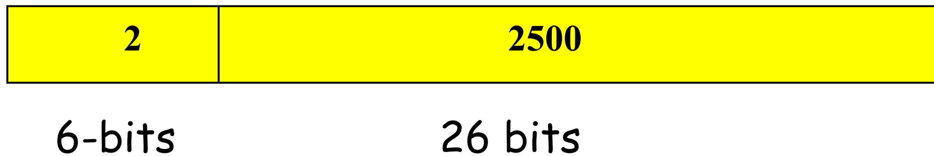
The instruction formats for jump and branch

J 10000 is represented as

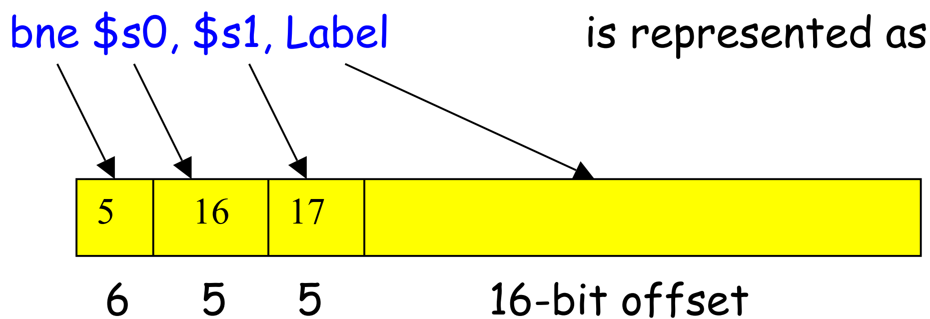


6-bits 26 bits

This is the J-type format of MIPS instructions.

Conditional branch is represented using I-type format:

bne $s0, $s1, Label is represented as



6 5 5 16-bit offset

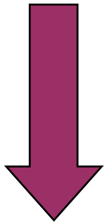
Current PC + (4 * offset) determines the branch target **Label**

This is called **PC-relative addressing**.

Revisiting machine language of MIPS

```
# starts from 80000
Loop:   add  $t1, $s3, $s3
        add  $t1, $t1, $t1
        add  $t1, $t1, $s6
        lw   $t0, 0($t1)
        bne  $t0, $s5, Exit
        add  $s3, $s3, $s4
        j    Loop
Exit:
```

What does this program do?



Machine language version

	6	5	5	5	5	6	
80000	0	19	19	9	0	32	R-type
80004	0	9	9	9	0	32	R-type
80008	0	9	22	9	0	32	R-type
80012	35	9	8	0			I-type
80016	5	8	21	2 (why?)			I-type
80020	0	19	20	19	0	32	R-type
80024	2	20000 (why?)					J-type
80028							

Addressing Modes

What are the different ways to access an operand?

Register addressing

Operand is in register

add $s1, $s2, $s3 means $s1 ← $s2 + $s3

Base addressing

Operand is in memory.

The address is the sum of a register and a constant.

lw $s1, 32($s3) means $s1 ← M[s3 + 32]

As special cases, you can implement

Direct addressing $s1 ← M[32]

Indirect addressing $s1 ← M[s3]

Which helps implement pointers.

Immediate addressing

The operand is a constant.

How can you execute $\$s1 \leftarrow 7$?

addi $s1, $zero, 7 means $\$s1 \leftarrow 0 + 7$

(add immediate, uses the I-type format)

PC-relative addressing

The operand address = PC + an offset

Implements position-independent codes. A small offset is adequate for short loops.

Pseudo-direct addressing

Used in the J format. The target address is the concatenation of the 4 MSB's of the PC with the 28-bit offset. This is a minor variation of the PC-relative addressing format.

Revisiting pseudoinstructions

These are simple assembly language instructions that do not have a direct machine language equivalent. During assembly, the assembler translates each pseudo-instruction into one or more machine language instructions.

Example

move $t0, $t1 # $t0 ← $t1

Implemented as add $t0, $zer0, $t1

How to implement li $v0, 4 ?

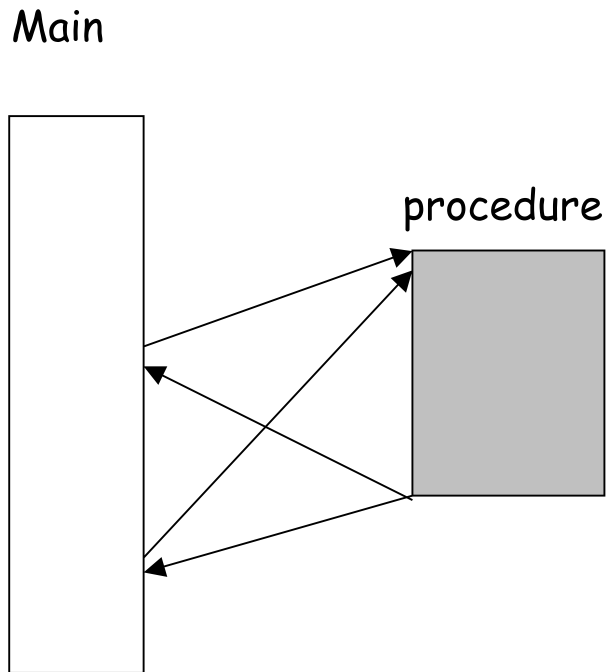
blt $s0, $s1, label # if $s0 < $s1 then goto label

Implemented as

```
slt $t0, $s0, $s1        # if $s0 < $s1 then $t0 =1 else $t0 = 0
bne $t0, $zero, label    # if $t0 ≠ 0 then goto label
```

Pseudo-instructions give MIPS a richer set of assembly language instructions.

Procedure Call



Typically uses a stack.

Question. Can we implement procedure calls using jump instructions (like **j xxxx**)?