CSE 210: Computer Architecture
Lecture 9: Computer Representation of MIPS instructions 2

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Announcements

- Problem Set 2 due today
- Lab 1 due Sunday
- Office Hours today 13:30 – 14:30

Representing Instructions

- MIPS instructions
  - Encoded as 32-bit instruction words
  - Small number of formats encoding operation code (opcode), register numbers, …
  - Regularity!

	6 bits	5 bits	5 bits	5 bits	5 bits	6 bits
R-type	**opcode**	**rs**	**rt**	**rd**	**sa**	**funct**
I-type	**opcode**	**rs**	**rt**	**immediate**		
J-type	**opcode**	**target**				

MIPS Instruction Formats

	6 bits	5 bits	5 bits	5 bits	5 bits	6 bits
R-type	**opcode**	**rs**	**rt**	**rd**	**sa**	**funct**
I-type	**opcode**	**rs**	**rt**	**immediate**		
J-type	**opcode**	**target**				

Which row contains correct examples of instructions with the given types?

	R-type	I-type
A	addi	sw
B	addi	sub
C	add	sw
D	add	sub
E	None of the above	

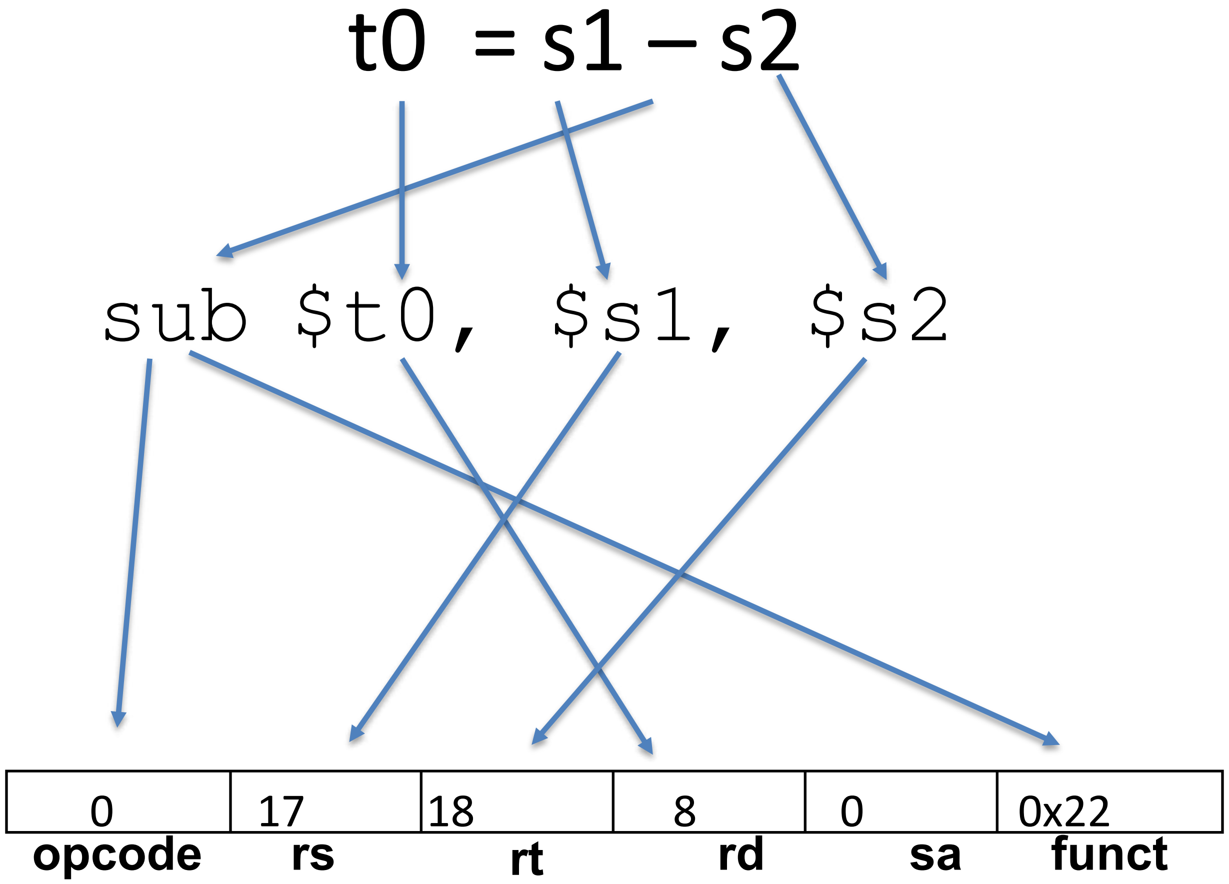
MIPS Instruction Fields

- MIPS fields are given names to make them easier to refer to

op	rs	rt	rd	shamt	funct

op	6-bits	opcode that specifies the operation
rs	5-bits	register file address of the first source operand
rt	5-bits	register file address of the second source operand
rd	5-bits	register file address of the result’s destination
shamt	5-bits	shift amount (for shift instructions)
funct	6-bits	function code augmenting the opcode

MIPS Arithmetic Instructions Format



R-format Example

op	rs	rt	rd	shamt	funct
6 bits	5 bits	5 bits	5 bits	5 bits	6 bits

```
add $t0, $s1, $s2
```

CORE INSTRUCTION SET

NAME, MNEMONIC		FOR-MAT	OPERATION (in Verilog)		OPCODE / FUNCT (Hex)
Add	add	R	R[rd] = R[rs] + R[rt]	(1)	0 / 20_{hex}
Add Immediate	addi	I	R[rt] = R[rs] + SignExtImm	(1,2)	8_{hex}
Add Imm. Unsigned	addiu	I	R[rt] = R[rs] + SignExtImm	(2)	9_{hex}
Add Unsigned	addu	R	R[rd] = R[rs] + R[rt]		0 / 21_{hex}

NAME	NUMBER	USE
$zero	0	The Constant Value 0
$at	1	Assembler Temporary
$v0-$v1	2-3	Values for Function Results and Expression Evaluation
$a0-$a3	4-7	Arguments
$t0-$t7	8-15	Temporaries
$s0-$s7	16-23	Saved Temporaries
$t8-$t9	24-25	Temporaries
$k0-$k1	26-27	Reserved for OS Kernel
$gp	28	Global Pointer
$sp	29	Stack Pointer
$fp	30	Frame Pointer
$ra	31	Return Address

Convert this MIPS machine instruction to assembly:

000000 01110 10001 10010 00000 100010

op	rs	rt	rd	shamt	funct
6 bits	5 bits	5 bits	5 bits	5 bits	6 bits

Selection	Instruction
A	add $s2, $t7, $s4
B	add $s1, $t6, $s3
C	sub $t6, $s1, $s2
D	sub $s2, $t6, $s1
E	None of the above

MIPS I-format Instructions

op	rs	rt	constant or offset
6 bits	5 bits	5 bits	16 bits

- Immediate arithmetic and load/store instructions
  - rt: destination or source register number
  - Constant: -2^{15} to $+2^{15} - 1$ (or 0 to 2^{16} for some instructions)
  - offset: offset added to base address in rs

Machine Language – I Format

op	rs	rt	constant or offset
6 bits	5 bits	5 bits	16 bits

- Load/Store Instruction Format:

```
lw $t0, 24($s3)
```

Load Linked	ll	I	R[rt] = M[R[rs]+SignExtImm]	(2,7)	30_{hex}
Load Upper Imm.	lui	I	R[rt] = {imm, 16'b0}		f_{hex}
Load Word	lw	I	R[rt] = M[R[rs]+SignExtImm]	(2)	23_{hex}
Nor	nor	R	R[rd] = ~ (R[rs] | R[rt])		$0 / 27_{hex}$

NAME	NUMBER	USE
$zero	0	The Constant Value 0
$at	1	Assembler Temporary
$v0-$v1	2-3	Values for Function Results and Expression Evaluation
$a0-$a3	4-7	Arguments
$t0-$t7	8-15	Temporaries
$s0-$s7	16-23	Saved Temporaries
$t8-$t9	24-25	Temporaries
$k0-$k1	26-27	Reserved for OS Kernel
$gp	28	Global Pointer
$sp	29	Stack Pointer
$fp	30	Frame Pointer
$ra	31	Return Address

Machine Language – I Format

op	rs	rt	constant or offset
6 bits	5 bits	5 bits	16 bits

- Immediate Addition Instruction Format:

```
addi $t0, $s3, 26
```

CORE INSTRUCTION SET

NAME, MNEMONIC		FOR-MAT	OPERATION (in Verilog)		OPCODE / FUNCT (Hex)
Add	add	R	R[rd] = R[rs] + R[rt]	(1)	$0 / 20_{hex}$
Add Immediate	addi	I	R[rt] = R[rs] + SignExtImm	(1,2)	8_{hex}
Add Imm. Unsigned	addiu	I	R[rt] = R[rs] + SignExtImm	(2)	9_{hex}
Add Unsigned	addu	R	R[rd] = R[rs] + R[rt]		$0 / 21_{hex}$

NAME	NUMBER	USE
$zero	0	The Constant Value 0
$at	1	Assembler Temporary
$v0-$v1	2-3	Values for Function Results and Expression Evaluation
$a0-$a3	4-7	Arguments
$t0-$t7	8-15	Temporaries
$s0-$s7	16-23	Saved Temporaries
$t8-$t9	24-25	Temporaries
$k0-$k1	26-27	Reserved for OS Kernel
$gp	28	Global Pointer
$sp	29	Stack Pointer
$fp	30	Frame Pointer
$ra	31	Return Address

Convert this MIPS assembly instruction to machine code

```
sw $t0, 32($s6)
```

Selection	Instruction
A	010101 11011 00100 0000 0000 0010 0000
B	101011 01000 10110 0000 0000 0010 0000
C	101011 10110 01000 0000 0000 0010 0000
D	000000 00010 00000 1010 1110 1100 1000
E	None of the above

Sign-extend vs. zero-extend

op	rs	rt	immediate
6 bits	5 bits	5 bits	16 bits

- The immediate field of an I-format instruction is either sign-extended or zero-extended
  - sign extension: the sign bit (bit 15) is copied into bits 31–16
  - zero extension: 0 is placed into bits 31–16
- Opcode determines which occurs

Add Immediate	addi	I	R[rt] = R[rs] + SignExtImm	(1,2)	8_{hex}
Add Imm. Unsigned	addiu	I	R[rt] = R[rs] + SignExtImm	(2)	9_{hex}
Add Unsigned	addu	R	R[rd] = R[rs] + R[rt]		$0 / 21_{hex}$
And	and	R	R[rd] = R[rs] & R[rt]		$0 / 24_{hex}$
And Immediate	andi	I	R[rt] = R[rs] & ZeroExtImm	(3)	c_{hex}

Disassemble the MIPS instruction 0xA20CFFE0

Hint: Convert to binary, break into fields, and convert

A. `sb $s0, 65504($t4)`
B. `sb $s0, -32($t4)`
C. `sb $t4, 65504($s0)`
D. `sb $t4, -32($s0)`
E. `sb $t4($s0), 0xFFE0`

What’s the mnemonic for the MIPS instruction 0x012A4025

A. add
B. addi
C. or
D. ori
E. nor

Reading

- Next lecture: Bit Level Operations
  - Section 2.6

- Problem Set 2 due today

- Lab 1 due Sunday