

CSE 141L

Computer Architecture Lab

Spring 2005

Lecture 2
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CSE141: Computer Architecture Lab



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Textbook: LogicWorks 5, Interactive Circuit Design Software
Capilano Computing Systems, 2004
(Available in UCSD Bookstore.)

Web-page: <http://www.cse.ucsd.edu/classes/sp05/cse141L>

Spring 2005 CSE 141L Course Schedule



Lecture #	Date	Day	Lecture Topic	Lab Due
1	3/29	Tuesday	No Class	
2	4/5	Tuesday	Lab1: 8-bit Processo ISA	-
3	4/12	Tuesday	Lab1 Discussion	-
4	4/19	Tuesday	Lab2: Assembler, ISS	Lab1
5	4/26	Tuesday	LogicWorks 5 Review	-
6	5/3	Tuesday	Lab 3: Data Path	Lab2
7	5/10	Tuesday	Lab 3 Discussion	-
8	5/17	Tuesday	Lab 4: Full CPU	Lab3
9	5/24	Tuesday	Lab4 Discussion	-
5/31 - 6/3			Lab 4 Demo by Students	Lab4

Microprocessor Design Steps



- ✓ Design Instruction Set Architecture (ISA)
- ✓ Code applications
 - Develop software generation tools
 - Develop instruction set simulator (ISS)
 - Design datapath, verify it
 - Design the Processor, simulate logic
 - Verify the processor
 - Fabricate the chip

Develop Assembler for your ISS



- Converts assembly file to hex code
- Language choice for assembler:
 - C, C++, Java or Perl
- Command line:

```
assembler -i mean.s -o mean.dis
```
- Output generated:
 - mean.dis (annotated with hex code)
 - mean.imi (memory image in hex)

Assembler Code



- Process command line options
- Open input file and output files
- Parse each line
 - Gather fields: label, instruction mnemonic, ...
 - Detect errors and report them
 - Assemble instruction
 - Generate output to .dis
 - Generate output to .imi
- Close files

Assembler Input and Output



- **Input**

```
// mean.s
// r0 used to index array
...
start: mov  r3, $0 // r3 = 0, has address of a[ 0 ]
ld    r0, *r3     // r0 points to a[ 0 ]
mov   r2,  $0     // r2 = sum_low = 0
```

- **Output**

```
// mean.dis
// r0 used to index array
...
0x0c 000 start: mov  r3, $0 // r3 = 0, has address of a[ 0 ]
0xe3 001      ld    r0, *r3 // r0 points to a[ 0 ]
0x08 002      mov   r2, $0 // r2 = sum_low = 0
```



Are your 3 programs functionally correct?

General Architecture Challenges



- ISA
 - What is the performance?
 - How to find it out for huge programs?
 - How to optimize the ISA?
 - How to test “what if” scenarios?
- Design
 - How to verify the design?
 - What is the golden reference for behavior?



Answer:
Instruction Set Simulator (ISS)

What is an ISS?



- Software model of your processor
- Runs on a PC or workstation
- Is aware of:
 - Processor's internal resources
 - ISA
 - Size and characteristics of I-Mem & D-Mem
- Provides
 - Run-time statistics
 - Debug capabilities

What does an ISS do?



- Input:
 - Instruction and data memory image
- Output:
 - Instruction trace
 - Run-time statistics
 - Number of instructions executed
 - Utilization of resources and instructions
 - ...



What is a Reset?

- What happens on PC when you hit
 - Power button (cold boot)
 - Does extensive Power On Self Test (POST)
 - Reset button (warm boot)
- Reset is a special pin on a processor
- Processor and hardware is initialized to a known state
 - PC set to a known value
 - Internal registers set to a known value
 - Instruction execution starts



Structure of ISS

- Written in C++ or Java (C is ok too)
- Define a class (say, Proc)
 - Members are resources of the processor
 - PC, register file, I-Mem, D-Mem, ...

Methods in ISS



- loadIMem(): loads instruction memory image
 - Reads hex machine code from a text file
- loadDMem(): loads data memory image
 - Reads hex data from a text file
- reset(): reset the processor
 - Initialize internal state of the processor
 - Set PC = 0 and start execution

Methods in ISS: Runloop()



- Executes instructions
- May take an argument
 - Number of instructions to execute
 - Enables single stepping
- Generates instruction trace
 - Disassembles instruction
 - Prints results and other side effects

Components of runloop()



- Fetch:
 - Read instruction from I-Mem at location pointed to by PC
- Decode:
 - Analyze instruction
 - Find opcode and other fields, such as, register(s), immediate data, branch offset, etc.
 - Note destination for the result
 - Read operand(s) from register(s) (if any)

Components of runloop()



- Execute:
 - Fetch operand(s) from register(s)
 - Do ALU operation
 - Read D-Mem
 - Select result: either ALU output or data read from D-Mem
 - Resolve whether a branch is taken or not

Components of runloop()



- Memory/Register Writeback
 - Write result to register/D-Mem
- Set next PC
 - If instruction is not a control transfer instruction, or branch is not taken
 - $PC = PC + 1$
 - Else
 - $PC = \text{target of the branch}$

Components of runloop()



- Generate instruction trace
 - Disassemble instruction
 - Print instruction side effects
- Stop execution if HALT instruction
- Else continue with the next instruction

Example Instruction Trace



```
0x5d 009: ADD   R3, $0x1  { Result = 0x 3 }
0xfb 010: ST    R2, *R3   { Addr = 0x3, Result = 0x15 }
0x18 011: MOV   R2, $0x4
0x65 012: SUB   R1, $0x    { Result = 0x 6 }
0x74 013: CMPEQ R1, $0x0   { Flag = 0 }
0x33 014: MOV   R0, $0xf
0x53 015: ADD   R0, $0x3   { Result = 0x12 }
0x51 016: ADD   R0, $0x1   { Result = 0x13 }
0x40 017: JMPF  *R0
0xf6 019: ST    R1, *R2   { Addr = 0x4, Result = 0x6 }
0x19 020: MOV   R2, $0x5
```

Utility Methods in ISS



- `dumpIMem()`:
 - Dumps contents of instruction memory
 - Optionally takes start and end address
- `dumpDMem()`
 - Dumps contents of data memory
 - Optionally takes start and end address
- Both useful for debugging the program

Main()



- Instantiate class Proc
- Load I-Mem, D-Mem
- Reset the processor
- Interactive loop
 - Receive user command
 - Execute runloop()
 - Dump memory

What you will turn in for Lab 2



- Summary of your ISA from Lab 1 as well as assembly listing for the three programs, including the machine code for each instruction.
- Complete code for the Assembler and ISS, including all the header files and makefile.
- Complete instruction trace for the three programs **executing correctly** on the ISS.
- Data memory dump before and after running each one of the three programs. Also, dynamic instruction count for each one of the three programs.
- Answer to the questions below.
- Use “turnin” script (instructions are on the web)

Tips for debugging programs



- Typical problems
 - Machine code translation errors
 - ISS bugs
 - Logic errors in your program code
 - Infinite loops
 - Branch to invalid I-Mem location
 - Memory fetch from invalid D-Mem location
 - Branch target may change if you modify code
- Print instruction side effects in trace!

What you need for Lab2



- UNIX workstations
 - Accounts
- Tools
 - GCC
 - GDB or DDD debugger

Lab Due Dates



- Lab 2 Due:
 - ⇒ Before 6:30 PM Tuesday, May 3rd
- No late submissions!
- I plan to disclose a range of clock cycles from your Lab 2 reports (no names)

You should have completely functional three programs at the end of Lab2!



Homework: Review LogicWorks 5



- Head start on Lab 3 where:
 - You will design datapath
 - Register file, ALU and other elements
 - Implement and test logic
- No submission for Homework!

LogicWorks 5 Review



- Various components available in Standard Libraries.
 - D Flip-flop, logic gates, multiplexors, registers, adders, clock, binary switch, binary display, hex keypad, hex display, etc.
- How to connect a bus to various components.
- How to define a subcircuit bottom up
 - Create a subcircuit
 - Use it to define the pins on the parent symbol.
- How to simulate a circuit and generate waveforms.