b	sel	out
0	0	0	0
0	1	0	0
1	0	0	1
1	1	0	1
0	0	1	0
0	1	1	1
1	0	1	0
1	1	1	1

## Basic Sequential Logic Gate



$$\text{out}(t) = \text{in}(t-1)$$

- triangle indicates implicitly connected to hardware clock
- out only changes on clock signal boundaries

## HDL

### Syntax:

- Basic Format: **ChipName** (in1=w1, in2=w2, ... out1=w3, out2=w4);
- Example: **Mux** (a=w1, b=w2, sel=w3, out=w4);
- Multiple wires connected to single output:  
**Mux** (a=w1, b=w2, sel=w3, out=w4, out=w5);

### Multi-Bit Buses:

- Accessing Single Bit: **w1[2]**
- Slicing Multiple Bits: **w1[0..3]** (indices inclusive)
- Multi-Bit Input/Output Declaration: **IN a[16];**

### Special Values:

- **true** is an any-width bus of all 1's, **false** of all 0's

## Hack Assembly Language

### Machine Characteristics:

- Two physical registers: **D, A**
- Pseudoregister **M** accesses memory at address **A**
- RAM and ROM have different, 0-indexed address spaces

### Existing Symbols:

- **R0 ... R15** are "virtual registers": symbols bound to addresses 0 ... 15 of RAM
- **SCREEN** is symbol bound to address at start of screen memory map
- **KBD** is bound to address of keyboard memory map (immediately after screen)

### Label: (**LABELNAME**)

- Binds symbol **LABELNAME** to line number of instruction after it

### A-Instructions: **@VALUE**

- Loads **VALUE** into A register

### C-Instructions: **DEST=COMP; JUMP**

- **DEST** or **JUMP** optional
- Performs **COMP**, result is stored in **DEST**, and if the result satisfies **JUMP** the PC jumps to address in **A** register

## C-Instructions: Options for Fields

### COMP

0
1
-1
D
A
!D
!A
-D
-A
D+1
A+1
D-1
A-1
D+A
D-A
A-D
D&A
D A
M
!M
-M
M+1
M-1
D+M
D-M
M-D
D&M
D M

### DEST

(empty)
M
D
A
MD
AM
AD
AMD

### JUMP

(empty)	No jump
JGT	Jump if out > 0
JEQ	Jump if out = 0
JGE	Jump if out >= 0
JLT	Jump if out < 0
JNE	Jump if out != 0
JLE	Jump if out <= 0
JMP	Always jump