Bitwise Operations

- Bitwise operations in high-level languages are applied to integers
- Java has three primary sizes for signed integers
  - short (16 bit chunks)
  - int (32 bit chunks)
  - long (64 bit chunks)
- Two types of Bitwise Operations
  - Boolean based operations
  - Shift-based operations
- Boolean-based Operations:

○ Complement:	`s1 = ~ t1`	`nor $s1, $t1, $zero # s1 = ~ ( t1 | 0 )`
○ And:	`s1 = t1 & t2`	`and $s1, $t1, $t2`
○ Or:	`s1 = t1 | t2`	`or $s1, $t1, $t2`
○ Xor:	`s1 = t1 ^ t2`	`xor $s1, $t1, $t2`

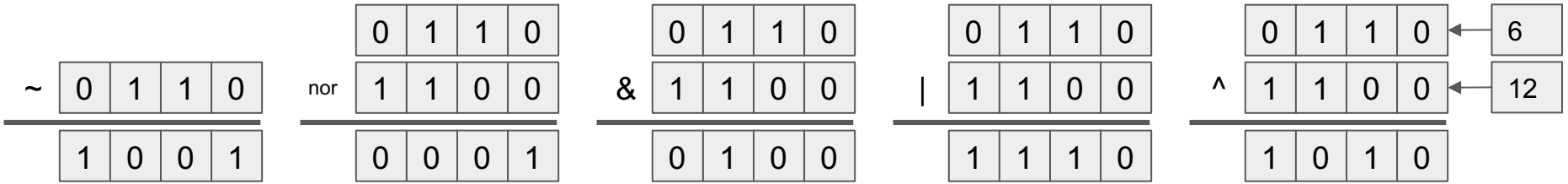
- Shift-based Operations:

○ Signed Left Shift	`s1 = t1 << 2`	`sll $s1, $t1, 2  # Shift Left Logical`
○ Signed Right Shift	`s1 = t1 >> 2`	`sra $s1, $t1, 2  # Shift Right Arithmetic`
~~○ Unsigned Left Shift~~	~~`s1 = t1 <<< t2`~~	
○ Unsigned Right Shift	`s1 = t1 >>> 2`	`srl $s1, $t1, 2  # Shift Right Logical`

Boolean-based Bitwise Operations

A	B	nor	&	|	^
0	0	1	0	0	0
0	1	0	0	1	1
1	0	0	0	1	1
1	1	0	1	1	0

- Let's assume 4-bit chunks:
  - Complement: `s1 = ~ t1` `nor $s1, $t1, $zero`
  - And: `s1 = t1 & t2` `and $s1, $t1, $t2`
  - Or: `s1 = t1 | t2` `or $s1, $t1, $t2`
  - Xor: `s1 = t1 ^ t2` `xor $s1, $t1, $t2`



Shift-based Operations

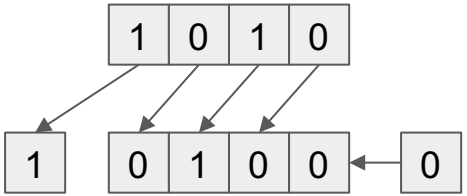
Foreshadow:
- Integers are encoded in 2's complement
- In such numbers, the MSB is represents the sign
- 1 -> a negative number

- Java and MIPS supported:

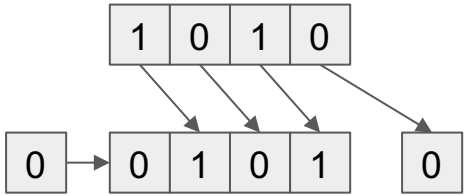
○ Shift Left Logical	`s1 = t1 << 2`	`sll $s1, $t1, 2`
○ Shift Right Logical	`s1 = t1 >>> 2`	`srl $s1, $t1, 2`
○ Shift Right Arithmetic	`s1 = t1 >> 2`	`sra $s1, $t1, 2`
○ Shift Left Logical Variable	`s1 = t1 << t2`	`sllv $s1, $t1, $t2`
○ Shift Right Logical Variable	`s1 = t1 >>> t2`	`srlv $s1, $t1, $t2`
○ Shift Right Arithmetic Variable	`s1 = t1 >> t2`	`srav $s1, $t1, $t2`

- Let's Assume 4-bits and a shift of "1"

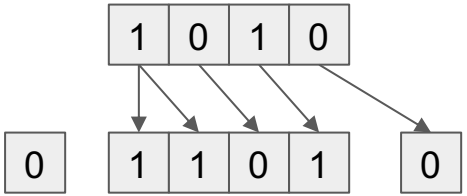
shift left logical



shift right logical



shift right arithmetic



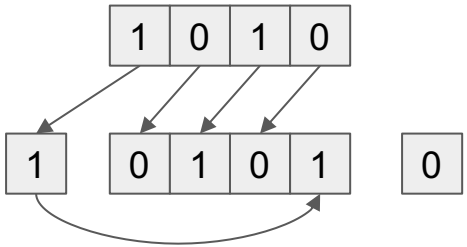
Additional Shift-based Operations

- Rotates or Circular Shifts
  - Rotate Left Logical `rol $s1, $t1, 2`
  - Rotate Right Logical `ror $s1, $t1, 2`
- Typically, not supported in high-level languages
- Let's Assume 4-bits and a shift of "1"

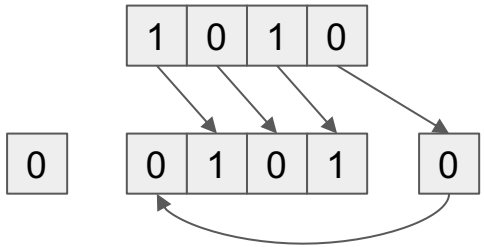
```
sll $s1, $t1, 2
srl $at, $t1, 30
or $s1, $s1, $at
```

```
srl $s1, $t1, 2
sll $at, $t1, 30
or $s1, $s1, $at
```

rotate left



rotate right



Repositioning Fields within a Register

The blue cells represent a field within the register!

- Consider a register (16 bits) containing information
- Consider extracting a subrange of bits