

Lecture #20
Introduction to Synchronous Digital Systems



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Scott Beamer, Guest Lecturer

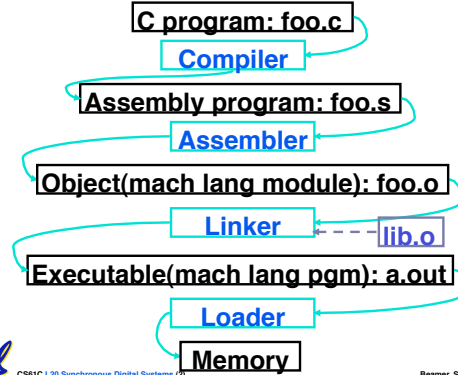
Wifi in Air Coast to Coast



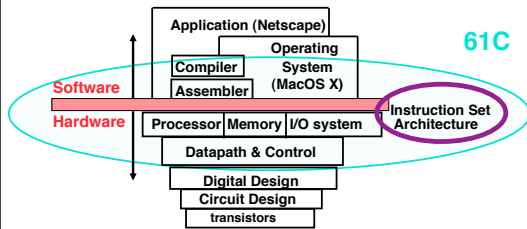
www.aircell.com



Review



What are "Machine Structures"?



Coordination of many *levels of abstraction*

ISA is an important abstraction level:
 contract between HW & SW



Below the Program

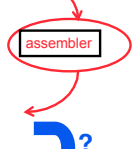
• High-level language program (in C)

```
swap int v[], int k){
    int temp;
    temp = v[k];
    v[k] = v[k+1];
    v[k+1] = temp;
}
```



• Assembly language program (for MIPS)

```
swap: sll $2, $5, 2
      add $2, $4, $2
      lw $15, 0($2)
      lw $16, 4($2)
      sw $16, 0($2)
      sw $15, 4($2)
      jr $31
```



• Machine (object) code (for MIPS)

```
000000 00000 00101 0001000010000000
```



Synchronous Digital Systems

The hardware of a processor, such as the MIPS, is an example of a Synchronous Digital System

Synchronous:

- Means all operations are coordinated by a central **clock**.
 - It keeps the "heartbeat" of the system!

Digital:

- Mean all values are represented by discrete values
- Electrical signals are treated as 1's and 0's and grouped together to form words.



Logic Design

- Next 4 weeks: we'll study how a modern processor is built; starting with basic elements as building blocks.

• Why study hardware design?

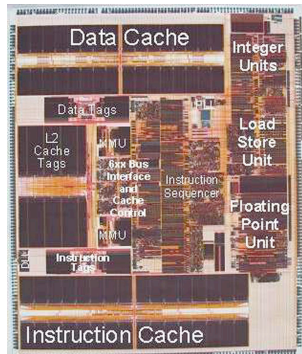
- Understand capabilities and limitations of hardware in general and processors in particular.
- What processors can do fast and what they can't do fast (avoid slow things if you want your code to run fast!)
- Background for more detailed hardware courses (CS 150, CS 152)
- There is just so much you can do with processors. At some point you may need to **design your own custom hardware.**



PowerPC Die Photograph



Let's look closer...



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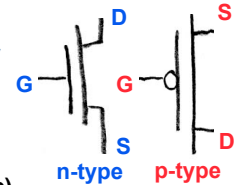
Transistors 101

• MOSFET

• Metal-Oxide-Semiconductor Field-Effect Transistor

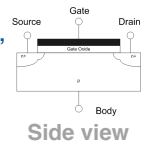
• Come in two types:

- n-type NMOSFET
- p-type PMOSFET



• For n-type (p-type opposite)

- If voltage not enough between G & S, transistor turns "off" (cut-off) and Drain-Source NOT connected
- If the G & S voltage is high enough, transistor turns "on" (saturation) and Drain-Source ARE connected



www.wikipedia.org/wiki/Mosfet

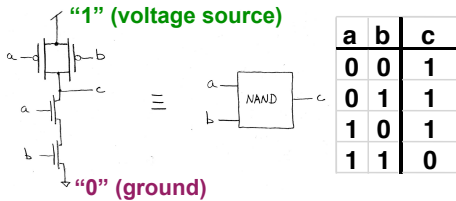
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Transistor Circuit Rep. vs. Block diagram

• Chips is composed of nothing but transistors and wires.

• Small groups of transistors form useful building blocks.



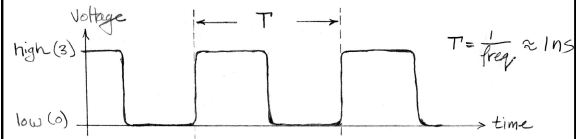
• Block are organized in a hierarchy to build higher-level blocks: ex: adders.



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Signals and Waveforms: Clocks



• Signals

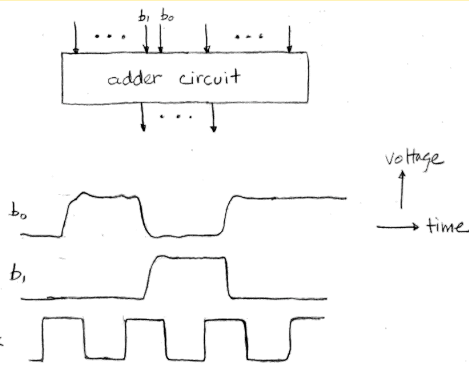
- When digital is only treated as 1 or 0
- Is transmitted over wires continuously
- Transmission is effectively instant
 - Implies that any wire only contains 1 value at a time



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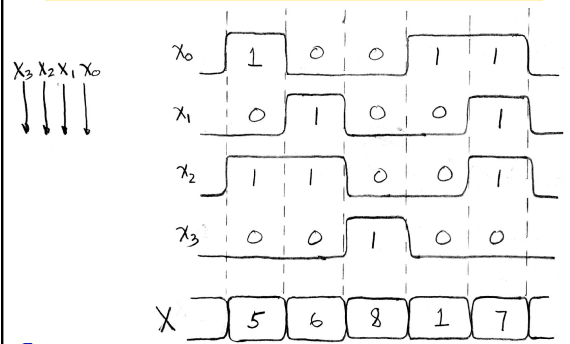
Signals and Waveforms



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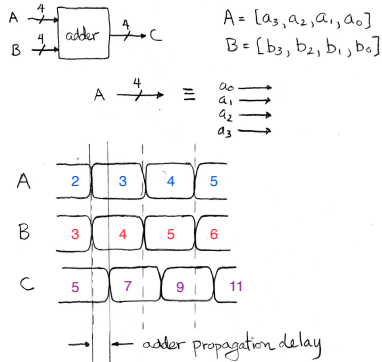
Signals and Waveforms: Grouping



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Signals and Waveforms: Circuit Delay



Type of Circuits

• **Synchronous Digital Systems** are made up of two basic types of circuits:

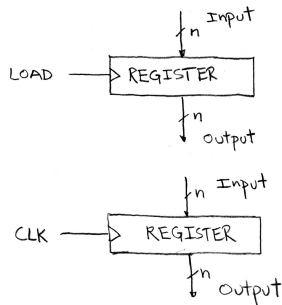
• **Combinational Logic (CL) circuits**

- Our previous adder circuit is an example.
- **Output is a function of the inputs only.**
- Similar to a pure function in mathematics, $y = f(x)$. (No way to store information from one invocation to the next. No side effects)

• **State Elements:** circuits that store information.



Circuits with STATE (e.g., register)



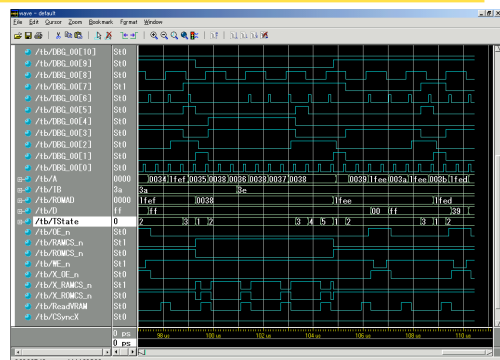
Peer Instruction

- SW can peek at HW (past ISA abstraction boundary) for optimizations
- SW can depend on particular HW implementation of ISA
- Timing diagrams serve as a **critical debugging tool** in the EE toolkit

	ABC
0:	FFF
1:	FTF
2:	FTT
3:	FTT
4:	FTF
5:	FTT
6:	FTT
7:	FTT



Sample Debugging Waveform



And in conclusion...

- ISA is very important abstraction layer
 - Contract between HW and SW
- Clocks control pulse of our circuits
- Voltages are analog, quantized to 0/1
- Circuit delays are fact of life
- Two types of circuits:
 - Stateless Combinational Logic (&,!,~)
 - State circuits (e.g., registers)

