

## L1: Introduction to Digital Systems



Sebastian Magierowski  
York University

## Web Stuff

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- Course **Wiki**
  - [https://wiki.cse.yorku.ca/course\\_archive/2013-14/F/3201/](https://wiki.cse.yorku.ca/course_archive/2013-14/F/3201/)

<b>Department of Electrical Engineering &amp; Computer Science</b>	<b>SC/CSE 3201 DIGITAL LOGIC DESIGN</b>
CSE3201	<b>Description</b>
What's New Course Outline Important Dates Grades Assignments Forums Contact Policies Resources Textbook FAQs Academic Dishonesty Wiki Help	LE/CSE 3201 4.00 Digital Logic Design  Theory and design of logic circuits used in digital systems. This is an intermediate level course that uses a Hardware Design Language to illustrate modern design techniques and is supplemented by hardware laboratory exercise (two hours per week). Prerequisites: A cumulative grade point average of 4.5 or better over all completed major computer science courses; SC/CSE 2021 4.00; SC/PHYS 3150 3.00 is strongly recommended. Prior to Fall 2009: Prerequisites: General prerequisites, including one of AK/AS/SC/COSC 2021 4.00, AK/AS/SC/COSC 2021 3.00, AK/AS/SC/CSE 2021 4.00; SC/PHYS 3150 3.00 is strongly recommended. Course credit exclusion: AK/AS/SC/COSC 3201 4.00.
	<b>Lecture Times</b>
	• Wednesdays and Fridays, 9:30am - 11:00am, CB 122
	<b>Lab Times</b>
	• Mondays, 9:30am - 11:30am, LAS 1004A

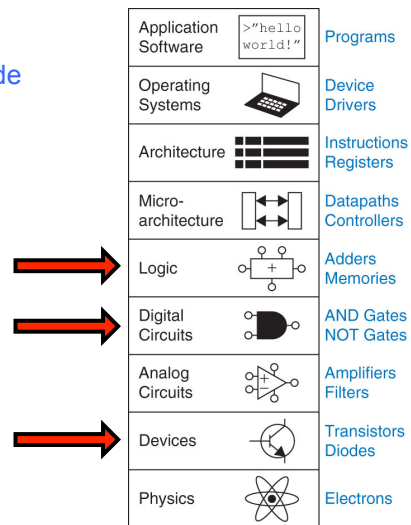
- Marks on **Moodle**

## Mark Breakdown

Component	Percentage
Assignments (4, 1 <sup>st</sup> one due Wed. Sept. 25)	10
Labs (9, 1 <sup>st</sup> one on Sept. 23)	15
Midterm (tentatively on Wed. Oct. 23 )	25
Final	50

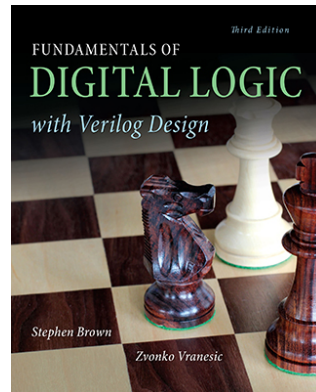
## Digital Logic Design

- We'll be studying logic circuits
  - stuff from which computers are made
  - treat signals as 1's and 0's
- Not just the desktop
  - embedded computers
  - everything is a computation
    - scientific calculations
    - spreadsheets
    - financial data
    - images
    - biometrics



## Textbook & Topics

- **Textbook:** Fundamentals of Digital Logic with Verilog Design
- Ch. 1 – 6 + B
  1. General Introduction
  2. Intro. to Logic Circuits
  3. Numbers and Arithmetic Circuits
  4. Combinational Circuits
  5. Flip-Flops, Registers, and Counters
  6. Synchronous Sequential Circuits
  - B. Implementation Technology












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## Textbook & Topics

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  6. Synchronous Sequential Circuits
  - B. **Implementation Technology**

Application Software		Programs
Operating Systems		Device Drivers
Architecture		Instructions Registers
Micro-architecture		Datapaths Controllers
Logic		Adders Memories
Digital Circuits		AND Gates NOT Gates
Analog Circuits		Amplifiers Filters
Devices		Transistors Diodes
Physics		Electrons

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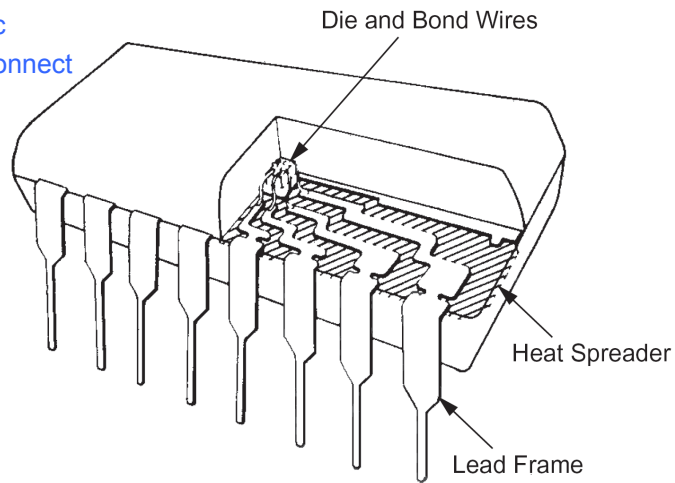
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## Digital Hardware: Intra-Packages

- Basic DIP stuff
  - re-flow plastic
  - simple interconnect



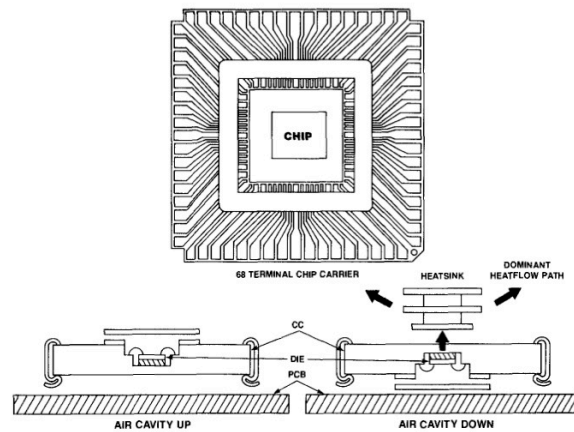
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## Digital Hardware: Intra-Packages

- Advanced packages
  - chips placed on ceramic substrate and sealed in air cavity (up or down)



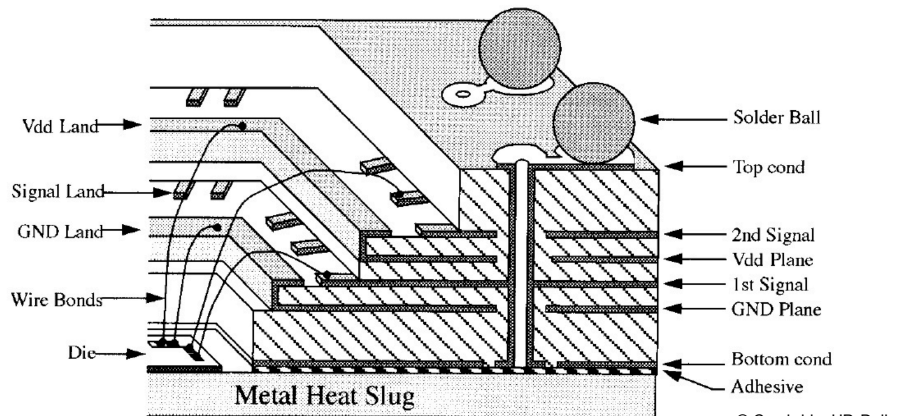
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## Digital Hardware: Intra-Packages

- Advanced packages
  - like mini boards



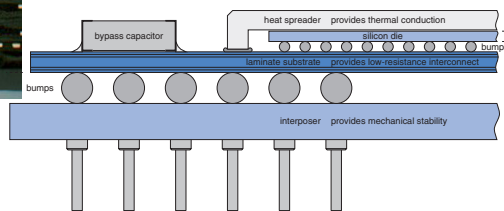
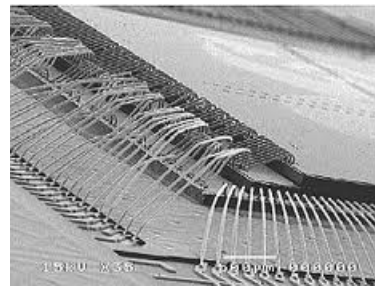
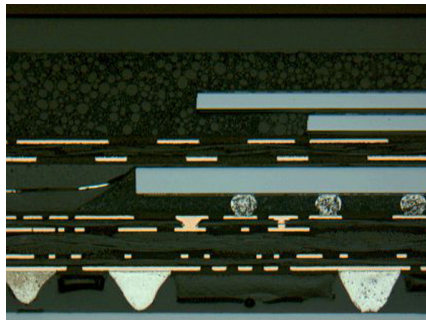
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## Digital Hardware: Intra-Packages

- Advanced packages
  - flip-chip and 3D stacking

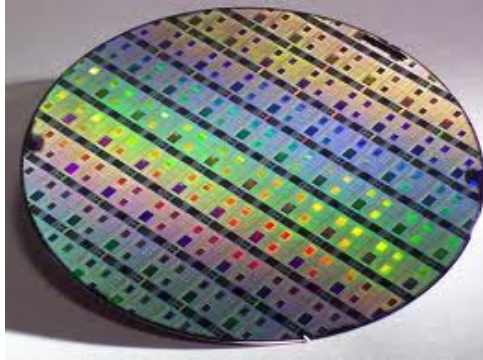


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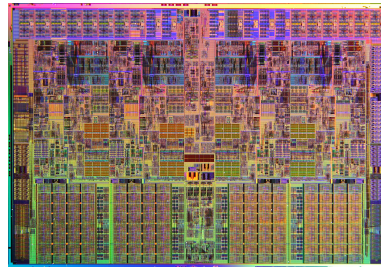
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## Digital Hardware: Wafers



30 cm diameter **wafer**

- **chips** ~ 25 mm on a side
- ~ 100 per wafer
- ~ 15 operational in new tech



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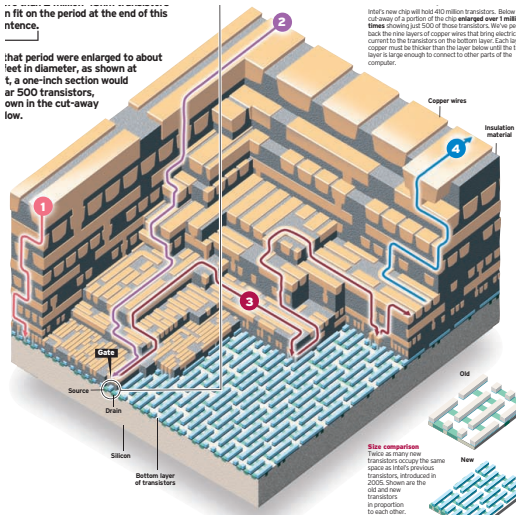
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## Digital Hardware: Chips

in fit on the period at the end of this sentence.

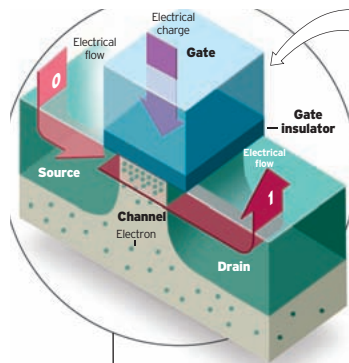
that period were enlarged to about 1 cent in diameter, as shown at right, a one-inch section would contain 500 transistors, own in the cut-away view.



Intel's new chip will hold 400 million transistors. Below is a cutaway of a portion of the chip enlarged over 1 million times showing just 500 of those transistors. We've overlaid the fine lines of copper wires that bring electrical current to the transistor on the bottom layer. Each box of copper must be thicker than the layer below and the foil layer is large enough to connect to other parts of the computer.

**Size comparison**  
Here, all four new transistors occupy the same space as their previous transistors, introduced in 2005. Shows are the old and new transistors, in proportion to each other.

source: Steve Cowden  
THE OREGONIAN



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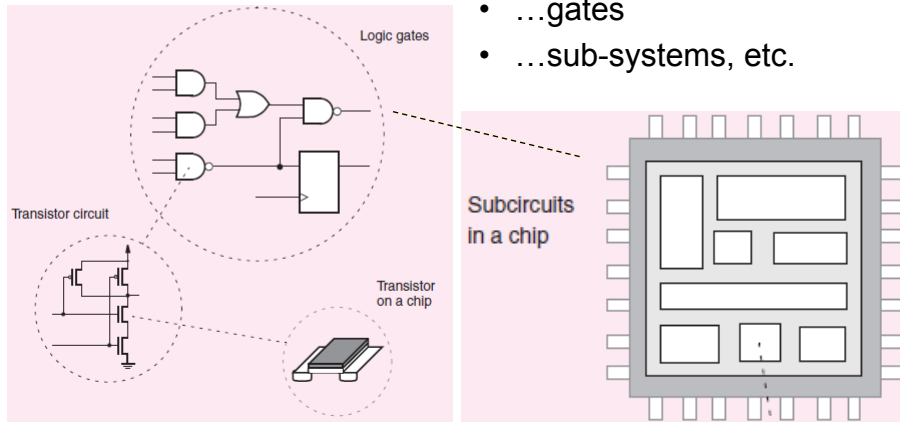
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## On Chip

• From transistors to...

- ...circuits
- ...gates
- ...sub-systems, etc.

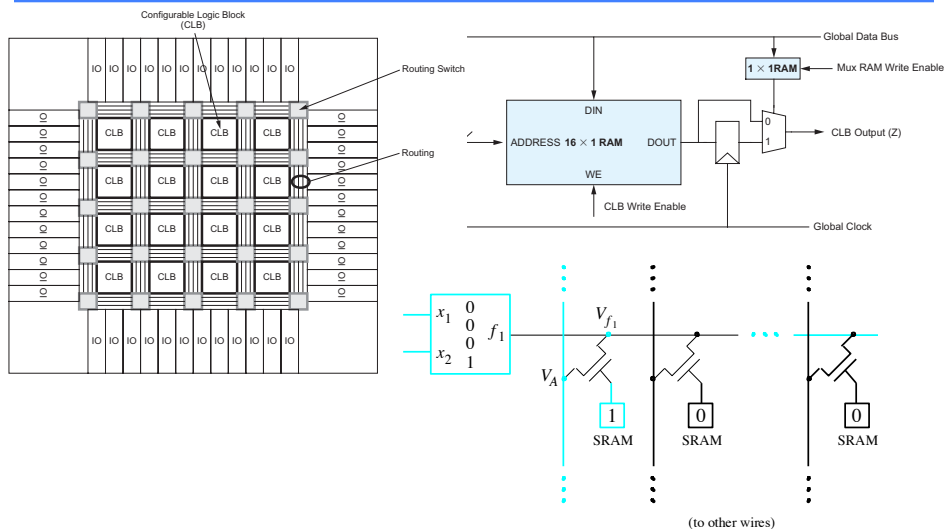


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## FPGAs



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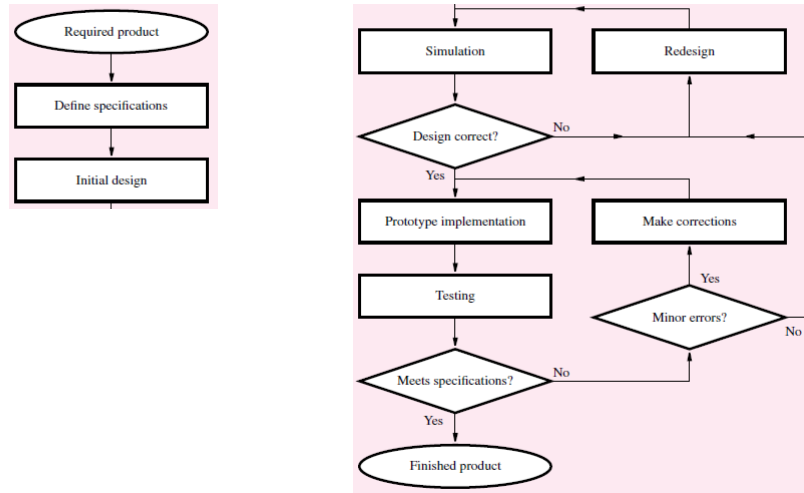
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## Design Process



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## The Three-Y's

- **Hierarchy**
  - A system divided into modules and submodules
- **Modularity**
  - Having well-defined functions and interfaces
- **Regularity**
  - Encouraging uniformity, so modules can be easily reused

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## Abstraction & Discipline

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- Complex systems are possible because of simplifications
- Digital Abstraction
  - physical world values are (seemingly) continuous
  - digital abstracts this to only a **discrete subset**
- Digital Discipline
  - limiting of design choices
  - Two discrete values: much simpler to **design**, easy to **combine** into sophisticated components
    - 1's and 0's
    - 1, TRUE, HIGH
    - 0, FALSE, LOW
  - Digital circuits use voltage to represent 1 and 0
  - **Bit**: Binary digit

## Number Systems: Positional Notation

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- Decimal numbers

1's column  
10's column  
100's column  
1000's column

$$5374_{10} =$$

- Binary numbers

1's column  
2's column  
4's column  
8's column

$$1101_2 =$$

## Powers of Two

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- $2^0 =$
- $2^1 =$
- $2^2 =$
- $2^3 =$
- $2^4 =$
- $2^5 =$
- $2^6 =$
- $2^7 =$
- $2^8 =$
- $2^9 =$
- $2^{10} =$
- $2^{11} =$
- $2^{12} =$
- $2^{13} =$
- $2^{14} =$
- $2^{15} =$

- Handy to memorize up to  $2^9$

## Number Conversion

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- Binary to decimal conversion:
  - Convert  $10011_2$  to decimal
- Decimal to binary conversion:
  - Convert  $47_{10}$  to binary

## Bits, Bytes, Nibbles...

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- Bits

10010110  
└─┬─┘ └─┬─┘  
most least  
significant significant  
bit bit

- Bytes & Nibbles

byte  
└──────────┘  
10010110  
└──┬──┘  
nibble

- Bytes

CEBF9AD7  
└──┬──┘ └──┬──┘  
most least  
significant significant  
byte byte

## Binary Values and Range

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- *N*-digit decimal number
  - How many values?
  - Range?
  - Example: 3-digit decimal number:
- *N*-bit binary number
  - How many values?
  - Range:
  - Example: 3-digit binary number:

## Large Powers of Two

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- $2^{10} = 1 \text{ kilo} \approx 1000$  (1024)
- $2^{20} = 1 \text{ mega} \approx 1 \text{ million}$  (1,048,576)
- $2^{30} = 1 \text{ giga} \approx 1 \text{ billion}$  (1,073,741,824)

## Estimating Powers of Two

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- What is the value of  $2^{24}$ ?
  
- How many values can a 32-bit variable represent?