Topic V06

Logic Instructions

Reading: (Section 2.6)

Logic Operations in RISC-V

shift left logical immediate

$2^4 = 16$

```
slli t2, s0, 4
```

s0 `0x00000002` = 2_{10}

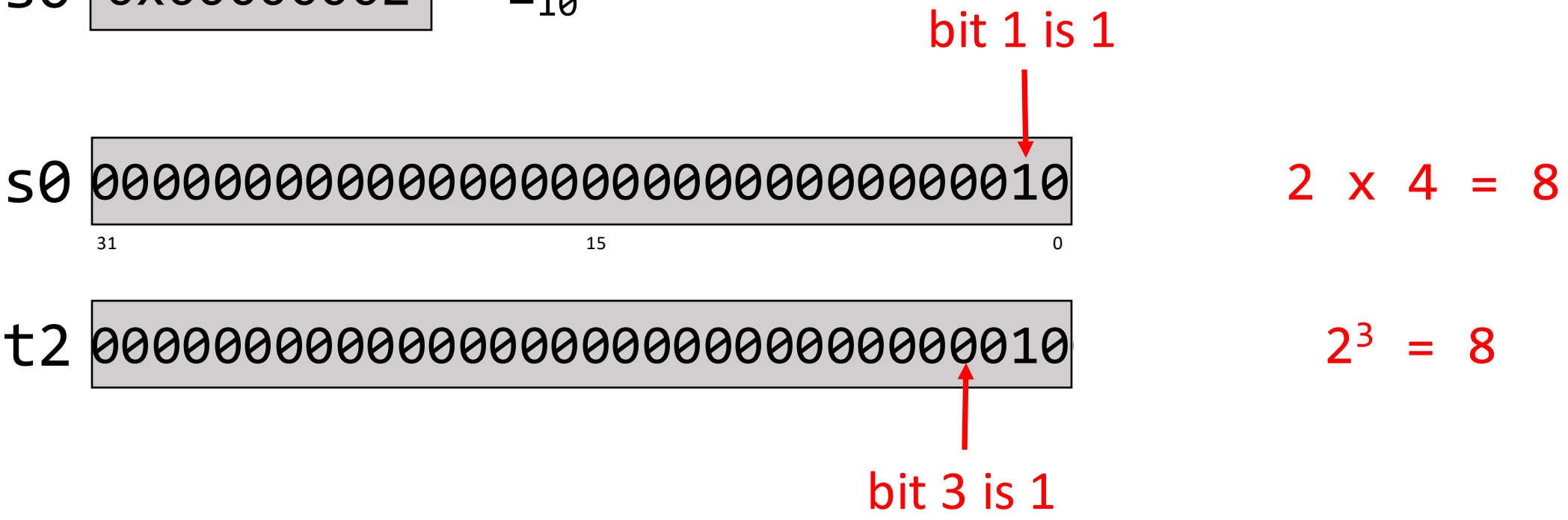
Logic Operations in RISC-V

shift left logical immediate

```
slli t2, s0, 2
```

s0 `0x00000002` = 2_{10}

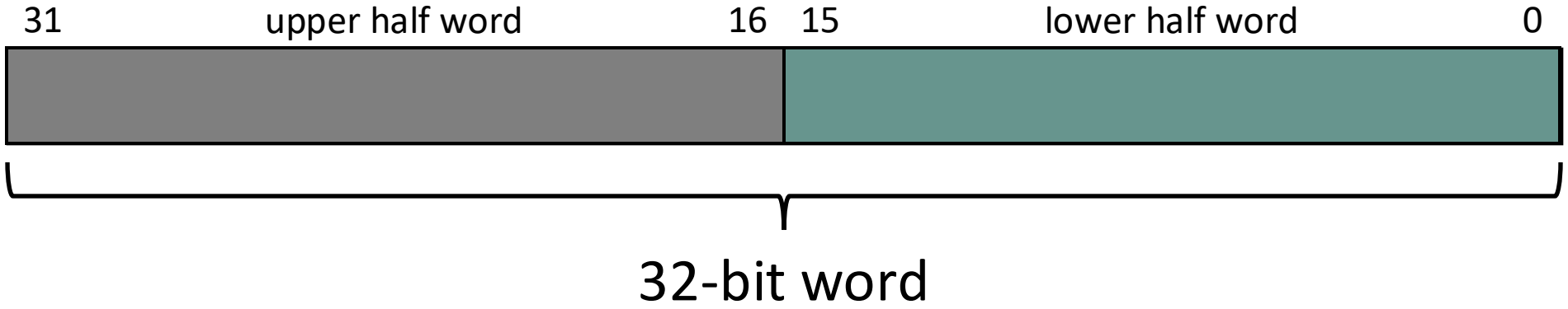
$2^2 = 4$



Using Shift Left for Multiplication

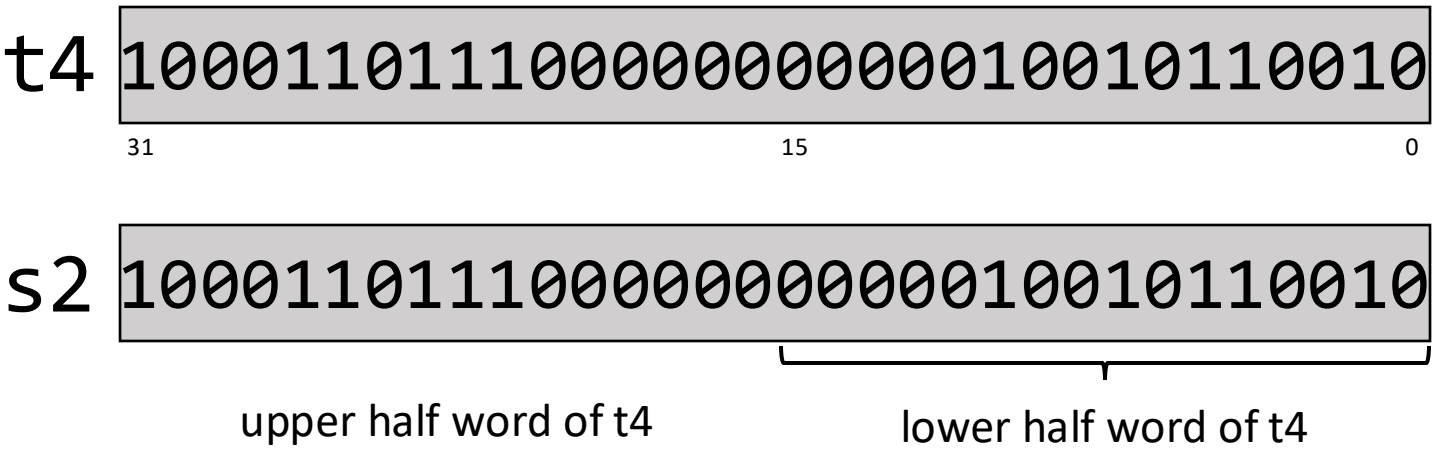
`slli t2, s0, k` is equivalent to: `t2 ← s0 x` 2^k

Moving Lower Half Word to Upper Half Word

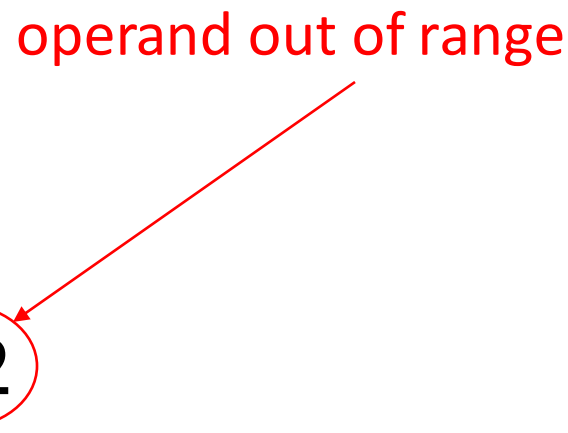


QUIZ: Write a RISC-V program to move the lower half word of `t4` into the upper half word of `s2` making the lower half word of `s2` equal zero

```
slli s2, t4, 16
```

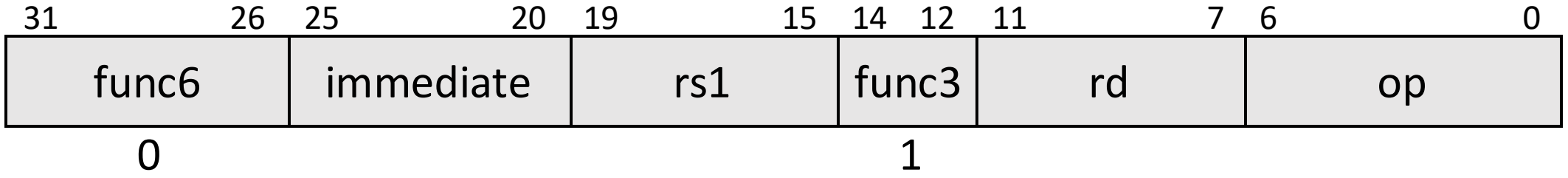


QUIZ: What would be the value stored in `s4` after the execution of the following instruction?



Answer: The value would be zero because all 32 bits of `t1` would be shifted out to the left and 32 zero bits would be shifted in from the right

Shifts With an Immediate Use a Modified I-Type Format



In RISC-V we can only shift up to 31 bits

⇒ a shift only needs the lower 6 bits of the I-type format's 12-bit immediate

6 upper bits form an additional opcode field: `funct6`

Attempting to `slli/srli` by more than 31:

⇒ RARS throws an 'operand out of range' error

Shift Left by an Amount in a Register

What happens when we don't know by how many bits we need to shift when we are writing the code?

Example: Write RISC-V assembly to shift the value of x (which is in s3) to the left by k bits (k is in s7)

```
sll s3, s3, s7              # x ← x << k
```

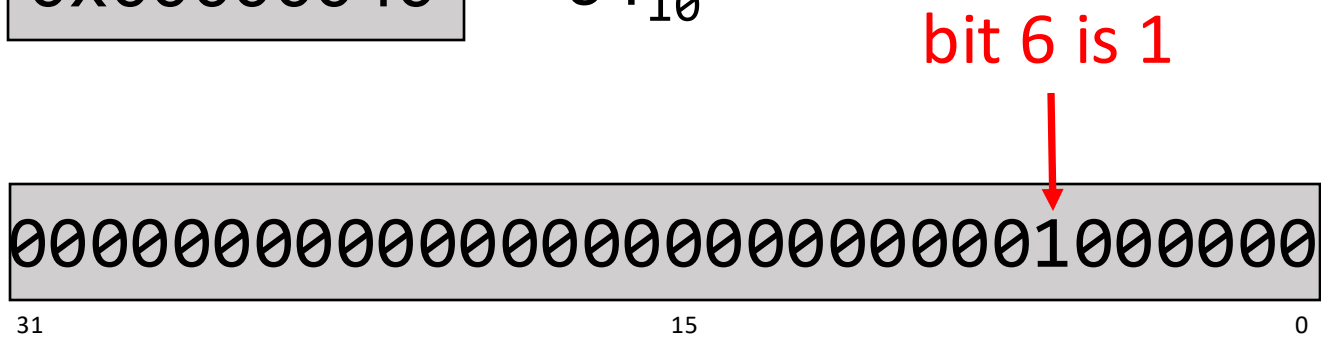
Shifting Right

shift right logical immediate

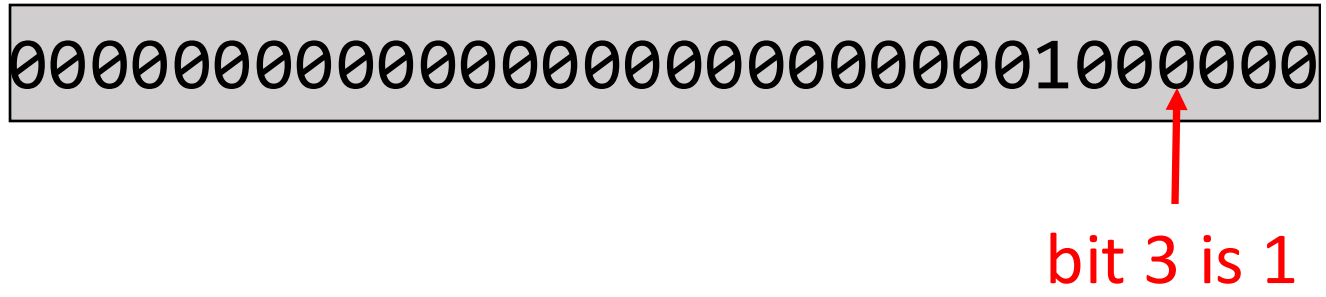
```
srli t2, s0, 3
```

s0 `0x00000040` = 64_{10}

$2^3 = 8$



$\left\lfloor \frac{64}{8} \right\rfloor = 8$



$2^3 = 8$

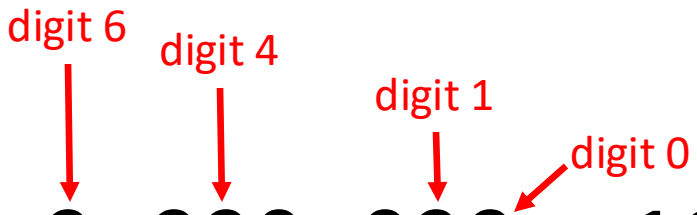
A quick way to find the decimal value of some binary numbers

In Decimal

$$999 = 1000 - 1$$
$$= 10^3 - 1$$

$$99999 = 100000 - 1$$
$$= 10^5 - 1$$

In Decimal



$$9,990,099 = 10,000,000 - 10,000 + 100 - 1$$

$$= 10^7 - 10^4 + 10^2 - 10^0$$

In Binary

What is the decimal value of the following binary number?

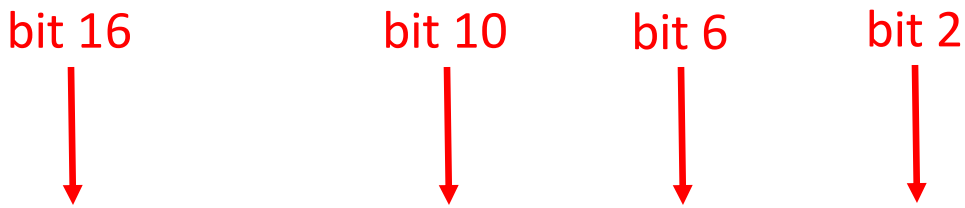
$x = 0000\ 0111\ 1111\ 1111\ 1111$

$x = 2^{15} - 1 = 2^{10} \times 2^{5} - 1 = 1024 \times 32 - 1$

$$\begin{array}{rll} & 0000\ 1000\ 0000\ 0000\ 0000 & = 2^{15} \\ - & 0000\ 0000\ 0000\ 0000\ 0001 & = 1 \\ \hline & 0000\ 0111\ 1111\ 1111\ 1111 & \end{array}$$

In Binary

What is the decimal value of the following binary number?



$x = 0001\ 1111\ 1100\ 0111\ 1100$

$x = 2^{17} - 2^{10} + 2^{7} - 2^{2}$

$= (2^{7} - 1) \times 2^{10} + (2^{5} - 1) \times 2^{2}$

$= (128 - 1) \times 1024 + (32 - 1) \times 4$

$= 127 \times 1024 + 31 \times 4$

$= 130{,}048 + 124$

$= 130{,}172$

Shifting Right

shift right logical immediate

```
srli t2, s0, 2
```

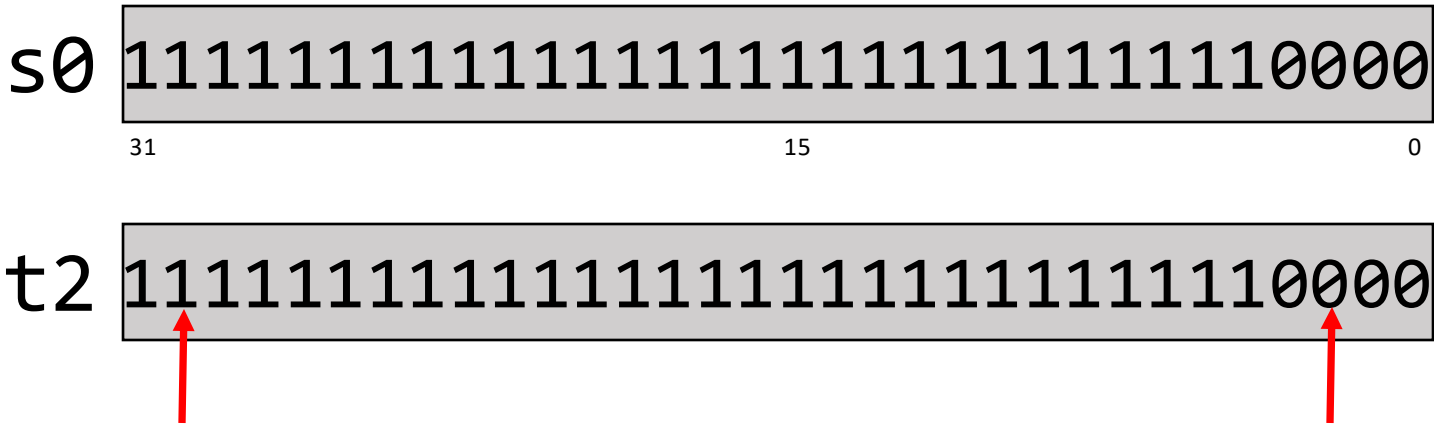
s0 `0xFFFFFFF0` = -16_{10}

$2^{30} - 2^{2}$

$= 2^{10} \times 2^{10} \times 2^{10} - 4$

$= 1024 \times 1024 \times 1024 - 4$

$= 1,073,741,820$



Shifting Right

shift right arithmetic immediate

How do I perform this computation?

```
srai t2, s0, 2
```

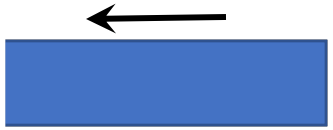
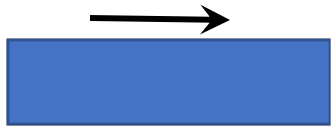
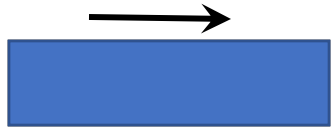
s0 `0xFFFFFFF0` = -16_{10}

$$\left\lfloor \frac{-16}{4} \right\rfloor = -4$$

s0 `11111111111111111111111111110000`

31 15 0

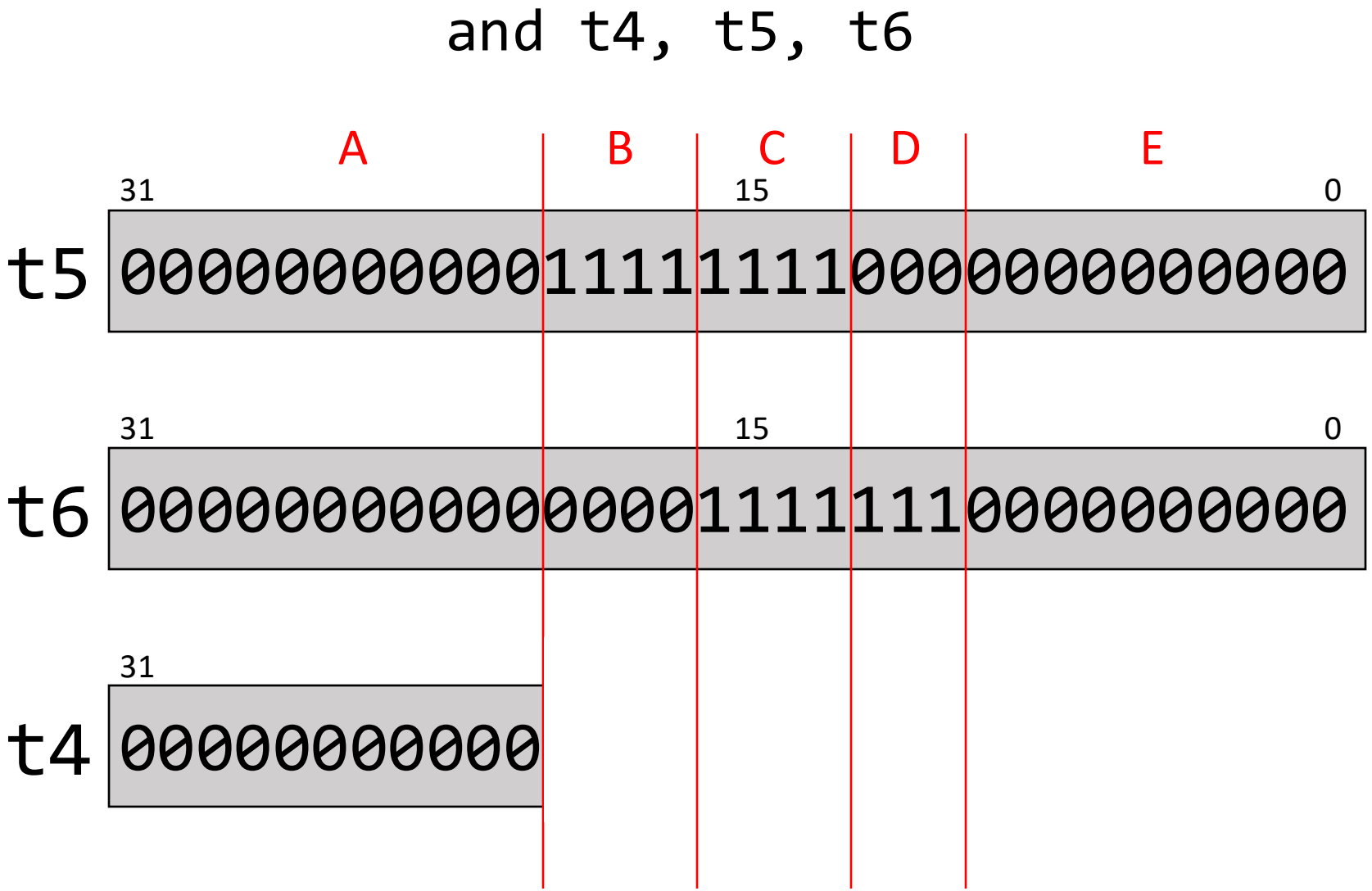
t2 `11111111111111111111111111110000` = -4_{10}

`slli t2, s0, k`	`srli t2, s0, k`	`srai t2, s0, k`
		
$t2 \leftarrow s0 \times 2^k$		$t2 \leftarrow \left\lfloor \frac{s0}{2^k} \right\rfloor$
`sll t2, s0, t4`	`srl t2, s0, t4`	`sra t2, s0, t4`

Recap of shift operations

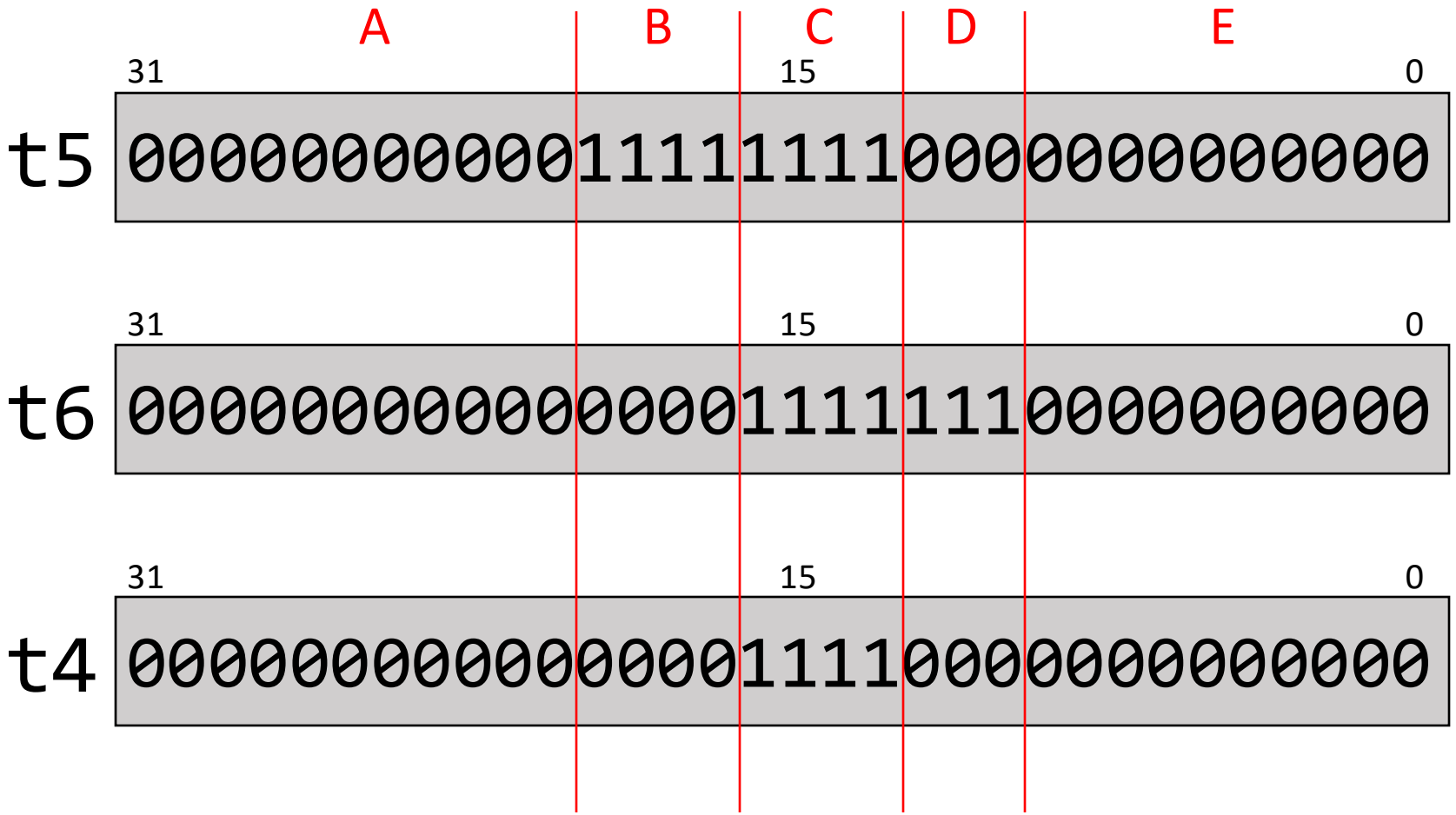
Bitwise Logical Operations

Bitwise Logical Operations



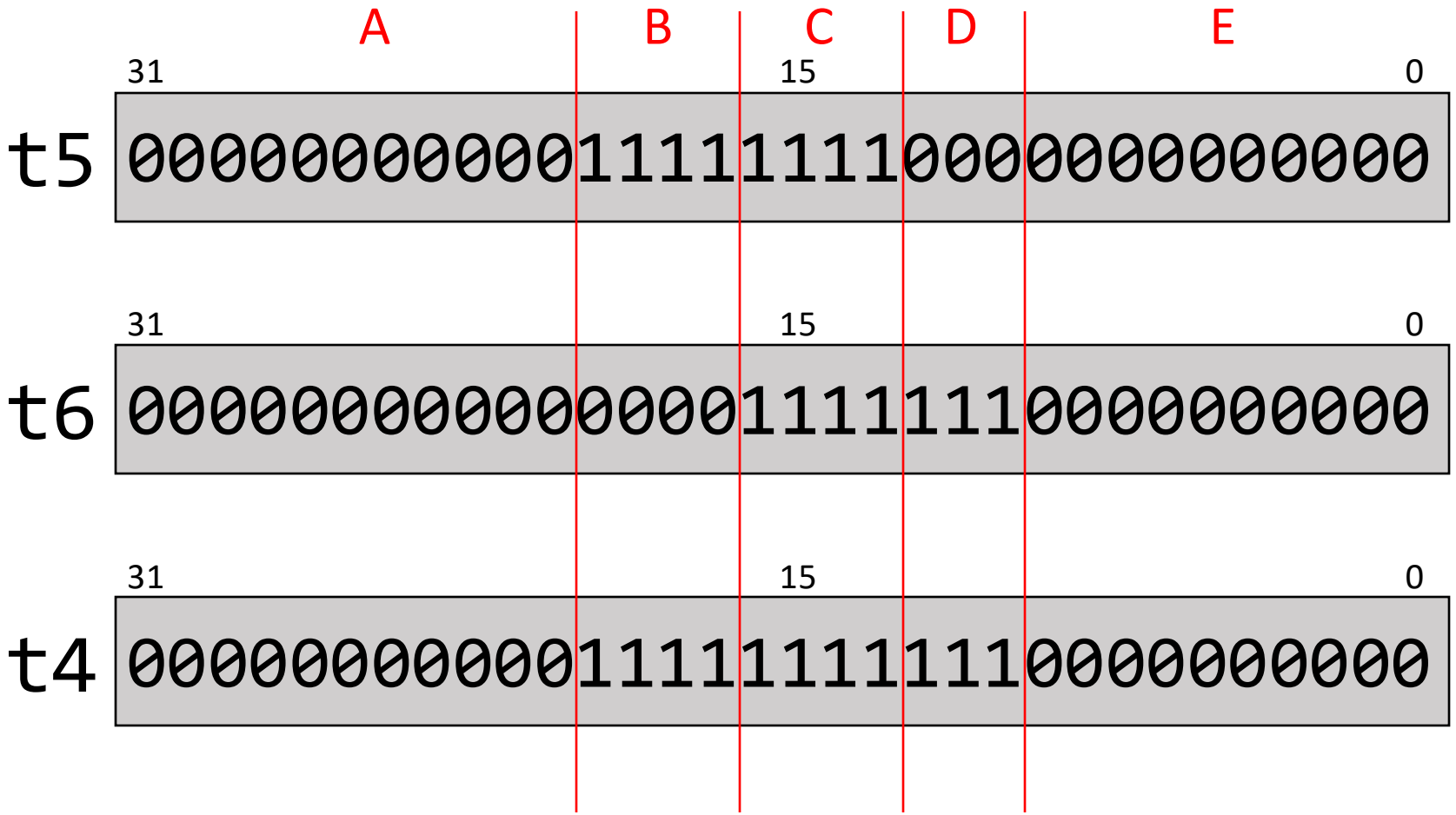
Bitwise Logical Operations

```
and t4, t5, t6
```

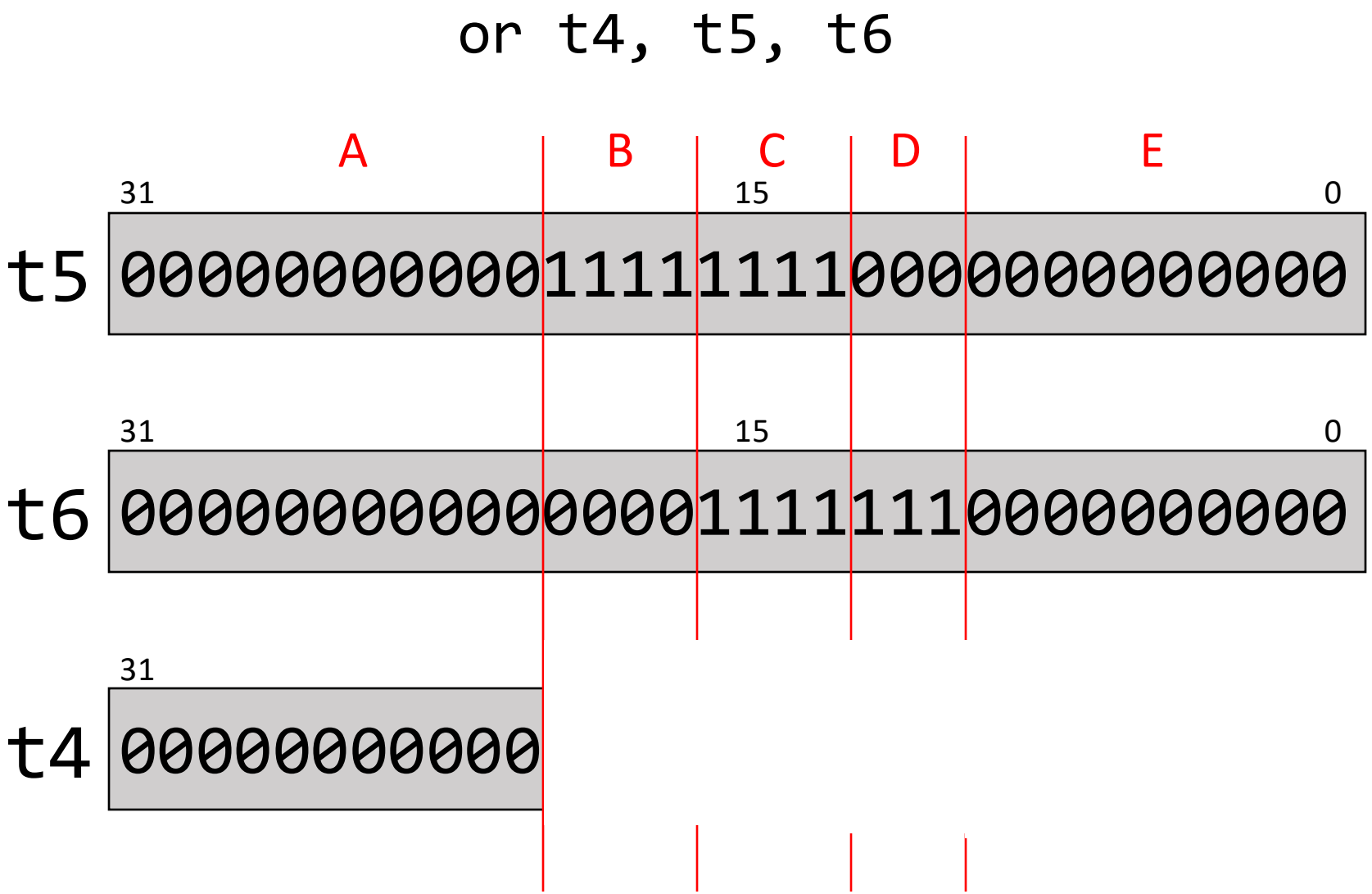


Bitwise Logical Operations

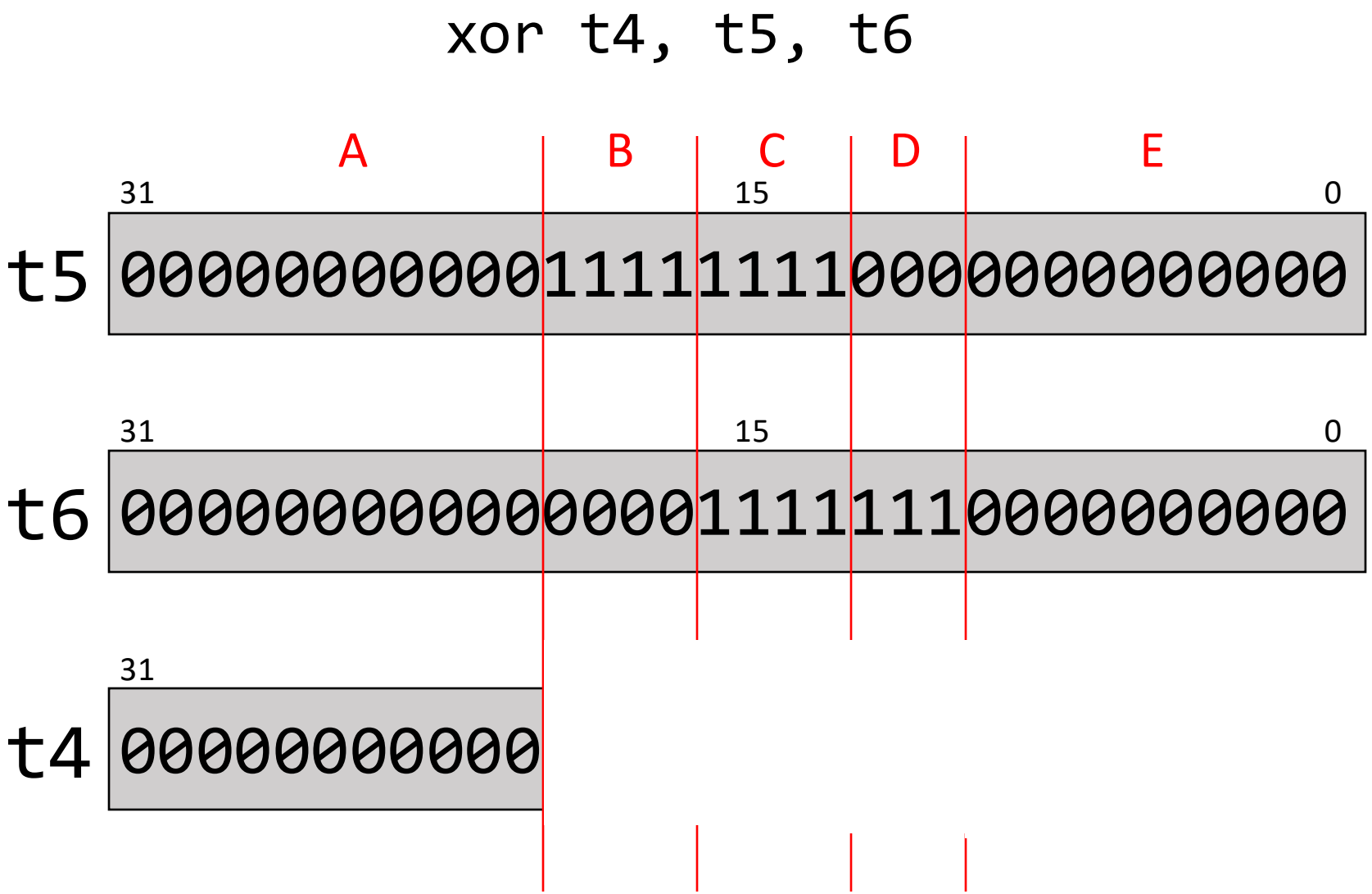
```
or t4, t5, t6
```



Bitwise Logical Operations

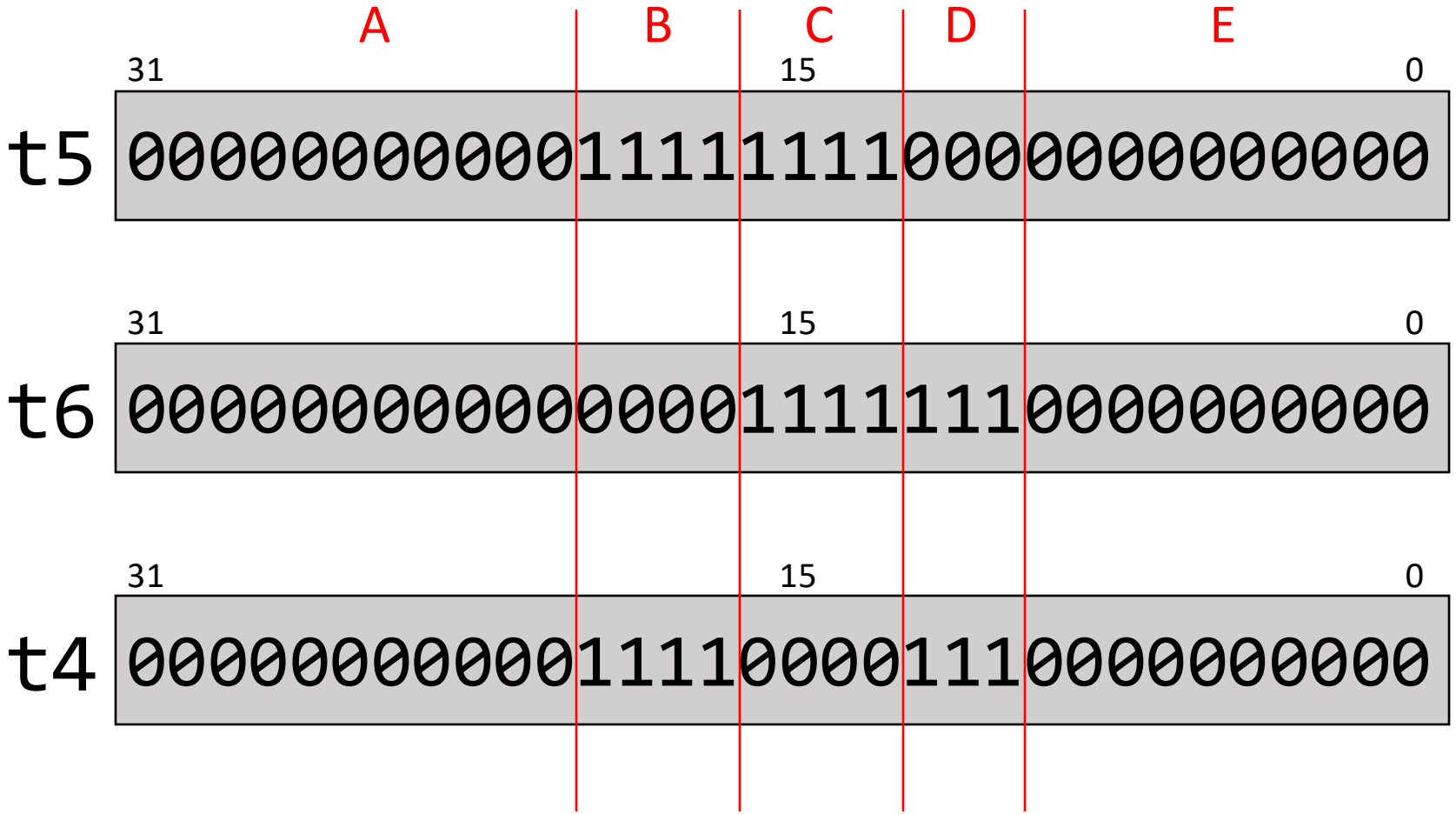


Bitwise Logical Operations



Bitwise Logical Operations

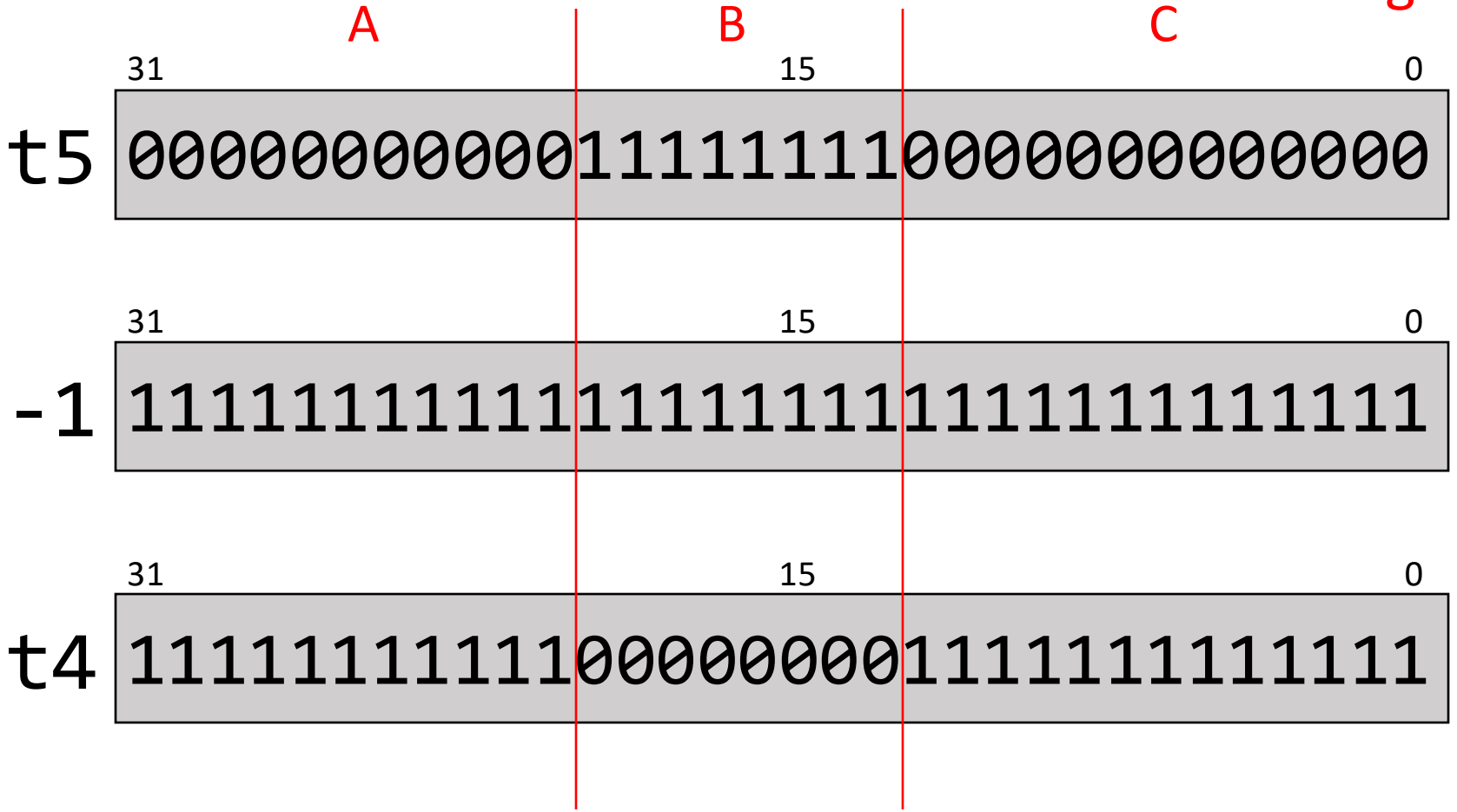
```
xor t4, t5, t6
```



Bitwise Logical Operations

```
xori t4, t5, -1
```

used for logical negation

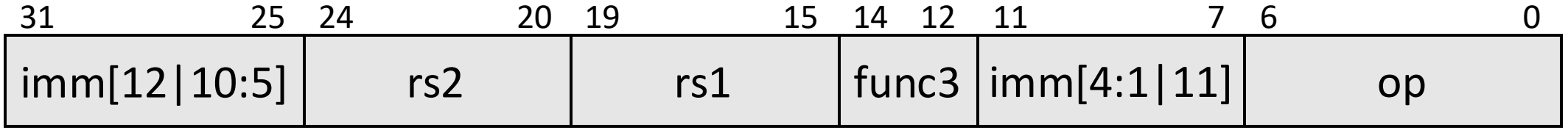


Warm Up

An unconditional branch can be created using a **beq** instruction with the same register for both source operands. Examples:

```
beq t3, t3, LeftSide
```

Binary format of a branch instruction:



Assume that **t0** has the binary representation of a **beq** instruction.
Write a sequence of RISC-V instructions that writes in **t1:**

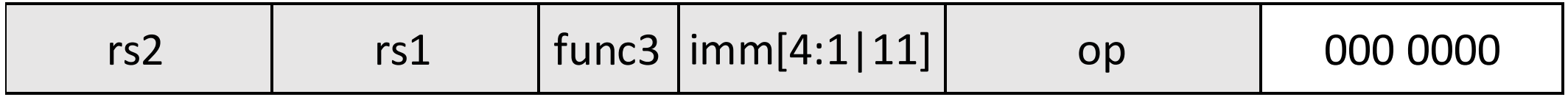
- zero: if that **beq** is an unconditional branch
- non-zero: if that **beq** is a conditional branch

slli t2, t0, 7

t2 =

srli t3, t2, 27

t3 =



slli t4, t0, 12

t4 =

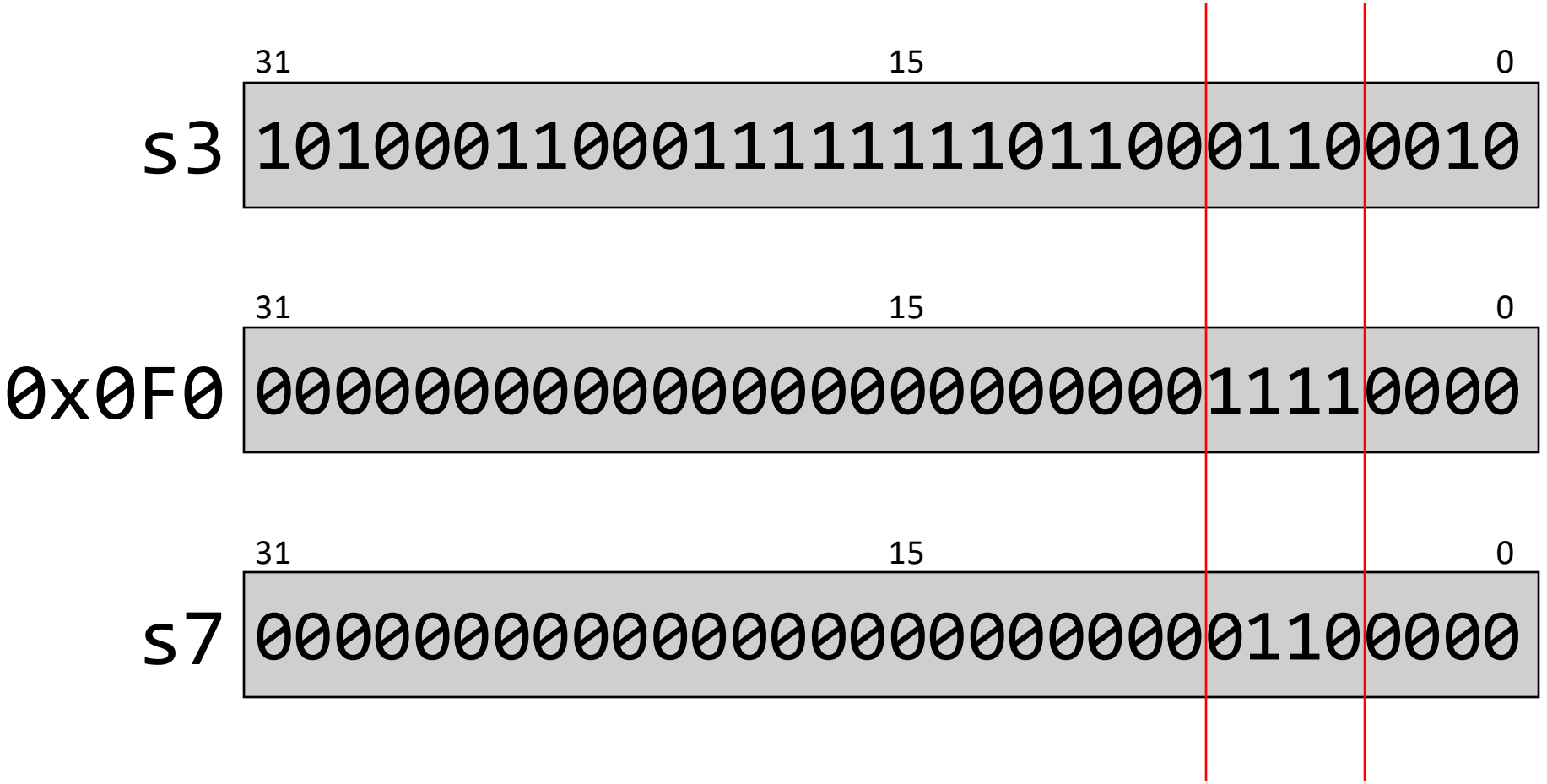
srli t5, t4, 27

t5 =

xor t1, t4, t5

Bitwise Logical Operations With Immediate Operand

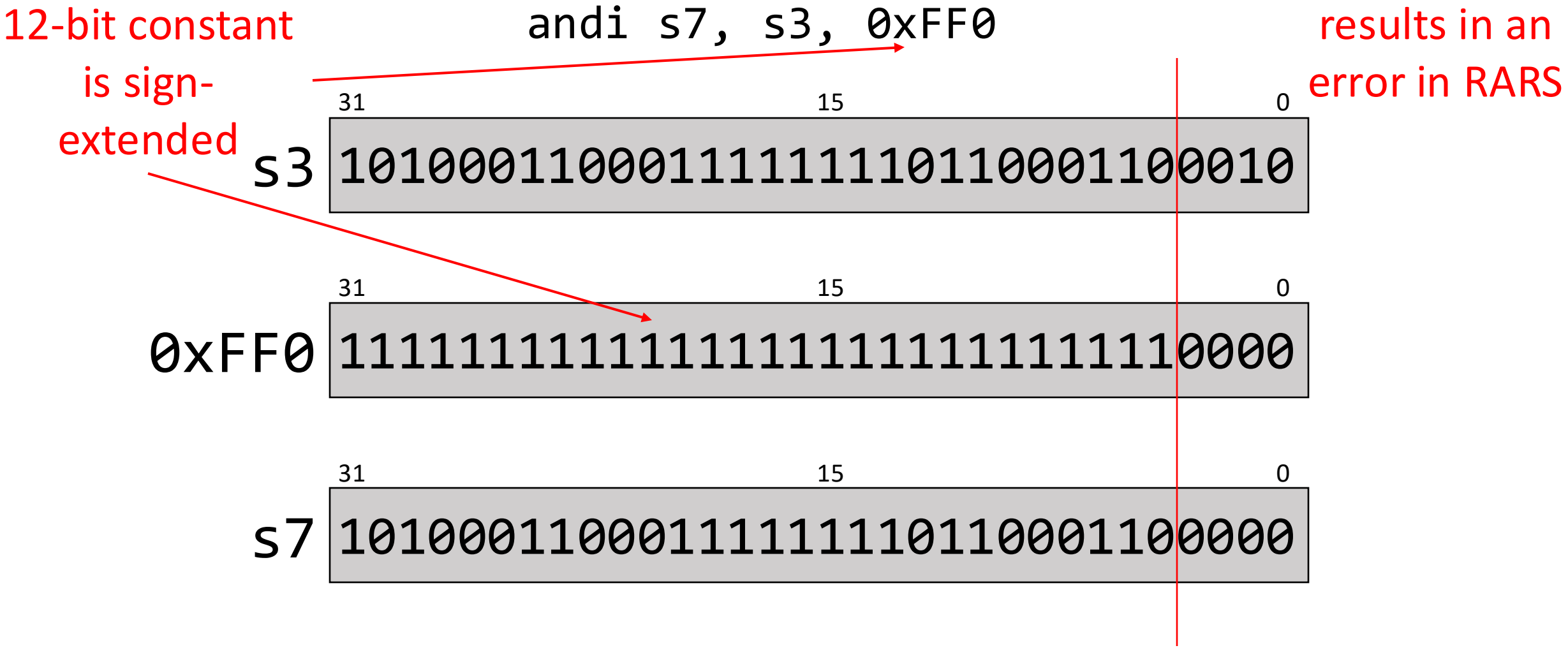
```
andi s7, s3, 0x0F0
```



A RARS Issue

RARS, incorrectly, zero extends constants expressed in hexadecimal.

Bitwise Logical Operations With Immediate Operand



A work around

Express the 12-bit constant in decimal.

```
0xFFFFFFF0 = -16
```

```
andi s7, s3, -16
```

The Load Immediate Instruction (li)

li is a pseudo instruction implemented by an addi instruction.

The immediate value is sign extended to 32 bits.

```
li  t0, 0x0FF # t0 ← 0x000000FF

li  t0, 0xFF0 # t0 ← 0xFFFFFFF0
```

RARS Bitwise Logic With Immediate

```
li   t0, 0x0FF    # t0 ← 0x000000FF
slli t0, t0, 4    # t0 ← 0x00000FF0
and s7, s3, t0
```