



## 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?*

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## Integrated Circuits

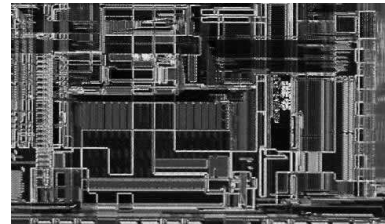
Integrated circuits (ICs) are the power source of the information revolution

- 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

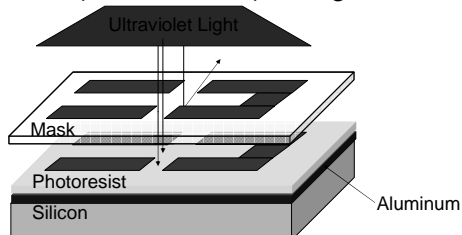


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## Photolithography

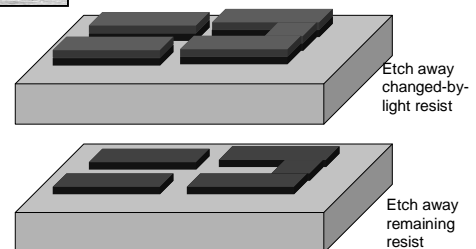
Consider process for depositing wires




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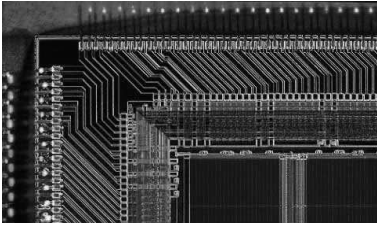
## Remove Resist




**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

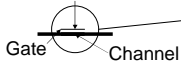
Send "yes" signal on wire      Detect presence/absence of "yes" s



## 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




A transistor has 3 wires

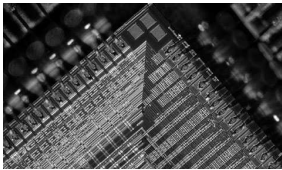
The charge of the control wire (gate) is key

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

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## MIPS R10000 Processor



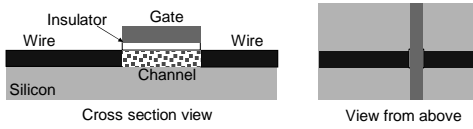
**Notice that wires cross over other wires ...**

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## MOS Transistors

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



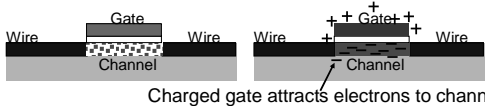
Cross section view      View from above

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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

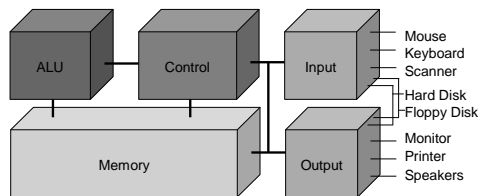
```

graph TD
    A[Instruction Fetch (IF)] --> B[Instruction Decode (ID)]
    B --> C[Data Fetch (DF)]
    C --> D[Instruction Execution (EX)]
    D --> E[Result Return (RR)]
    E --> A
  
```

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## Anatomy of a Computer



**The Hard Disk is the  $\alpha$ -device**

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## Memory ...

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

Memory locations

0	1	2	3	4	5	6	7	8	9	10	11	...			
						G	o	D	a	w	s	!	!	0	...

byte=8 bits

0 1 0 0 0 1 0 0

memory contents

**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

10	11	12	13	14	15	16	17	18	19	20	21	...
6						12				18		...

**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

10	11	12	13	14	15	16	17	18	19	20	21	...
8						7				15		...

10	11	12	13	14	15	16	17	18	19	20	21	...
60						-55				5		...

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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  
 686/24 | ADD 210,216,230 | 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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