www.eetimes.com/electronics-news/4230235/Thailand-floods-take-toll-on-PC-makers

EETimes 61C In the News

**Thailand Floods Take Toll on PC Makers**

Sylvie Barak 10/31/2011

The Thai floods have already claimed the lives of hundreds of people, with tens of thousands more having had to flee their homes in Bangkok. On a financial scale too the floods have wreaked havoc…

Around 25 percent of the world's hard drive manufacturing plants are situated in and around Bangkok…

Western Digital corp., the world's largest producer of hard disc drives has had to close all its factories in Thailand down completely, as has Toshiba corp. and a number of other smaller HDD makers, leaving the industry with just two months' worth of remaining inventory.

"We expect PC sales to be lower than expected. As a result, we expect weakness in DRAM prices," a Samsung executive said



# CS 61C: Great Ideas in Computer Architecture (Machine Structures) Lecture 29: Single-Cycle CPU *Datapath Control Part 2*

Instructors:
Mike Franklin
Dan Garcia
http://inst.eecs.Berkeley.edu/~cs61c/fa11



# Review: Processor Design 5 steps

Step 1: Analyze instruction set to determine datapath requirements
- Meaning of each instruction is given by register transfers
- Datapath must include storage element for ISA registers
- Datapath must support each register transfer

Step 2: Select set of datapath components & establish clock methodology

Step 3: Assemble datapath components that meet the requirements

Step 4: Analyze implementation of each instruction to determine setting of control points that realizes the register transfer

Step 5: Assemble the control logic



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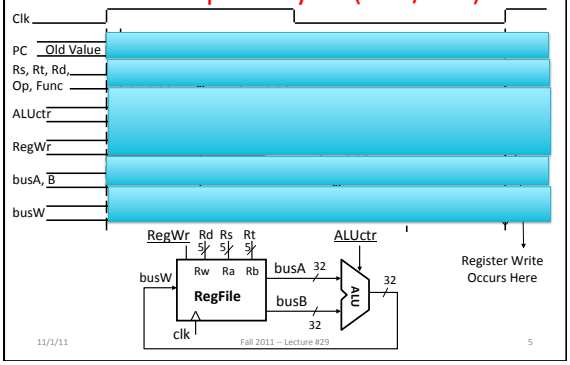
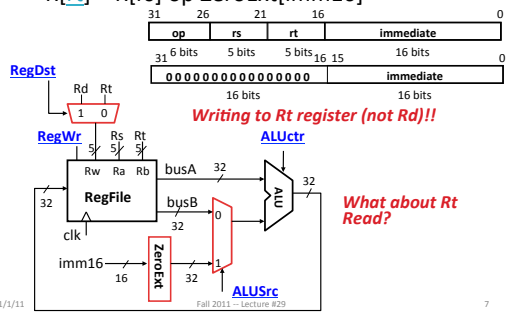
# Register-Register Timing: One Complete Cycle (Add/Sub)





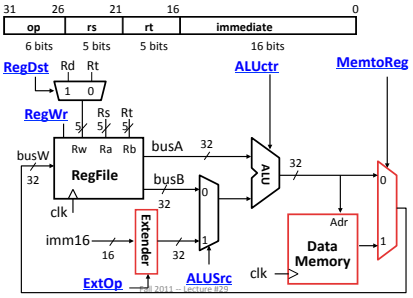

# 3c: Logical Op (or) with Immediate

- R[rt] = R[rs] op ZeroExt[imm16]



# 3d: Load Operations

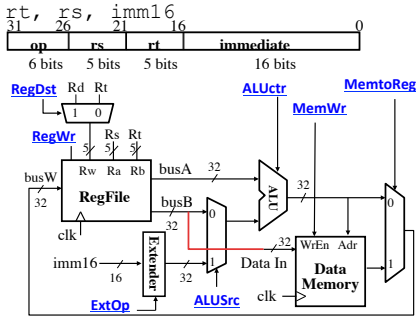
- R[rt] = Mem[R[rs] + SignExt[imm16]]
  Example: `lw rt,rs,imm16`






# 3e: Store Operations

- Mem[ R[rs] + SignExt[imm16] ] = R[rt]
  Ex.: `sw rt, rs, imm16`

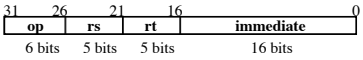



# 3e: Store Operations

- Mem[ R[rs] + SignExt[imm16] ] = R[rt]
  Ex.: `sw rt, rs, imm16`




# 3f: The Branch Instruction



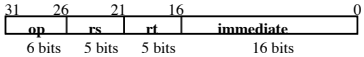

`beq rs, rt, imm16`

– mem[PC] Fetch the instruction from memory
– Equal = R[rs] == R[rt] Calculate branch condition
– if (Equal) Calculate the next instruction's address
  - PC = PC + 4 + ( SignExt(imm16) x 4 )

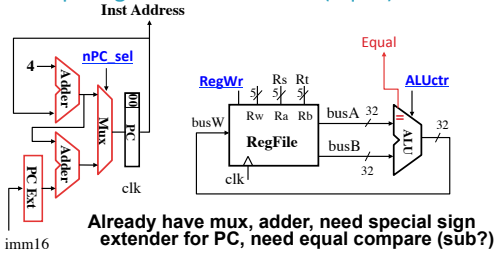
else
  - PC = PC + 4

# Datapath for Branch Operations

beq rs, rt, imm16

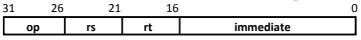



Datapath generates condition (Equal)

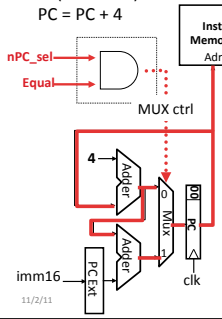



**Already have mux, adder, need special sign extender for PC, need equal compare (sub?)**

# *Instruction Fetch Unit* including Branch




- if (Zero == 1) then PC = PC + 4 + SignExt[imm16]*4 ; else PC = PC + 4

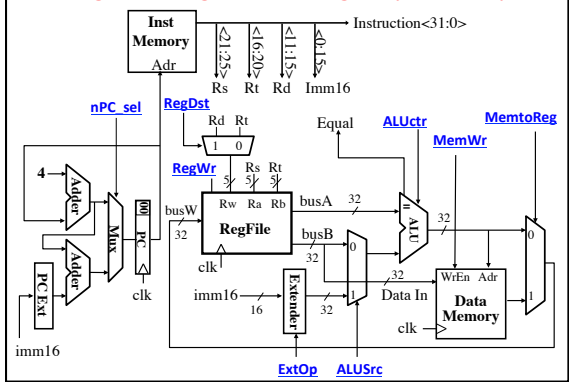



- How to encode nPC_sel?
  - Direct MUX select?
  - Branch inst. / not branch inst.
- Let's pick 2nd option

| nPC_sel | zero? | MUX |
|---|---|---|
| 0 | x | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

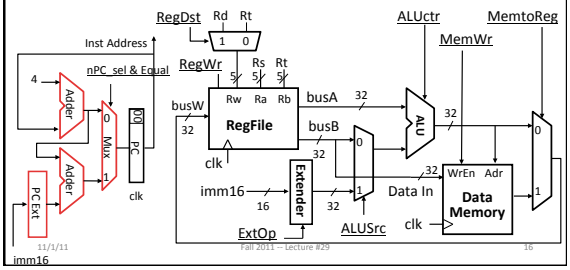
Q: What logic gate?

## Putting it All Together:A Single Cycle Datapath

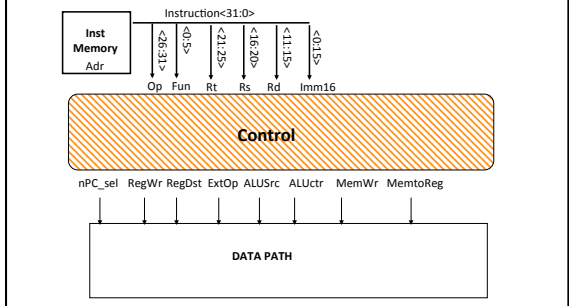



## Datapath Control Signals

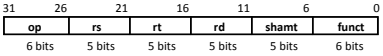
- ExtOp: "zero", "sign"
- ALUsrc: 0 ⇒ regB; 1 ⇒ immed
- ALUctr: "ADD", "SUB", "OR"
- MemWr: 1 ⇒ write memory
- MemtoReg: 0 ⇒ ALU; 1 ⇒ Mem
- RegDst: 0 ⇒ "rt"; 1 ⇒ "rd"
- RegWr: 1 ⇒ write register




## Given Datapath: RTL → Control




## RTL: The Add Instruction



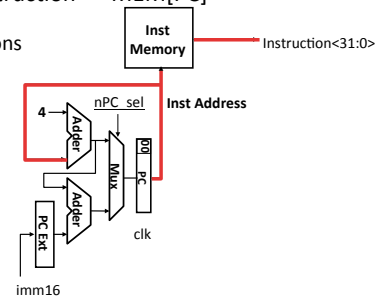

`add rd, rs, rt`

- MEM[PC] Fetch the instruction from memory
- R[rd] = R[rs] + R[rt] The actual operation
- PC = PC + 4 Calculate the next instruction's address

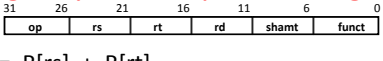


## Instruction Fetch Unit at the Beginning of Add

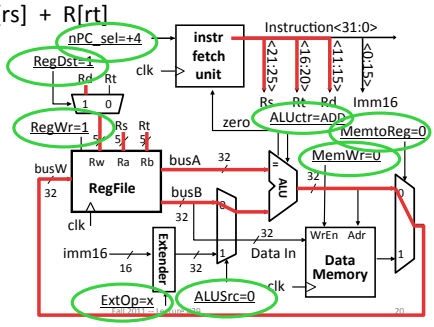
- Fetch the instruction from Instruction memory: Instruction = MEM[PC]
  - same for all instructions




## Single Cycle Datapath during Add

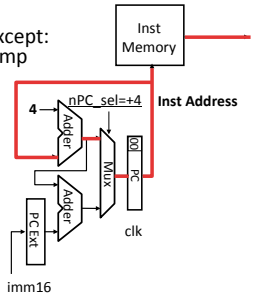



R[rd] = R[rs] + R[rt]



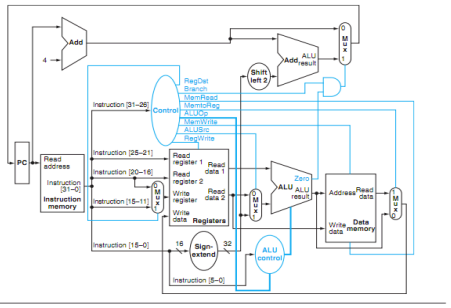
## Instruction Fetch Unit at End of Add

- PC = PC + 4
  - Same for all instructions except: Branch and Jump






## P&H Figure 4.17






## Summary of the Control Signals (1/2)

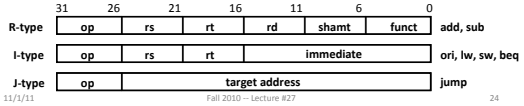
| inst | Register Transfer |
|---|---|
| add | R[rd] ← R[rs] + R[rt]; PC ← PC + 4 |
| | ALUsrc=RegB, ALUctr="ADD", RegDst=rd, RegWr, nPC_sel="+4" |
| sub | R[rd] ← R[rs] – R[rt]; PC ← PC + 4 |
| | ALUsrc=RegB, ALUctr="SUB", RegDst=rd, RegWr, nPC_sel="+4" |
| ori | R[rt] ← R[rs] + zero_ext(Imm16); PC ← PC + 4 |
| | ALUsrc=Im, Extop="Z", ALUctr="OR", RegDst=rt,RegWr, nPC_sel="+4" |
| lw | R[rt] ← MEM[ R[rs] + sign_ext(Imm16)]; PC ← PC + 4 |
| | ALUsrc=Im, Extop="sn", ALUctr="ADD", MemtoReg, RegDst=rt, RegWr, nPC_sel = "+4" |
| sw | MEM[ R[rs] + sign_ext(Imm16)] ← R[rs]; PC ← PC + 4 |
| | ALUsrc=Im, Extop="sn", ALUctr = "ADD", MemWr, nPC_sel = "+4" |
| beq | if (R[rs] == R[rt]) then PC ← PC + sign_ext(Imm16)] \|\| 00 else PC ← PC + 4 |
| | nPC_sel = "br", ALUctr = "SUB" |



## Summary of the Control Signals (2/2)

See Appendix A

| | func | 10 0000 | 10 0010 | We Don't Care :-) | | | |
|---|---|---|---|---|---|---|---|
| | op | 00 0000 | 00 0000 | 00 1101 | 10 0011 | 10 1011 | 00 0100 | 00 0010 |
| | | add | sub | ori | lw | sw | beq | jump |
| RegDst | | 1 | 1 | 0 | 0 | x | x | x |
| ALUSrc | | 0 | 0 | 1 | 1 | 1 | 0 | x |
| MemtoReg | | 0 | 0 | 0 | 1 | x | x | x |
| RegWrite | | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| MemWrite | | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| nPCsel | | 0 | 0 | 0 | 0 | 0 | 1 | ? |
| Jump | | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| ExtOp | | x | x | 0 | 1 | 1 | x | x |
| ALUctr<2:0> | | Add | Subtract | Or | Add | Add | Subtract | x |






## Boolean Expressions for Controller

```
RegDst    = add + sub
ALUSrc    = ori + lw + sw
MemtoReg  = lw
RegWrite  = add + sub + ori + lw
MemWrite  = sw
nPCsel    = beq
Jump      = jump
ExtOp     = lw + sw
ALUctr[0] = sub + beq   (assume ALUctr is 00 ADD, 01 SUB, 10 OR)
ALUctr[1] = or
```

*Where:*

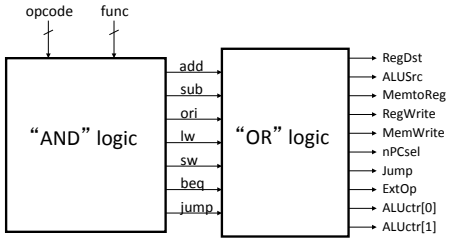
$$rtype = \sim op_5 \cdot \sim op_4 \cdot \sim op_3 \cdot \sim op_2 \cdot \sim op_1 \cdot \sim op_0$$
$$ori = \sim op_5 \cdot \sim op_4 \cdot op_3 \cdot op_2 \cdot \sim op_1 \cdot op_0$$
$$lw = op_5 \cdot \sim op_4 \cdot \sim op_3 \cdot \sim op_2 \cdot op_1 \cdot op_0$$
$$sw = op_5 \cdot \sim op_4 \cdot op_3 \cdot \sim op_2 \cdot op_1 \cdot op_0$$
$$beq = \sim op_5 \cdot \sim op_4 \cdot \sim op_3 \cdot op_2 \cdot \sim op_1 \cdot \sim op_0$$
$$jump = \sim op_5 \cdot \sim op_4 \cdot \sim op_3 \cdot \sim op_2 \cdot op_1 \cdot \sim op_0$$

How do we implement this in gates?

$$add = rtype \cdot func_5 \cdot \sim func_4 \cdot \sim func_3 \cdot \sim func_2 \cdot \sim func_1 \cdot \sim func_0$$
$$sub = rtype \cdot func_5 \cdot \sim func_4 \cdot \sim func_3 \cdot \sim func_2 \cdot func_1 \cdot \sim func_0$$



## Controller Implementation



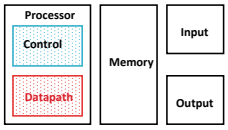
## Peer Instruction

1) We should use the main ALU to compute PC=PC+4 in order to save some gates
2) The ALU is inactive for memory reads (loads) or writes (stores).

| | 12 |
|---|---|
| a) | FF |
| b) | FT |
| c) | TF |
| d) | TT |
| e) | Help! |

## Summary: Single-cycle Processor

- Five steps to design a processor:
  1. Analyze instruction set → datapath requirements
  2. Select set of datapath components & establish clock methodology
  3. Assemble datapath meeting the requirements
  4. Analyze implementation of each instruction to determine setting of control points that effects the register transfer.
  5. Assemble the control logic
     - Formulate Logic Equations
     - Design Circuits



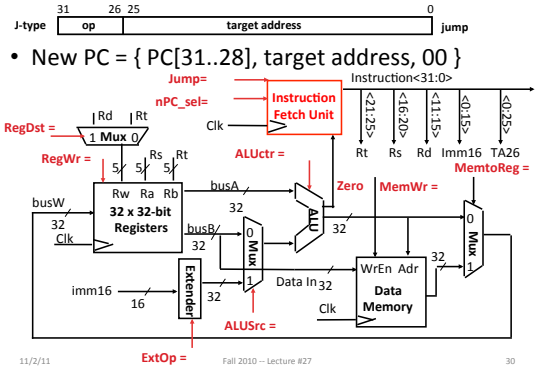



## Bonus Slides

- How to implement Jump



## Single Cycle Datapath during Jump

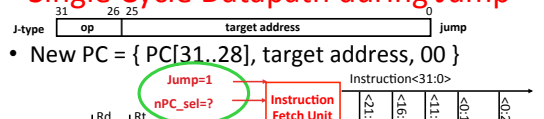



- New PC = { PC[31..28], target address, 00 }






## Single Cycle Datapath during Jump

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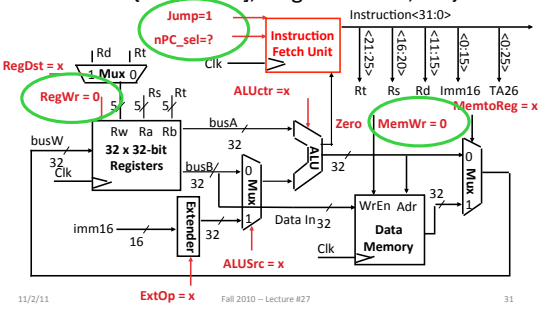
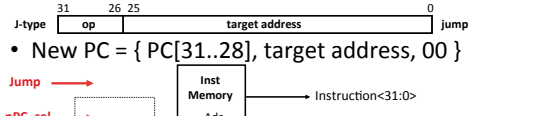
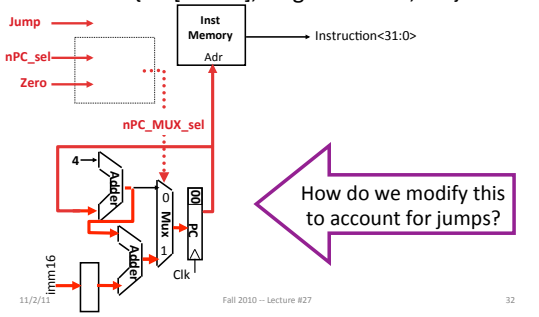




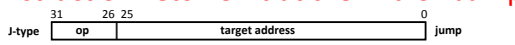

## *Instruction Fetch Unit* at the End of Jump



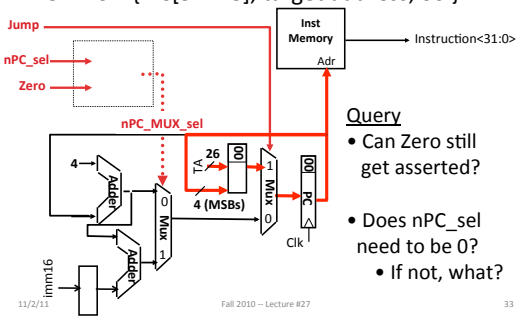

- New PC = { PC[31..28], target address, 00 }



## *Instruction Fetch Unit* at the End of Jump




- New PC = { PC[31..28], target address, 00 }




Query

- Can Zero still get asserted?
- Does nPC_sel need to be 0?
  - If not, what?