Announcements

Project 2B turn-in Wednesday 11:00PM

Midterm 2 on Friday

Only on material since last midterm

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Computer Basics

How exactly does a computer work?

Integrated Circuits

Integrated circuits (ICs) are the power source of the information revolution

- **When computers were made of discrete parts, wires of every transistor (3), capacitor (2), resistor (2), etc. had to be hand-connected**
- **Labor intensive, expensive, error prone, unreliable, cumbersome, … even with robots!**
- **Integrated circuits solved that by 2 ideas**
  - **Integration -- circuits built as a unit from like parts**
  - **Photolithography -- printing process to make chips**

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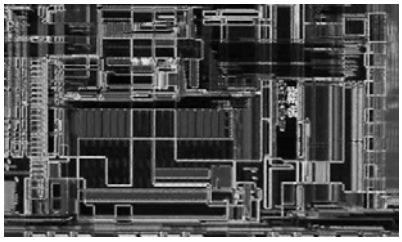
Intel Pentium Processor



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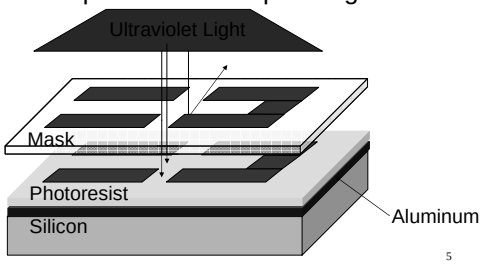
Photolithography

Consider process for depositing wires



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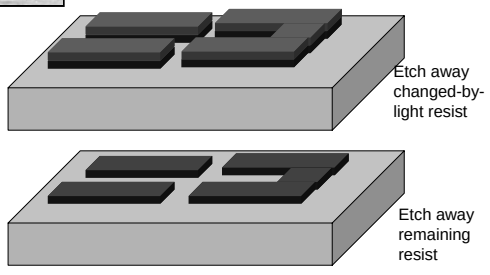
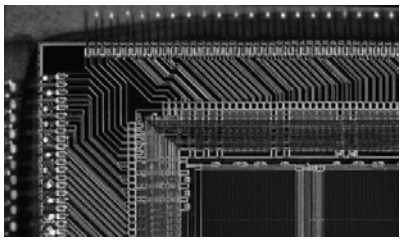
Remove Resist



The cost of the circuit is not related to complexity

R4400 NEC/MIPS Processor



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Semiconductors

Silicon, a semiconductor -- sometimes it conducts and sometimes it doesn't

- **It's possible to control when semiconductors do and don't conduct**

Compute by controlling conducting

Ex.: Use control to test (`Mars AND rover`)

Make semiconductor conduct if "Mars" is found

Make semiconductor conduct if "rover" is found

Send "yes" signal on wire

Detect presence/absence of "yes"

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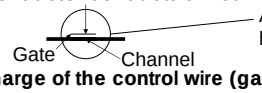
Field Effect

Charged objects are familiar -- use a nylon comb on a dry day

- **A charged field can control whether a semiconductor conducts or not**



The charge of the control wire (gate) is key

- **Neutral gate, channel doesn't conduct**
- **Charged gate, channel conducts**

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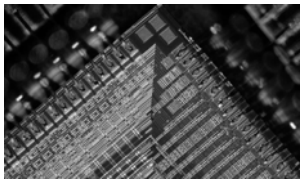
MIPS R10000 Processor



Notice that wires cross over other wires ...

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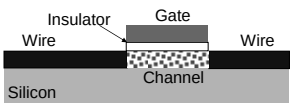
MOS Transistors

The field effect idea is implemented in metal-oxide-semiconductor transistors



Cross section view

View from above

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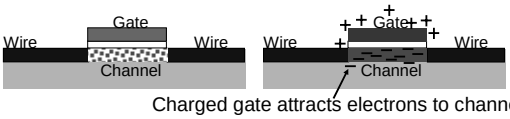
Operation

The two cases: the gate is neutral or the gate is charged



Charged gate attracts electrons to channel

Notice key points of integrated circuits:
Constructed as a unit of compatible parts
Fabricated in layers by photolithography

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Computers …

Deterministically execute instructions to process information

"Deterministically" means that when a computer chooses the next instruction to perform it is required by its construction to execute a specific instruction based only on the program and input it is given

Computers have no free will and they are not cruel

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Fetch/Execute Cycle

Computer = instruction execution engine

- **The fetch/execute cycle is the process that executes instructions**

Instruction Fetch (IF)
Instruction Decode (ID)
Data Fetch (DF)
Instruction Execution (EX)
Result Return (RR)

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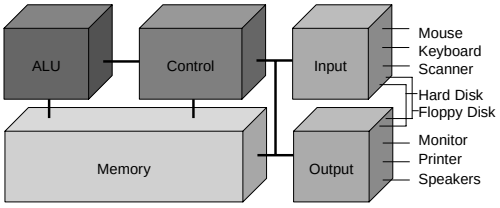
Anatomy of a Computer



The Hard Disk is the α-device

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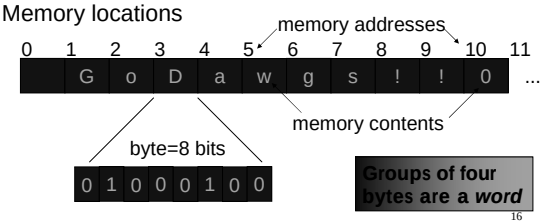
Memory …

Programs and their data must be in the memory while they are running

Memory locations



Groups of four bytes are a *word*

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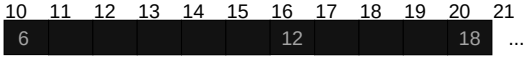
Control

The Fetch/Execute cycle is hardwired into the computer's control, i.e. it is the actual "engine"

The instructions executed have the form
ADDB 20, 10, 16

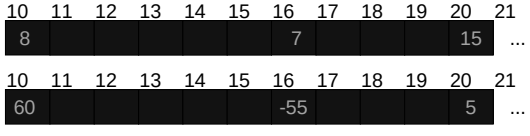


Put in memory location 20 the contents of memory location 10 + contents of memory location 16

Indirect Data Reference

Instructions tell *where* the data is, not *what* the data is … contents change

One instruction has many effects
ADDB 20, 10, 16



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ALU

The Arithmetic/Logic Unit does the actual computation

Each type of data has its own separate instructions			
ADDB	: add bytes	ADDBU	: add bytes unsigned
ADDH	: add half words	ADDHU	: add halves unsigned
ADD	: add words	ADDU	: add words unsigned
ADDS	: add short decimal numbers		
ADDD	: add long decimal numbers		

Most computers have only about a 100-150 instructions hard wired

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Input/Output

Input units bring data to memory from outside world; output units send data to outside world from memory

- Most peripheral devices are "dumb" meaning that the processor assists in their operation
- Disks are *memory* devices because they can output information and input it back again

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The PC's PC

The program counter (PC) tells where the next instruction comes from

- **Instructions are a word long, so add 4 to the PC to find the next instruction**

Program Counter: 112

110	111	112	113	114	115	116	117	118	119	120	121
688	724	ADD	210	216	220	AND	414	418	720	OR	...

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Clocks Run The Engine

The rate a computer "spins around" the Fetch/Execute cycle is controlled by it's clock

- **Current clocks run 2-3 GHz**
- **In principle, the computer should do one instruction per cycle, but often it fails to**
- **Modern processors try to do more than one instruction per cycle, and often succeed**

Clock rate is not a good indicator of speed

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Summary

Semiconductors make Info Revolution

- Semiconductors properties ...
  - **Fields controls when semiconductor conducts**
  - **On/off of conductors allows us to compute**

Fetch/execute cycle runs instructions

- 5 steps to interpret machine instructions
- Programs must be in the memory
- Data is moved in and out of memory

Instructions, data are represented in binary

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