COS 126 Lecture 12: Sequential circuits

It's not enough to know how to add,
we want to remember the answer!
(also, we need to know how to count...)

Combinational circuits

characterized by no loops
output well-defined function of input

Sequential circuits

characterized by loops (FEEDBACK)
output depends on TIME as well as input

FLIP-FLOP

Simple sequential circuit

Capable of "storing" a bit

- pulse on SET (S) line turns flip-flop on
- pulse on RESET (R) line turns flip-flop off

RS flip-flop

"Clocked" flip-flop

- extra line to control moment of flip

Clocked RS flip-flop

Use flip-flops to build registers and memory

Register

Sequence of flip-flops for storing bits

LOAD line (and clock)
    controls when new values are loaded

Use registers for
- PC
- memory addresses
- memory buffer
- arithmetic

Memory (bits)

Memory cell

 contents on OUT if SELECT and READ on

 IN used to set/reset if SELECT and WRITE on

Connect SELECT lines to decoder

 101 into decoder, SELECT and READ

 puts value of 101 flip-flop on OUT

Note: bits don’t move; their values propogate

Memory (words)

"Bit slice"

build circuit for first bit in every word

copy circuit 16 times for 16-bit word

Long and thin: actual memories split address into "row" and "column"

Other kinds of flip-flops

"Copy" bit value

D flip-flop

On clock pulse

- D = 1 set
- D = 0 reset

Edge-triggered

make sure bit value isn't used until ready

Master-slave flip-flop

Counter

Master-slave flip-flop with feedback

Internal state changes when clock goes on
Output changes when clock goes from on to off

Chain these cells together

on				
off	**on**			**1 0 0**
on				
off	**off**	**on**		**0 1 0**
on				
off	**on**			**1 1 0**
on				
off	**off**	**off**	**on**	**0 0 1**
on				
off	**on**			**1 0 1**
on				
off	**off**	**on**		**0 1 1**
on				
off	**on**			**1 1 1**
on				
off	**off**	**off**	**off**	**0 0 0**

High-level view of computer

Memory with feedback, clocked

Each clock tick

    enables change in memory state

Everything determined by wires, gates

    EXCEPT clock tick