Logical Operations

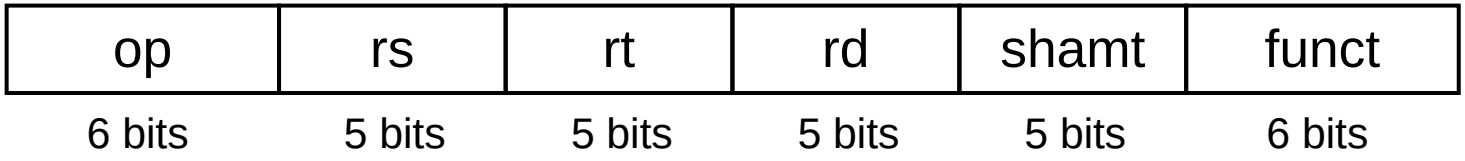
Logical Operations

- Instructions for bitwise manipulation

Operation	C	Java	MIPS
Shift left	<<	<<	`sll`
Shift right	>>	>>>	`srl`
Bitwise AND	&	&	`and, andi`
Bitwise OR	|	|	`or, ori`
Bitwise NOT	~	~	`nor`

- Useful for extracting and inserting groups of bits in a word

Shift Operations

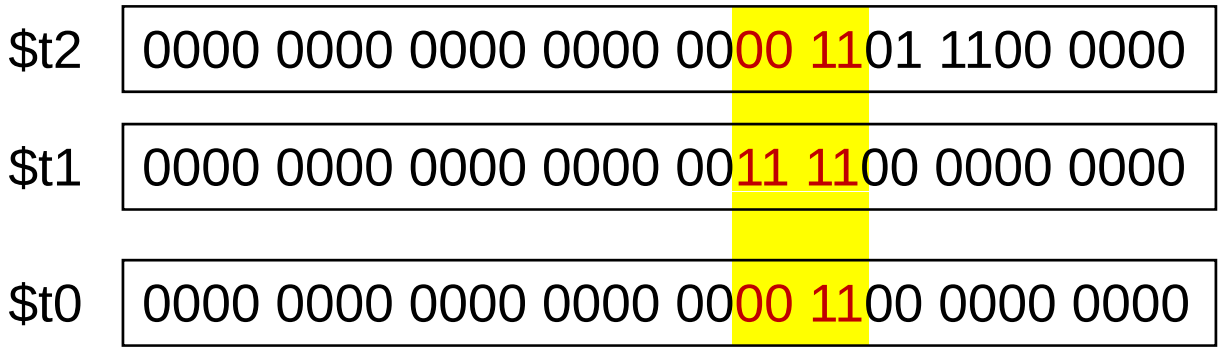


- shamt: how many positions to shift
- Shift left logical (`sll`)
  - Shift left and fill with 0 bits
  - `sll` by *i* bits = multiplies by 2^i
- Shift right logical (`srl`)
  - Shift right and fill with 0 bits
  - `srl` by *i* bits = divides by 2^i (unsigned only)

AND Operations

- Useful to mask bits in a word
  - Select some bits, clear others to 0

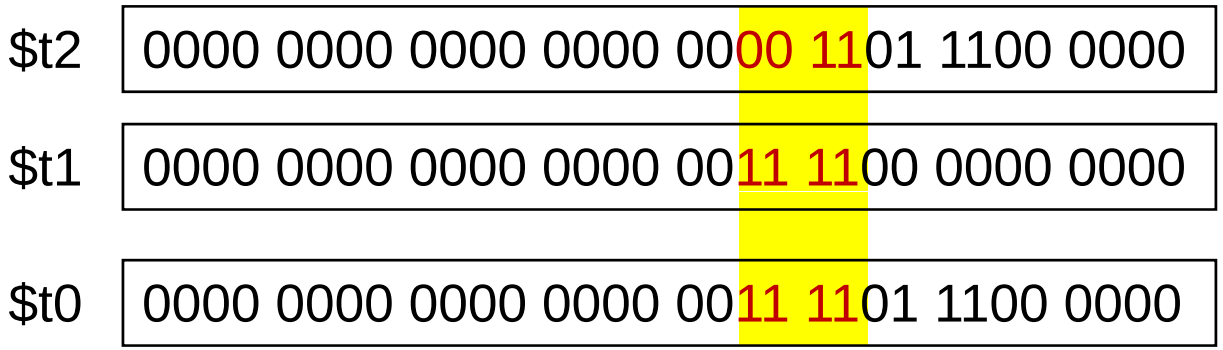
```
and $t0, $t1, $t2
```



OR Operations

- Useful to include bits in a word
  - Set some bits to 1, leave others unchanged

```
or $t0, $t1, $t2
```



NOT Operations

- Useful to invert bits in a word
  - Change 0 to 1, and 1 to 0
- MIPS has NOR 3-operand instruction
  - `a NOR b == NOT ( a OR b )`

```
nor $t0, $t1, $zero
```

Register 0: always read as zero

$t1	0000	0000	0000	0000	0011	1100	0000	0000
$t0	1111	1111	1111	1111	1100	0011	1111	1111

Question

- Which operation can isolate a field in a word?
  - AND
  - A shift left followed by a shift right

Conditional Operations

Conditional Operations

- Branch to a labeled instruction if a condition is true
  - Otherwise, continue sequentially

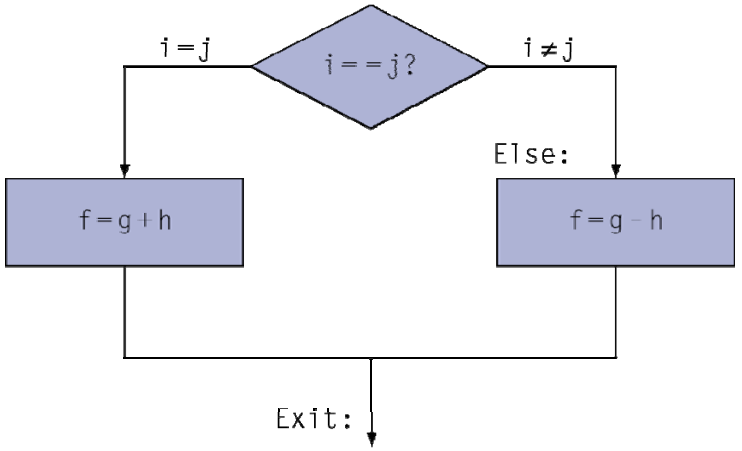
- `beq rs, rt, L1` — if (rs == rt) branch to instruction labeled L1;
- `bne rs, rt, L1` — if (rs != rt) branch to instruction labeled L1;
- `j L1` — unconditional jump to instruction labeled L1

Compiling If Statements

- C code:

```
if (i==j) f = g+h;
else f = g-h;
```

  - i, j → $s3, $s4
  - f, g,h → $s0, $s1, $s2



- Compiled MIPS code:

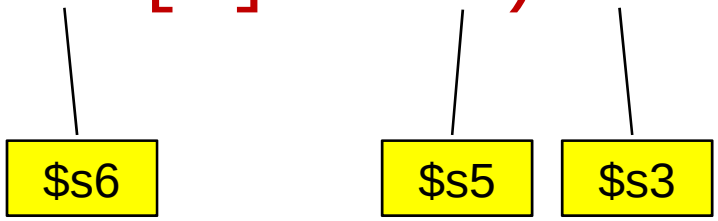
Assembler calculates addresses

```
      bne $s3, $s4, Else
      add $s0, $s1, $s2
      j   Exit
Else: sub $s0, $s1, $s2
Exit: …
```

Compiling Loop Statements

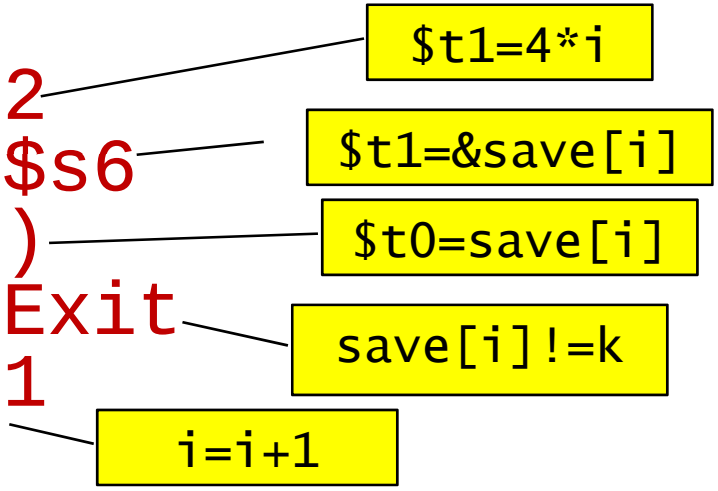
- C code:

```
while (save[i] == k) i += 1;
```



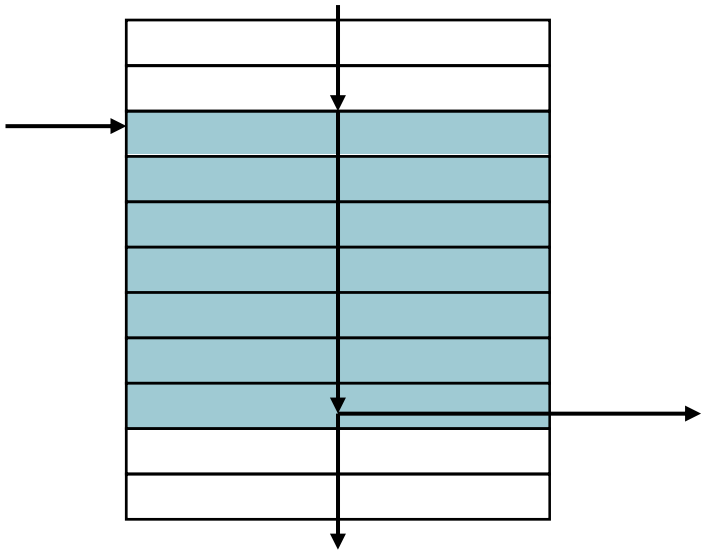
- Compiled MIPS code:

```
Loop: sll  $t1, $s3, 2
      add  $t1, $t1, $s6
      lw   $t0, 0($t1)
      bne  $t0, $s5, Exit
      addi $s3, $s3, 1
      j    Loop
Exit: …
```



Basic Blocks

- A basic block is a sequence of instructions with
  - No embedded branches (except at end)
  - No branch targets (except at beginning)



- A compiler identifies basic blocks for optimization
- An advanced processor can accelerate execution of basic blocks

More Conditional Operations

- Set result to 1 if a condition is true

- `slt rd, rs, rt`

if (rs < rt) rd = 1; else rd = 0;

- `slti rt, rs, constant`

if (rs < constant) rt = 1;
else rt = 0;

```
slt = set on less than
slti = set on less than a const
```

- Use in combination with `beq, bne`

```
slt $t0, $s1, $s2  # if ($s1 < $s2)
bne $t0, $zero, L  #   branch to L
```

Signed vs. Unsigned

- Signed comparison: `slt`, `slti`
- Unsigned comparison: `sltu`, `sltui`
- Example
  - $s0 = 1111 1111 1111 1111 1111 1111 1111 1111
  - $s1 = 0000 0000 0000 0000 0000 0000 0000 0001
  - `slt  $t0, $s0, $s1  # signed`
    - –1 < +1 ⇒ $t0 = 1
  - `sltu $t0, $s0, $s1  # unsigned`
    - +4,294,967,295 > +1 ⇒ $t0 = 0