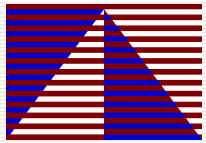
ECE3055
Computer Architecture and Operating Systems

Lecture 5 Datapath



Prof. Hsien-Hsin Sean Lee
School of Electrical and Computer Engineering
Georgia Institute of Technology

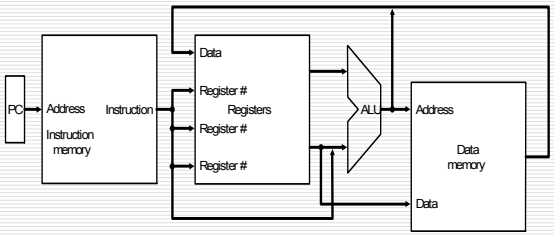
Edited by Ney Calazans
08/10/2008

The Processor: Datapath and Control

- We're ready to look at an implementation of the MIPS
- Simplified to contain only:
  - memory-reference instructions: `lw, sw`
  - arithmetic-logical instructions: `add, sub, and, or, slt`
  - control flow instructions: `beq, j`
- Generic Implementation:
  - use the program counter (PC) to supply instruction address
  - get the instruction from memory
  - read registers
  - use the instruction to decide exactly what to do
- All instructions use the ALU after reading the registers
  Why? memory-reference? arithmetic? control flow?

More Implementation Details

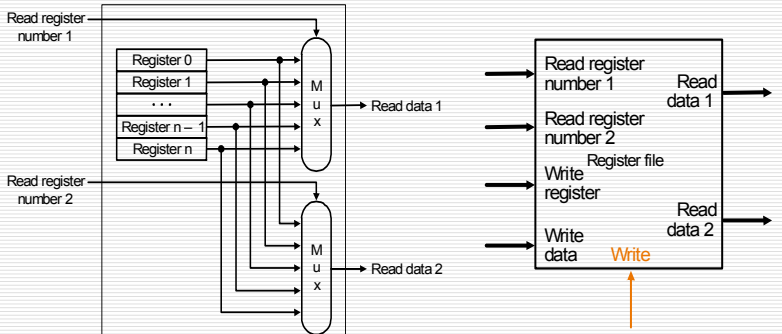
- Abstract / Simplified View:



Two types of functional units:
- Elements that operate on data values (combinational)
- Elements that contain state (sequential)

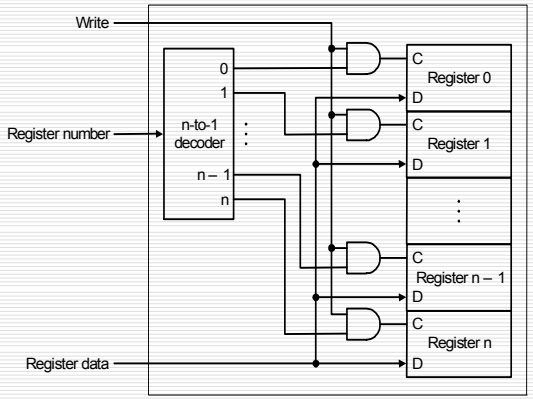
Register File

- Built using D flip-flops



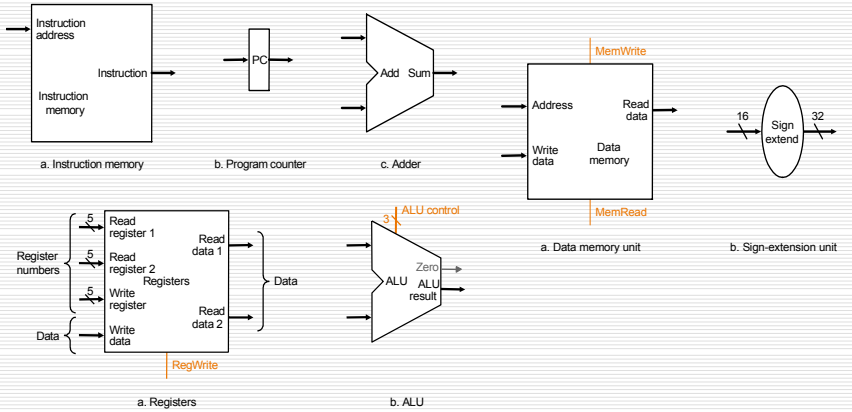
Register File

- Note: we still use the real clock to determine when to write



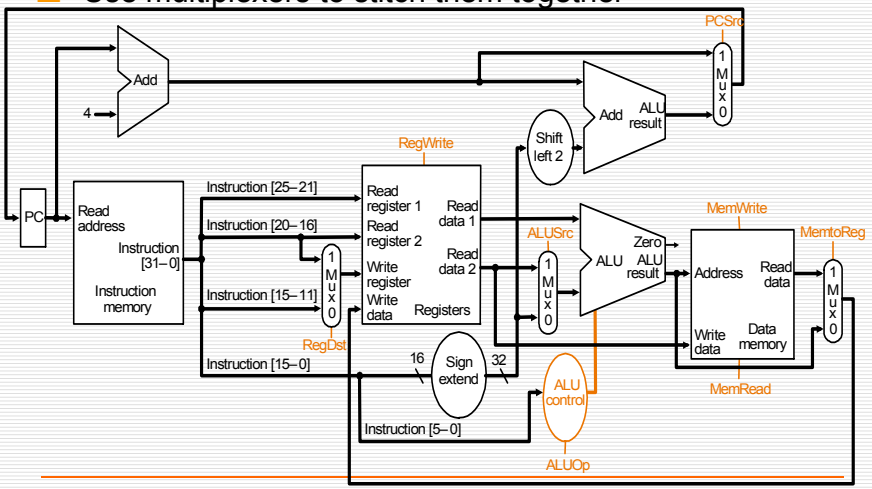
Simple Implementation

- Include the functional units we need for each instruction

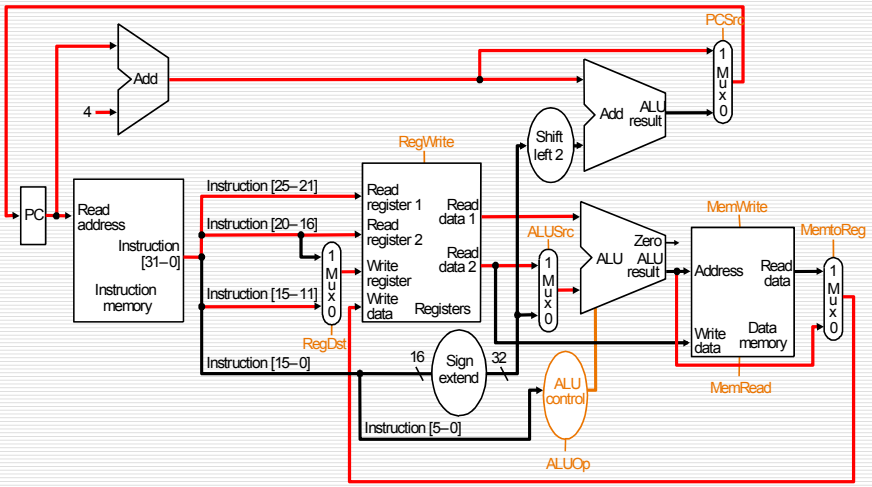


Building the Datapath

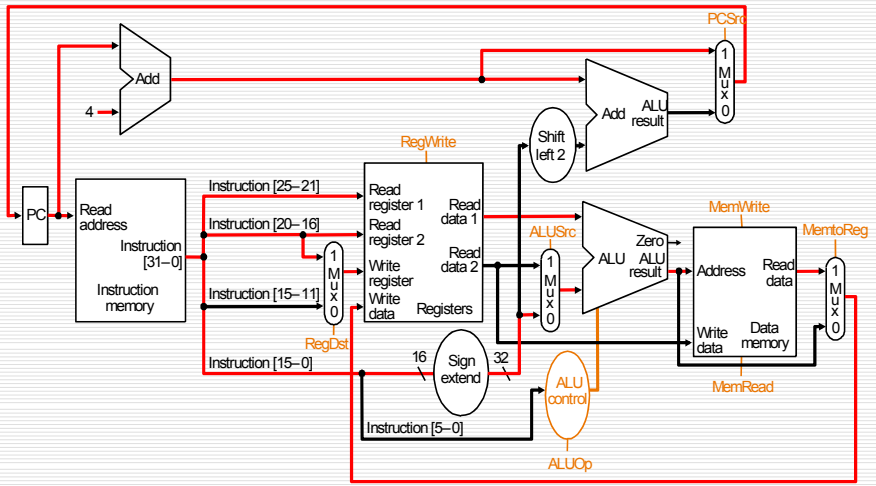
- Use multiplexers to stitch them together



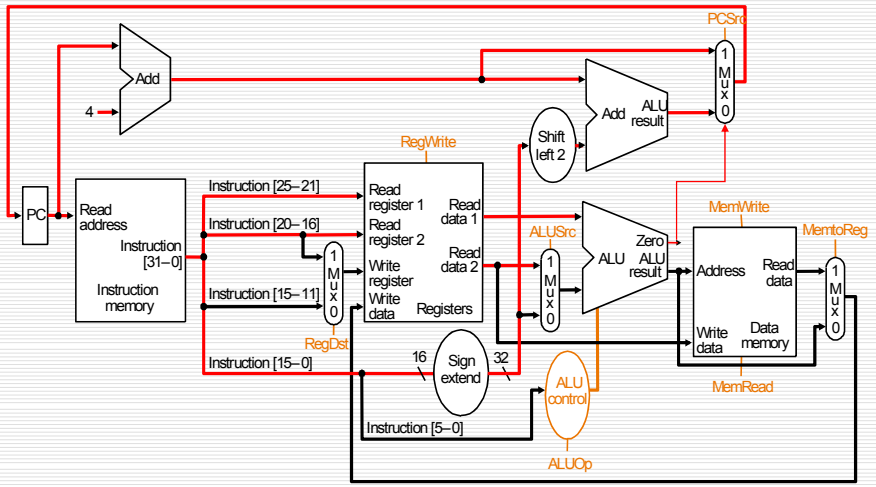
R-Type Instructions
(e.g. add $2, $3, $4; Not JR/JALR)



I-Type Instructions
(e.g. lw $4, 1000($15))



I-type Instruction for Branches
(e.g. beq $4, $5, Label7)



Control

- Selecting the operations to perform (ALU, read/write, etc.)
- Controlling the flow of data (multiplexer inputs)
- Information comes from the 32 bits of the instruction
- Example:

add $8, $17, $18 **Instruction Format:**

000000	10001	10010	01000	00000	100000

op	rs	rt	rd	shamt	funct

- ALU's operation based on instruction type and function code

Control

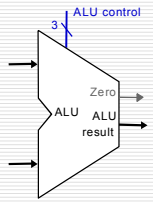
- **e.g., what should the ALU do with this instruction**
- **Example: lw $1, 100($2)**

35	2	1	100

op	rs	rt	16 bit offset

- **ALU control input**

```
000   AND
001   OR
010   add
110   subtract
111   set-on-less-than
```



- **Why is the code for subtract 110 and not 011? What do you need for slt instruction?**

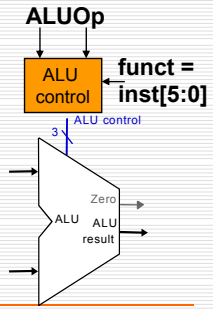
Control the ALU

- Must describe hardware to compute 3-bit ALU control input
  - given instruction type
    00 = lw, sw
    01 = beq,
    11 = arithmetic (incl. slt)

    ALUOp computed from instruction type
  - function code for arithmetic
- Describe it using a truth table (can turn into gates):

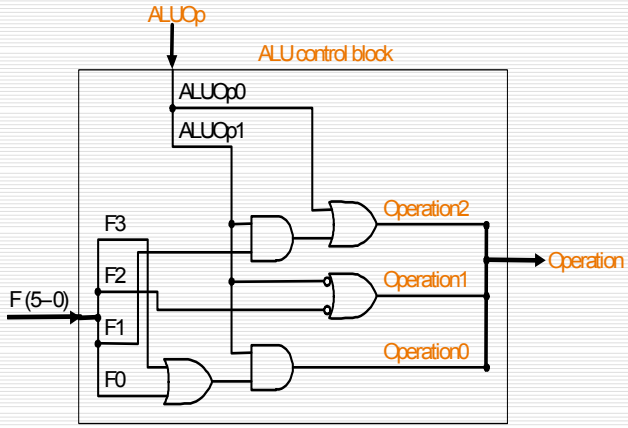
	ALUOp		Funct field						ALU Control	
	ALUOp1	ALUOp0	F5	F4	F3	F2	F1	F0		
lw/sw	0	0	X	X	X	X	X	X	010	add
beq	X	1	X	X	X	X	X	X	110	sub
arith	1	X	X	X	0	0	0	0	010	add
	1	X	X	X	0	0	1	0	110	sub
	1	X	X	X	0	1	0	0	000	and
	1	X	X	X	0	1	0	1	001	or
	1	X	X	X	1	0	1	0	111	slt

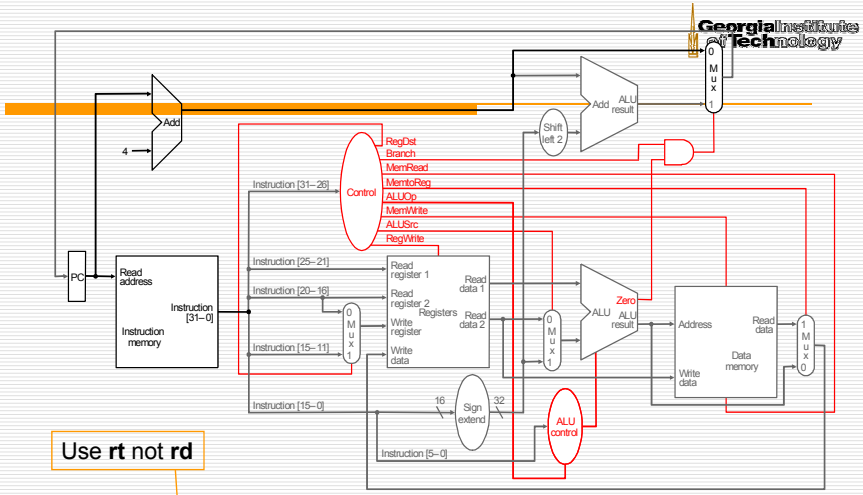
Generated from Decoding inst[31:26] — inst[5:0]



ALU Control

- Simple combinational logic (truth tables)



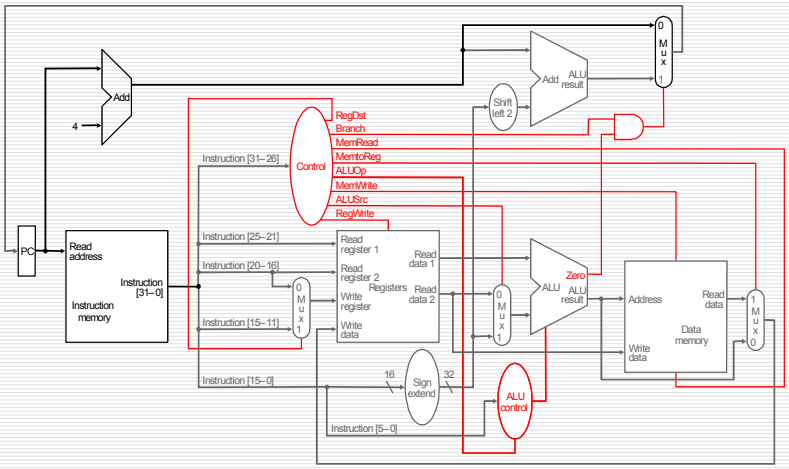


Use **rt** not **rd**

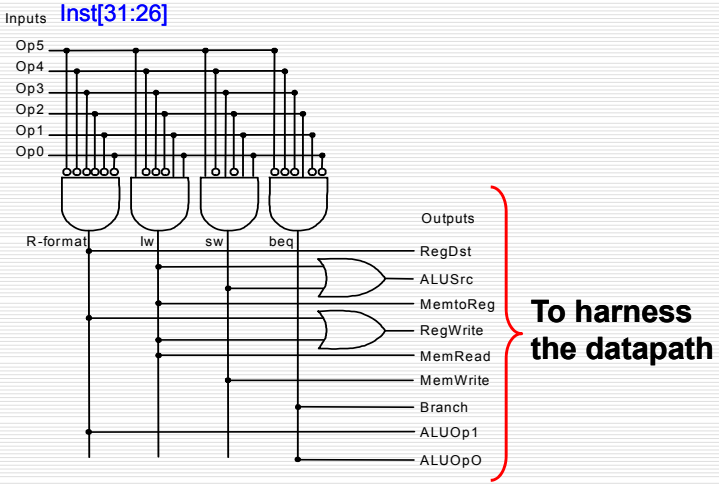
Instruction	RegDst	ALUSrc	Memto-Reg	Reg Write	Mem Read	Mem Write	Branch	ALUOp1	ALUp0
R-format	1	0	0	1	0	0	0	1	0
`lw`	0	1	1	1	1	0	0	0	0
`sw`	X	1	X	0	0	1	0	0	0
`beq`	X	0	X	0	0	0	1	0	1

Use **rt** not **rd**

Instruction	RegDst	ALUSrc	Memto-Reg	Reg Write	Mem Read	Mem Write	Branch	ALUOp1	ALUp0
R-format	1	0	0	1	0	0	0	1	0
`lw`	0	1	1	1	1	0	0	0	0
`sw`	X	1	X	0	0	1	0	0	0
`beq`	X	0	X	0	0	0	1	0	1

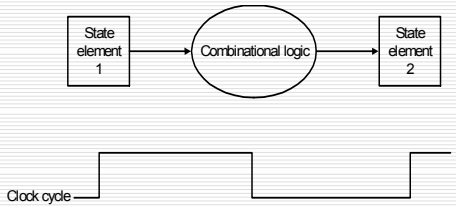


Control Unit Signals



Our Simple Control Structure

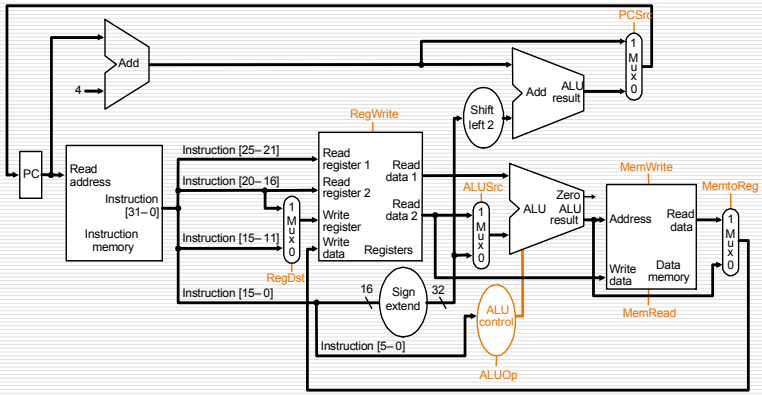
- All of the logic is combinational
- We wait for everything to settle down, and the right thing to be done
  - ALU might not produce “right answer” right away
  - we use write signals along with clock to determine when to write
- Cycle time determined by length of the longest path



We are ignoring some details like setup and hold times

Single Cycle Implementation

- Calculate cycle time assuming negligible delays except:
  - memory (2ns), ALU and adders (2ns), register file access (1ns)



Where we are headed

- Single Cycle Problems:
  - what if we had a more complicated instruction like floating point?
  - wasteful of area
- One Solution:
  - use a “smaller” cycle time
  - have different instructions take different numbers of cycles
  - a “multicycle” datapath: