

Architecture

- ❏ Software visible registers
- ❏ Memory Addressing
- ❏ **The instruction set**
- ❏ The exception / reset mechanism



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Instruction Set

RISC Architecture

- Only simple instructions
- All instructions have the same size (32 bits)
- 3-operand instructions (2 read, 1 write)
- No operation involving operands in memory - Only load and store operations



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Instruction Set

3 instruction formats

- R Register-register instructions
- I Immediate instructions
- J Jump instructions

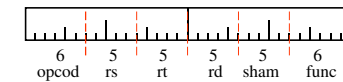


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Instruction Set

R format



opcod	Operation code
func	Function (opcod extension)
rs	# of source register
rt	# of source register
rd	# of destination register
sham	Shift amount (# of bit the opr. is shifted)

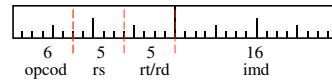


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Instruction Set

I format



opcode Operation code
rs # of source register
rt / rd # of source or destination register
imd Immediate value

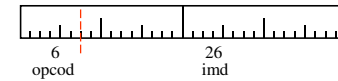


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Instruction Set

J format



opcode Operation code
imd Immediate value



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Instruction Set

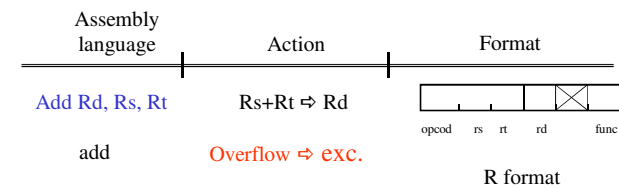
- **Computation instructions**
- Memory access instructions
- Control instructions
- System instructions



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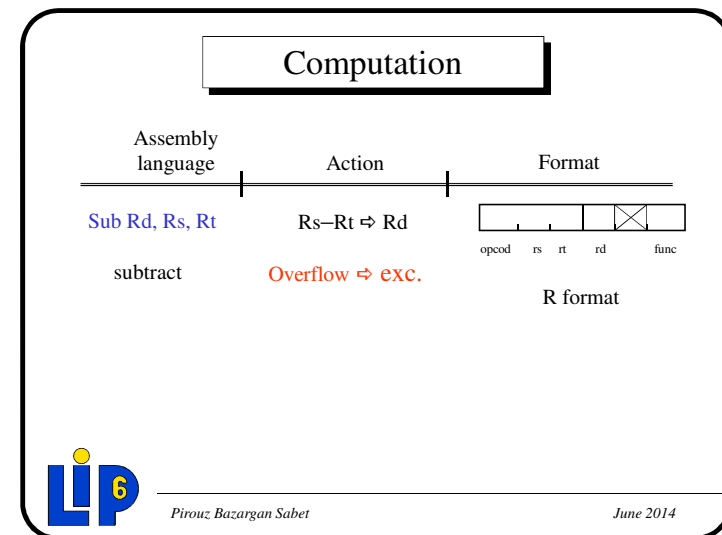
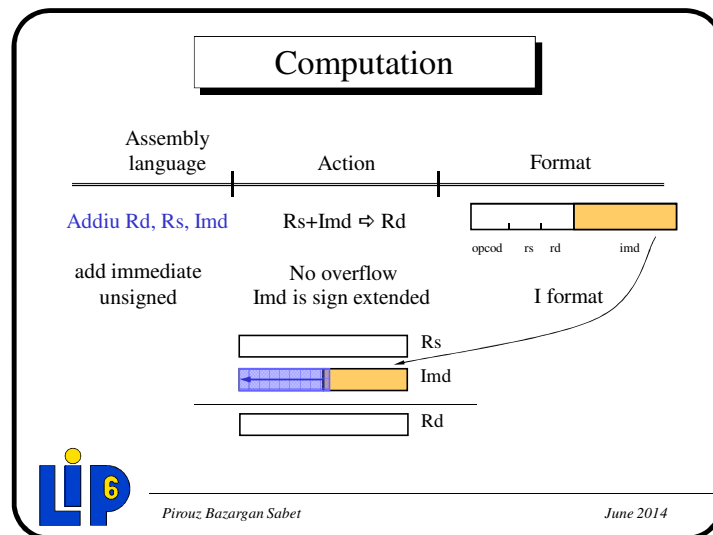
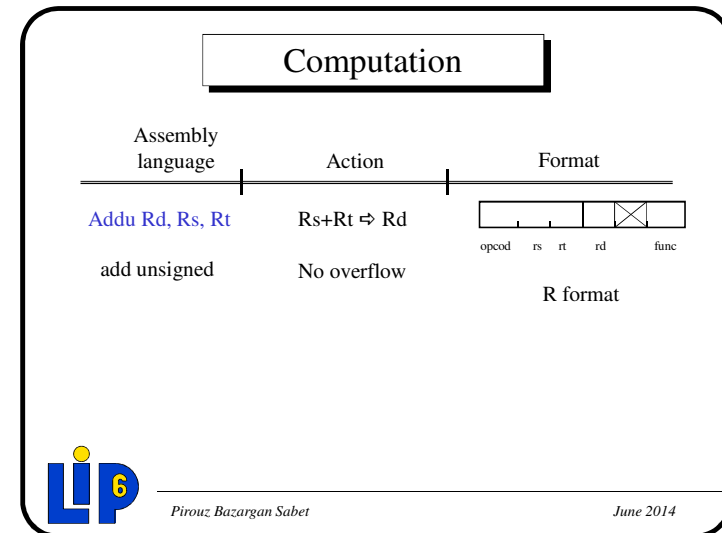
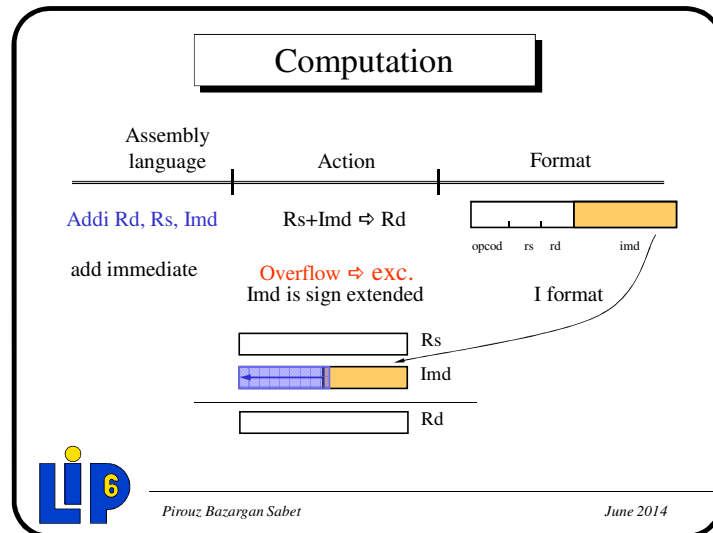
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Computation



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Computation

Assembly language	Action	Format
Subu Rd, Rs, Rt	$Rs - Rt \Rightarrow Rd$	
Subtract unsigned	No overflow	R format

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Computation

Assembly language	Action	Format
Or Rd, Rs, Rt	$Rs \text{ or } Rt \Rightarrow Rd$	
bitwise logic OR		R format

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Computation

Assembly language	Action	Format
Ori Rd, Rs, Imd	$Rs \text{ or } Imd \Rightarrow Rd$	
bitwise logic OR immediate	Imd is zero extended	I format

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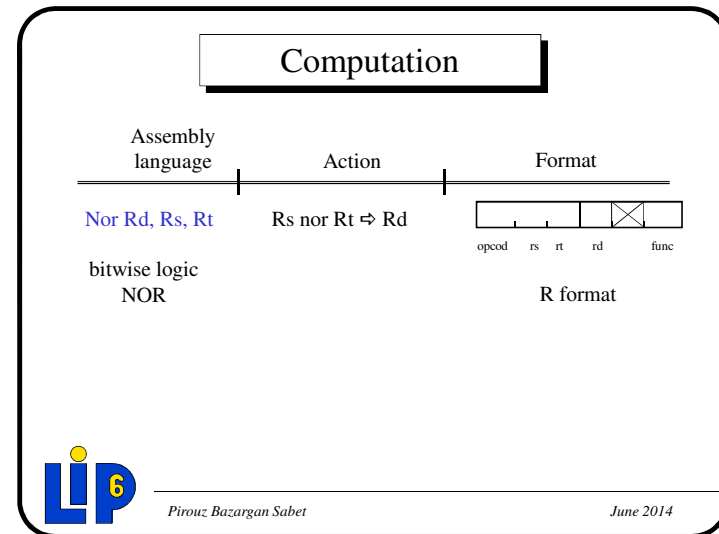
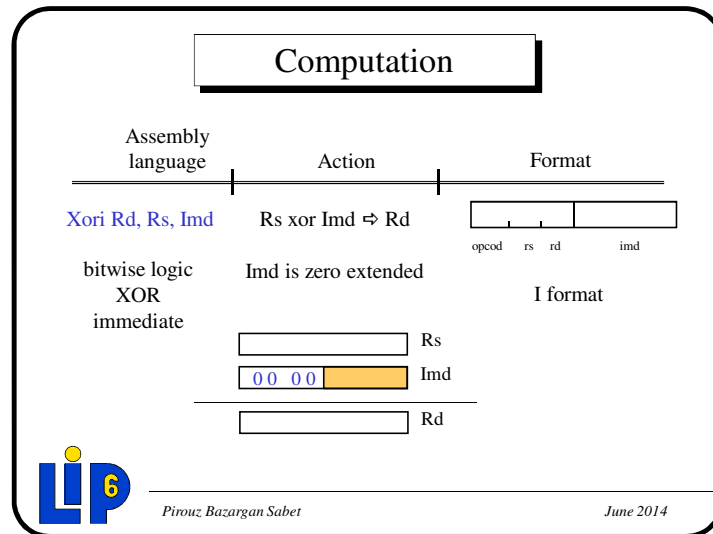
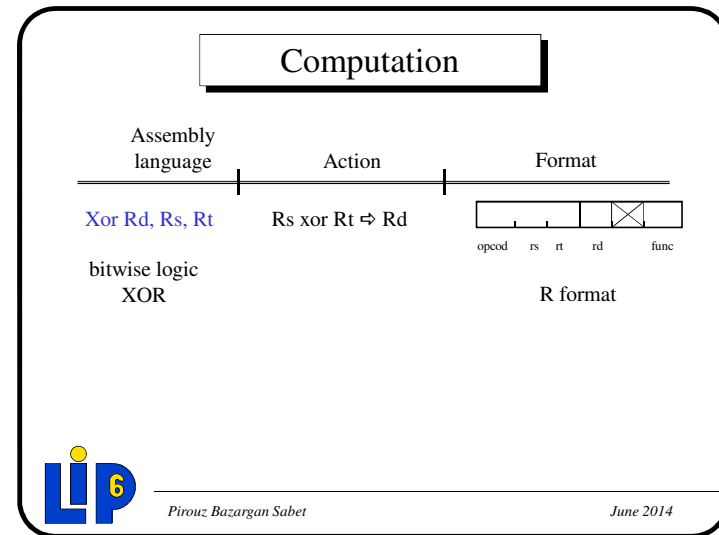
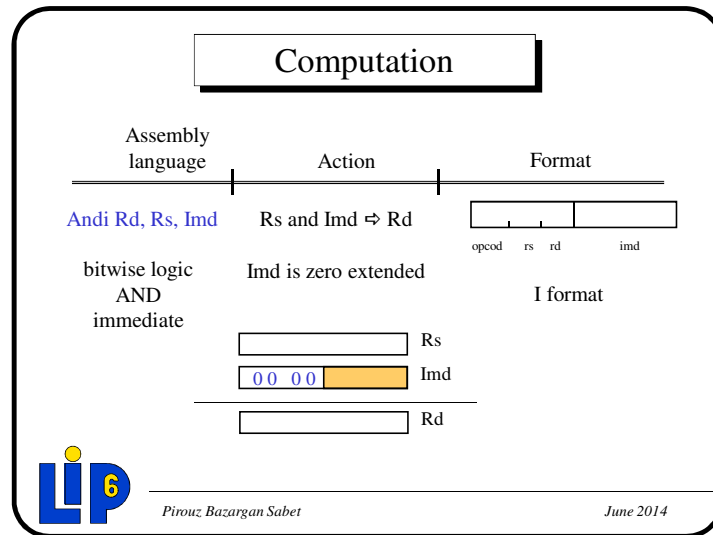
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Computation

Assembly language	Action	Format
And Rd, Rs, Rt	$Rs \text{ and } Rt \Rightarrow Rd$	
bitwise logic AND		R format

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Computation

Assembly language	Action	Format
<code>Sll Rd, Rt, Sham</code>	$Rt \ll Sham \Rightarrow Rd$	<div style="display: flex; align-items: center; gap: 10px;"> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> X </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rt rd sham func </div>
Shift left logic		R format

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Computation

Assembly language	Action	Format
<code>Sllv Rd, Rt, Rs</code>	$Rt \ll Rs \Rightarrow Rd$	<div style="display: flex; align-items: center; gap: 10px;"> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> X </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rs rt rd func </div>
Shift left logic variable		R format

Only the 5 lsb of Rs are meaningful

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Computation

Assembly language	Action	Format
<code>Srl Rd, Rt, Sham</code>	$Rt \gg Sham \Rightarrow Rd$	<div style="display: flex; align-items: center; gap: 10px;"> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> X </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rt rd sham func </div>
Shift right logic		R format

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Computation

Assembly language	Action	Format
<code>Srlv Rd, Rt, Rs</code>	$Rt \gg Rs \Rightarrow Rd$	<div style="display: flex; align-items: center; gap: 10px;"> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> X </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rs rt rd func </div>
Shift right logic variable		R format

Only the 5 lsb of Rs are meaningful

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Computation

Assembly language	Action	Format
Sra Rd, Rt, Sham	$Rt \gg Sham \Rightarrow Rd$	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px; margin-top: 5px;"> opcod rt rd sham func </div>
Shift right arithmetic		R format

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Computation

Assembly language	Action	Format
Srav Rd, Rt, Rs	$Rt \gg Rs \Rightarrow Rd$	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> </div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px; margin-top: 5px;"> opcod rs rt rd func </div>
Shift right arithmetic variable		R format

Only the 5 lsb of Rs are meaningful

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Computation

Assembly language	Action	Format
Slt Rd, Rs, Rt	$Rs < Rt ?$ Yes : $1 \Rightarrow Rd$ No : $0 \Rightarrow Rd$	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; position: relative;"> </div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px; margin-top: 5px;"> opcod rs rt rd func </div>
Set if less than		R format

Operands are signed

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Computation

Assembly language	Action	Format
Slti Rd, Rs, Imd	$Rs < Imd ?$ Yes : $1 \Rightarrow Rd$ No : $0 \Rightarrow Rd$	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px;"></div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px; margin-top: 5px;"> opcod rs rd imd </div>
Set if less than immediate		I format

Operands are signed
Imd is sign extended

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Computation

Assembly language	Action	Format
<p>Sltu Rd, Rs, Rt</p> <p>Set if less than unsigned</p>	<p>Rs < Rt ?</p> <p>Yes : 1 ⇒ Rd</p> <p>No : 0 ⇒ Rd</p> <p>Operands are unsigned</p>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between; font-size: 0.8em;"> opcod rs rt rd func </div> <div style="display: flex; height: 20px; border-top: 1px solid black; border-bottom: 1px solid black; position: relative;"> </div> </div> <p style="text-align: center;">R format</p>

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Computation

Assembly language	Action	Format
<p>Sltiu Rd, Rs, Imd</p> <p>Set if less than immediate, unsigned</p>	<p>Rs < Imd ?</p> <p>Yes : 1 ⇒ Rd</p> <p>No : 0 ⇒ Rd</p> <p>Operands are unsigned Imd is sign extended</p>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between; font-size: 0.8em;"> opcod rs rd imd </div> <div style="display: flex; height: 20px; border-top: 1px solid black; border-bottom: 1px solid black; position: relative;"> </div> </div> <p style="text-align: center;">I format</p>

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Computation

Assembly language	Action	Format
<p>Lui Rd, Imd</p> <p>load upper immediate</p>	<p>Imd << 16 ⇒ Rd</p>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between; font-size: 0.8em;"> opcod rd imd </div> <div style="display: flex; height: 20px; border-top: 1px solid black; border-bottom: 1px solid black; position: relative;"> </div> </div> <p style="text-align: center;">I format</p>

00 00
Rd

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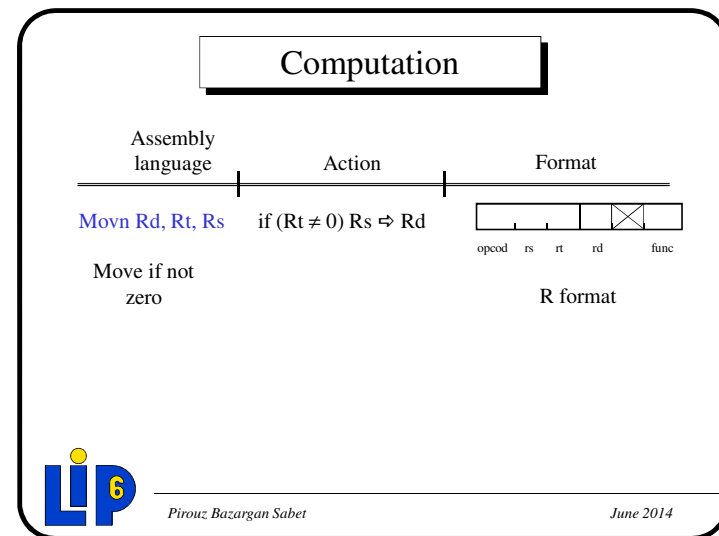
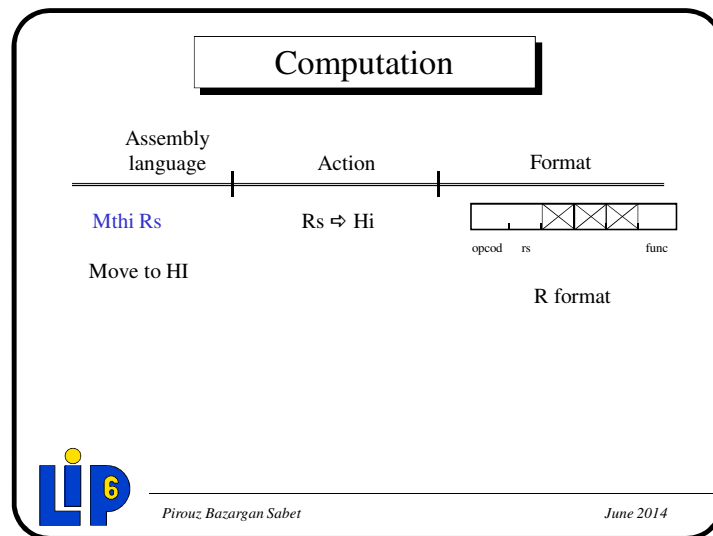
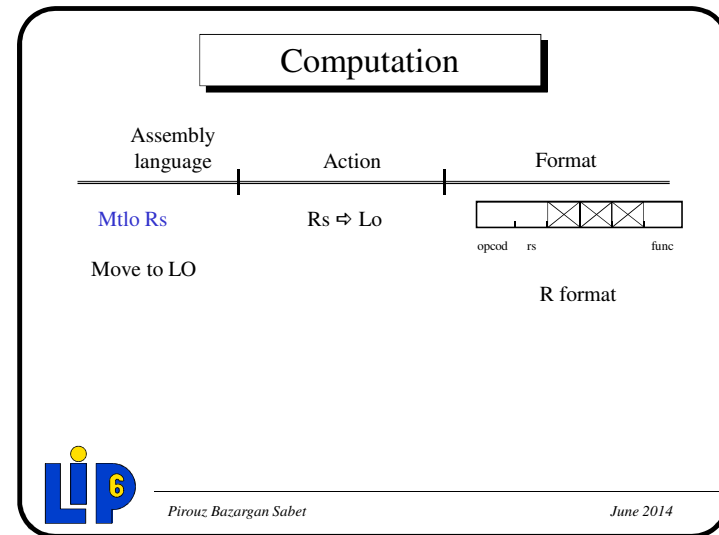
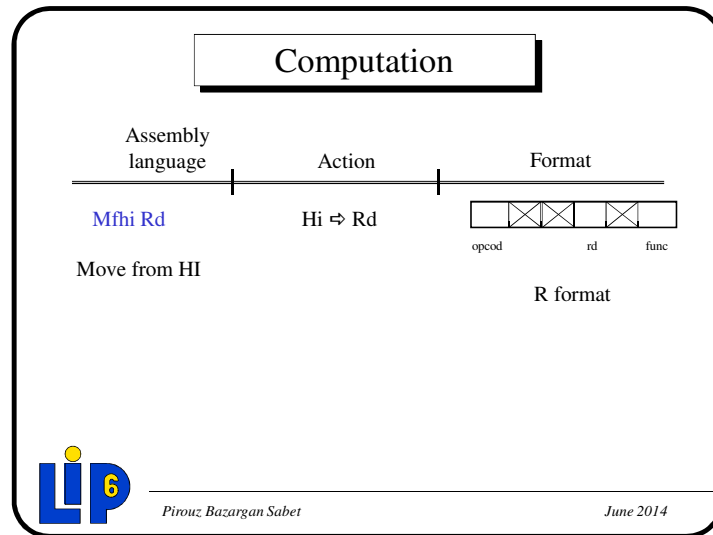
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Computation

Assembly language	Action	Format
<p>Mflo Rd</p> <p>Move from LO</p>	<p>Lo ⇒ Rd</p>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between; font-size: 0.8em;"> opcod rd func </div> <div style="display: flex; height: 20px; border-top: 1px solid black; border-bottom: 1px solid black; position: relative;"> </div> </div> <p style="text-align: center;">R format</p>

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Computation

Assembly language	Action	Format
<p>Movz Rd, Rt, Rs</p> <p>Move if zero</p>	<p>if (Rt = 0) Rs \Rightarrow Rd</p>	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <div style="display: flex; justify-content: space-around; font-size: 0.8em;"> opcodrsrtrdfunc </div> </div> <p style="text-align: center;">R format</p>

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Computation

Assembly language	Action	Format
<p>Mult Rs, Rt</p> <p>Multiply</p>	<p>Rs \times Rt \Rightarrow (Hi, Lo)</p> <p>Operands are signed</p>	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <div style="display: flex; justify-content: space-around; font-size: 0.8em;"> opcodrsrtfunc </div> </div> <p style="text-align: center;">R format</p>

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Computation

Assembly language	Action	Format
<p>Multu Rs, Rt</p> <p>Multiply unsigned</p>	<p>Rs \times Rt \Rightarrow (Hi, Lo)</p> <p>Operands are unsigned</p>	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <div style="display: flex; justify-content: space-around; font-size: 0.8em;"> opcodrsrtfunc </div> </div> <p style="text-align: center;">R format</p>

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Computation


Assembly language	Action	Format
<p>Madd Rs, Rt</p> <p>Multiply and add</p>	<p>Rs \times Rt + (Hi, Lo) \Rightarrow (Hi, Lo)</p> <p>Operands are signed</p>	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <div style="display: flex; justify-content: space-around; font-size: 0.8em;"> opcodrsrtfunc </div> </div> <p style="text-align: center;">R format</p>

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Computation


Assembly language	Action	Format
Maddu Rs, Rt Multiply and add unsigned	$Rs \times Rt + (Hi, Lo)$ $\Rightarrow (Hi, Lo)$ Operands are unsigned	<div> <div>opcod</div> <div>rs</div> <div>rt</div> <div>func</div> </div> R format



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Computation


Assembly language	Action	Format
Msub Rs, Rt Multiply and subtract	$(Hi, Lo) - Rs \times Rt$ $\Rightarrow (Hi, Lo)$ Operands are signed	<div> <div>opcod</div> <div>rs</div> <div>rt</div> <div>func</div> </div> R format



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Computation


Assembly language	Action	Format
Msubu Rs, Rt Multiply and subtract unsigned	$(Hi, Lo) - Rs \times Rt$ $\Rightarrow (Hi, Lo)$ Operands are unsigned	<div> <div>opcod</div> <div>rs</div> <div>rt</div> <div>func</div> </div> R format



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Computation

Assembly language	Action	Format
Mul Rd, Rs, Rt Multiply word	$Rs \times Rt \Rightarrow Rd$ 32 least significant bits of the product are saved into Rd Operands are signed	<div> <div>opcod</div> <div>rs</div> <div>rt</div> <div>rd</div> <div>func</div> </div> R format



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Computation

Assembly language	Action	Format
Div Rs, Rt	Rs / Rt \Rightarrow Lo	<div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rs rt func </div>
Divide	Remainder (Rs / Rt) \Rightarrow Hi	
	Operands are signed	

R format

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Computation

Assembly language	Action	Format
Divu Rs, Rt	Rs / Rt \Rightarrow Lo	<div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rs rt func </div>
Divide	Remainder (Rs / Rt) \Rightarrow Hi	
	Operands are unsigned	

R format

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Computation

Assembly language	Action	Format
Clz Rd, Rs	the number of ones in the most significant bits of Rs \Rightarrow Rd	<div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rs rd func </div>
Count leading ones		

R format

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Computation

Assembly language	Action	Format
Clz Rd, Rs	the number of zeros in the most significant bits of Rs \Rightarrow Rd	<div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px;"></div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> <div style="border: 1px solid black; width: 20px; height: 20px; margin-right: 5px; text-align: center;">X</div> </div> <div style="display: flex; justify-content: space-around; font-size: 8px;"> opcod rs rd func </div>
Count leading zeros		

R format

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