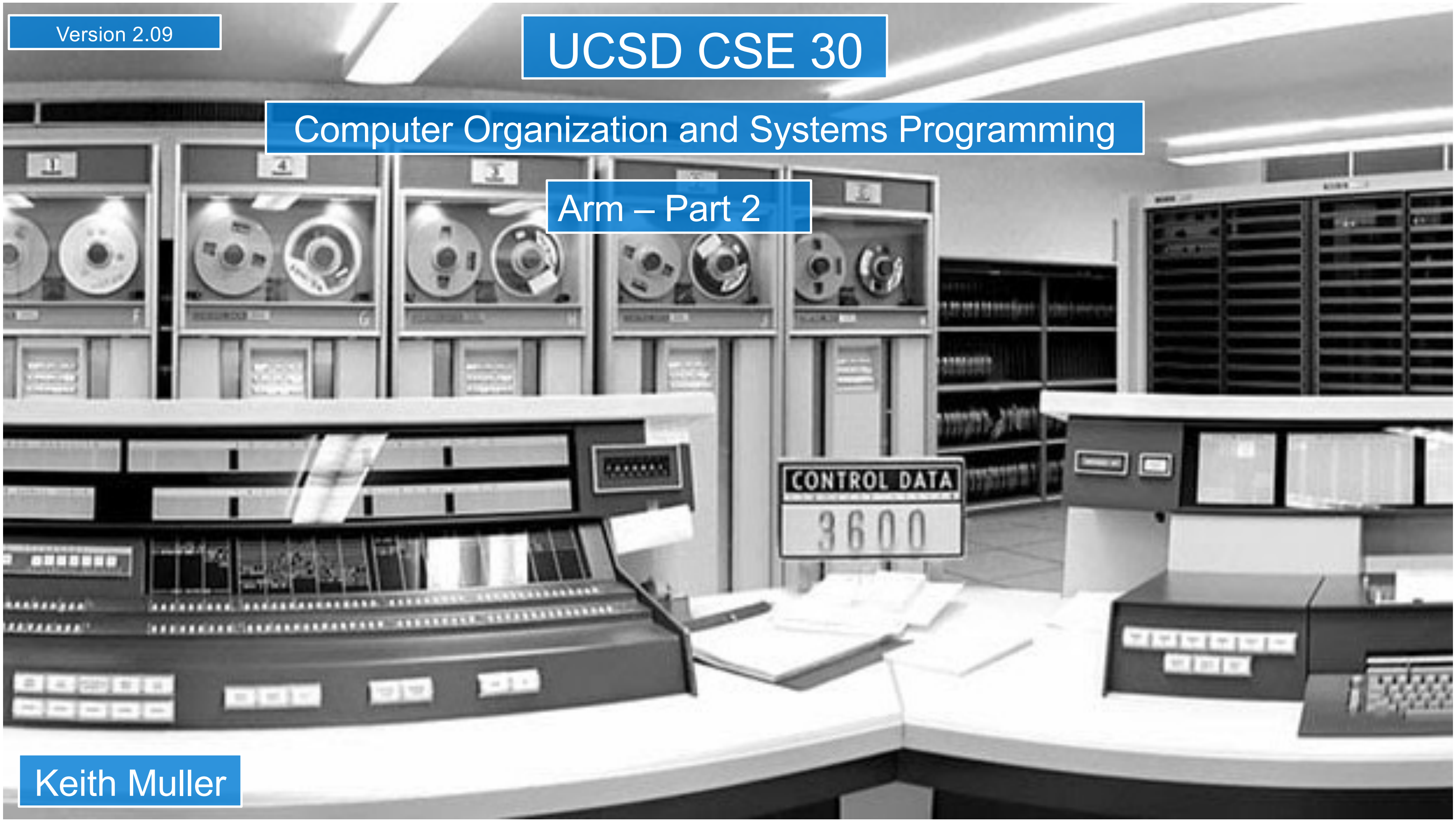
Version 2.09

UCSD CSE 30

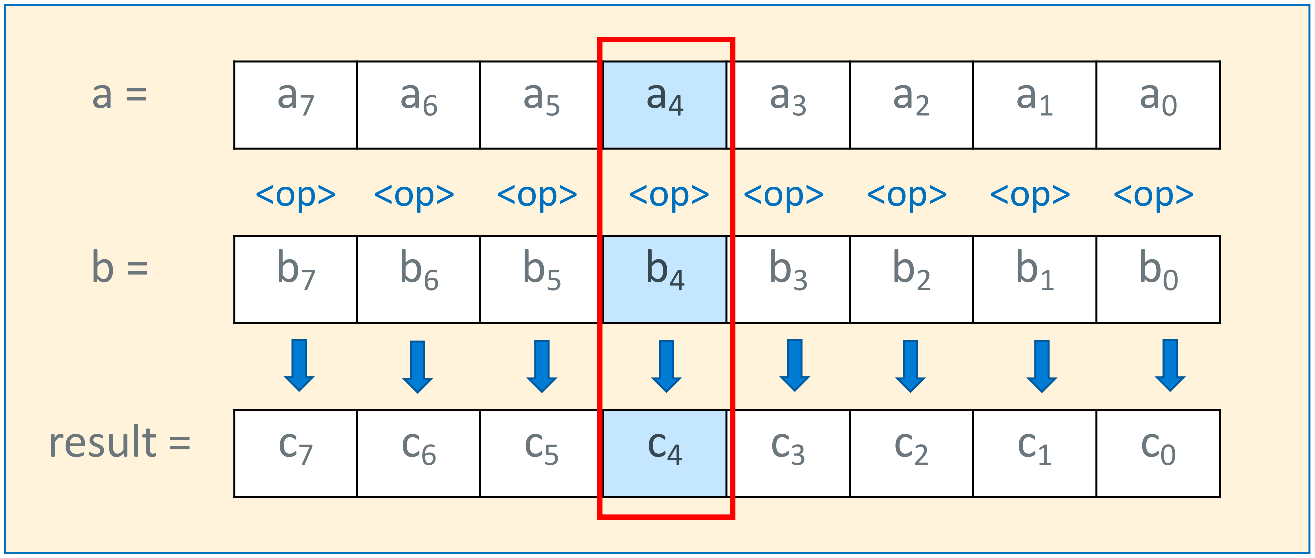
Computer Organization and Systems Programming

Arm – Part 2



Keith Muller

What is a Bitwise Operation?



- Bitwise operators are applied independently to each of the corresponding bit positions in each variable
- Each bit position of the result depends only on bits in the same bit position within the operands

x

Bitwise (Bit to Bit) Operators in C

```
output = ~a;
```

a	~a
0	1
1	0

```
output = a & b;
```

a	b	a & b
0	0	0
0	1	0
1	0	0
1	1	1

& with 1 to let a **bit through**
& with 0 to **set a bit to 0**

```
output = a | b;
```

a	b	a | b
0	0	0
0	1	1
1	0	1
1	1	1

| with 1 to **set a bit to 1**
| with 0 to let a **bit through**

```
output = a ^ b; //EOR
```

a	b	a ^ b
0	0	0
0	1	1
1	0	1
1	1	0

^ with 1 **will flip the bit**
^ with 0 to let a **bit through**

Bitwise NOT

```
~ 1100
  ----
  0011
```

Bitwise AND

```
  0110
& 1100
  ----
  0100
```

Bitwise OR

```
  0110
| 1100
  ----
  1110
```

Bitwise EOR

```
  0110
^ 1100
  ----
  1010
```


x

Bitwise Not (vs Boolean Not)

```
in C
int output = ~a;
```

a	~a
0	1
1	0

Bitwise NOT

```
~ 1100
  ----
  0011
```

	Bitwise Not
number	0101 1010 0101 1010 1111 0000 1001 0110
~number	1010 0101 1010 0101 0000 1111 0110 1001

Meaning	*Operator*	*Operator*	*Meaning*
Boolean NOT	!b	~b	Bitwise NOT

Boolean operators act on the entire value not the individual bits

Type	*Operation*	result
bitwise	~0x01	1111 1111 1111 1111 1111 1111 1111 1110
Boolean	!0x01	0000 0000 0000 0000 0000 0000 0000 0000

x

MVN (not)

```
mvn   r0, r1

// Copies all 32 bits
// of the value held
// in register r1 into
// the register r0
// then does a bitwise NOT
```

register r1

register r0

```
mvn   r0, 12

// Expands an imm8 value 0x0c
// stored in the instruction
// into a register then does
// a bitwise NOT
```

0x0c

register r0 0xffff fff3

Bitwise NOT

```
~ 1100
  ----
  0011
```

- A **bitwise NOT** operation

`0x      0c`

imm8 expansion

`0x0000000c`

bitwise not

`0xfffffff3`

x

mvn – Copies NOT (~)

mvn	Rd	rot4	imm8

Rd: destination register; rot4 imm8: constant (immediate value)

mvn	Rd	Rm

Rd: destination register; Rm: source register

```
mvn   Rd, constant    // Rd = constant
mvn   Rd,  Rm         // Rd = Rm
```

```
~ 1100
  ----
  0011
```

Bitwise NOT

bitwise NOT operation. Immediate (constant) version copies to 32-bit register, then does a bitwise NOT

imm8	extended imm8	inverted imm8	signed base 10
0x00	0x00 00 00 00	0xff ff ff ff	-1
0xff	0x00 00 00 ff	0xff ff ff 00	-256

```
mvn    r1, 4           // x = ~4
mvn    r1, r5          // x = ~y in C

mvn    r1, 0           // x = -1
```

invert the bits — copy into 32 bits zero extend

r1 0xfffffffb ← 0x00000004 ← 0x4

r1 0x55555555 ← 0xaaaaaaaa r5

r1 0xffffffff ← 0x0

x

Bitwise Instructions

<op>	Rd	Rn	rot4	imm8
	destination	operand 1	Operand 2 constant	

<op>	Rd	Rn	Rm
	destination	operand 1	Operand 2

```
<op>  Rd,  Rn,  constant   // Rd = Rn <op> constant
<op>  Rd,  Rn,  Rm         // Rd = Rn <op> Rm
```

Bytes: 0 <= imm8 <= 255 + values from "rotating" rot 4 bits

Bitwise <op> description	C Syntax	***Arm <op> Syntax Op2: either register or constant value***	***Operation***
Bitwise **AND**	a & b	and R_d, R_n, Op2	$R_d = R_n \& Op2$
Bitwise **OR**	$a \mid b$	orr R_d, R_n, Op2	$R_d = R_n \mid Op2$
Exclusive **OR**	a ^ b	eor R_d, R_n, Op2	$R_d = R_n$ ^ $Op2$
Bitwise **NOT**	a = ~b	mvn R_d, R_n	$R_d = \sim R_n$

x

Bitwise versus C Boolean Operators

Boolean Operators			Bitwise Operators	
Meaning	*Operator*		*Operator*	*Meaning*
`Boolean AND`	`a && b`		`a & b`	`Bitwise AND`
`Boolean OR`	`a || b`		`a | b`	`Bitwise OR`
`Boolean NOT`	`!b`		`~b`	`Bitwise NOT`

Boolean operators **act on the entire value not the individual bits**

bitwise & versus Boolean &&

```
0x10 &  0x01 = 0x00 (bitwise)
0x10 && 0x01 = 0x01 (Boolean)
```

bitwise ~ versus Boolean !

```
~0x01 = 0xfffffffe (bitwise)
!0x01 = 0x0 (Boolean)
!0xff = 0x0 (Boolean)
```


x

The act (operation) of *Masking*

a =	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0
	<op>	<op>	<op>	<op>	<op>	<op>	<op>	<op>
b =	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
result =	c_7	c_6	c_5	c_4	c_3	c_2	c_1	c_0

- Bit masks access/modify specific bits in memory
- Masking act of applying a mask to a value with a specific op:
- `orr:` 0 passes bit unchanged, 1 sets bit to 1 `(a = b | c; // in C)`
- `eor:` 0 passes bit unchanged, 1 inverts the bit `(a = b ^ c; // in C)`
- `and:` 0 clears the bit, 1 passes bit unchanged `(a = b & c; // in C)`

x

Mask on

force bits to 1 "**mask on**" operation

- 1 to **set a bit to 1**
- 0 to let a **bit through unchanged**

```
orr  r1, r2, r3

r1 = r2 | r3; // in C
```

Example: force lower 16 bits to 1

```
DATA: r2 0xab ab ab 77
orr
MASK: r3 0x00 00 ff ff
  unchanged        forces to a 1
RSLT: r1 0xab ab ff ff
```

Example: force lower 8 bits to 1

```
DATA: r2 0xab ab ab 77

orr   r1   r2, 0xff

r1 = r2 | 0xff; // in C

RSLT: r1 0xab ab ab ff
```


x

Mask off

force bits to 0 "**mask off**" operation

- 0 to **set a bit to 0** ("clears the bit")
- 1 to let a **bit through unchanged**

```
and  r1, r2, r3

r1 = r2 & r3; // in C
```

Example: force lower 8 bits to 0

```
DATA: r2 0xab ab ab 77
and
MASK: r3 0xff ff ff 00
   unchanged          forces to a 0
RSLT: r1 0xab ab ab 00
```

Example: force lower 8 bits to 0

```
DATA: r2 0xab ab ab 77
and r1  r2, 0xffffff00
r1 = r2 & 0xffffff00; // in C
RSLT: r1 0xab ab ab 00
```


x

Extracting (Isolate) a Field of Bits with a mask

extract top 8 bits of r2 into r1

- 0 to **set a bit to 0** ("clears the bit")
- 1 to let a **bit through unchanged**

```
and  r1, r2, r3
```

```
DATA: r2 0xab ab ab 77
and
MASK: r3 0xff 00 00 00
   unchanged          forces to a 0
RSLT: r1 0xab 00 00 00
```

extract top 8 bits of r2 into r1

```
DATA: r2 0xab ab ab 77

and  r1, r2, 0xff000000

RSLT: r1 0xab 00 00 00

r1 = r2 & 0xff000000;  // in C
```


x

Finding if a bit is set

query the status of a bit "**bit status**" operation

- 0 to **set a bit to 0** ("clears the bit")
- 1 to let a **bit through unchanged**

```
    and  r1, r2, 0x02
    cmp r1, 0
    beq .Lendif
    // code for is set
.Lendif:
```

```
Example is bit 1 set
DATA: r2 0xab ab ab 77
and
MASK:    0x00 00 00 02   is bit 1 set?
forces to a 0                unchanged
RSLT: r1 0x00 00 00 02   != 0 if set
```

```
unsigned int r1, r2;
// code
r1 = r2 & 0x02
if  (r1 != 0) {
    // code for is set
}
```

```
unsigned int r2;
// code
if ((r2 & 0x02) != 0) {
    // code for is set
}
```

Even/Odd

Even or odd, check LSB (same as mod %2)

```
check LSB (bit 0) if set then odd, else even
       and  r1, r2, 0x01
       cmp  r1, 0x01
       bne .Lendif
       // code for handling odd numbers
.Lendif:
```

```
unsigned int r2;
// code
if ((r2 & 0x01) != 0) {
    // code for handling odd numbers
}
```

```
DATA: r2 0xab ab ab 77
and
MASK: r3 0x00 00 00 01 (mod 2 even or odd)
forces to a 0            unchanged
RSLT: r1 0x00 00 00 01 (odd)
```

MOD %<power of 2>

remainder (mod): num % d where num ≥ 0 and d = 2^k

`mask = 2^k -1 so for mod 16, mask = 16 -1 = 15`

`and  r1, r2, r3`

```
Example: %2

DATA: r2 0xab ab ab 77

and

MASK: r3 0x00 00 00 01 (mod 2 even or odd)

 forces to a 0                unchanged

RSLT: r1 0x00 00 00 01 (odd)
```

```
Example: Mod 16

DATA: r2 0xab ab ab 77

and

MASK: r3 0x00 00 00 0f (mod 16)

 forces to a 0                unchanged

RSLT: r1 0x00 00 00 07
```


x

Flipping bits: bit toggle
Used in PA7/PA8

invert (*flip*) bits "**bit toggle**" operation

- 1 **will flip the bit**
- 0 to let a **bit through**

```
eor  r1, r2, r3
```

- Observation: When applied twice, it returns the original value (symmetric encoding)
- With a mask of all 1's is a 1's compliment

Example: *flip* the lower 8-bits

```
eor  r1, r2, 0xff
```

```
unsigned int r1, r2;
r1 = r2 ^ 0xff;
```

Example: invert (*flip*) the lower 8-bits

```
DATA: r2 0xab ab ab 77    77: 0111 0111
eor
MASK: r3 0x00 00 00 ff
  unchanged                inverts (flips)
RSLT: r1 0xab ab ab 88    88: 1000 1000
```

```
DATA: r1 0xab ab ab 88
eor
MASK: r3 0x00 00 00 ff apply a 2nd time
                        inverts (flips)
RSLT: r1 0xab ab ab 77 original value!
```


x

Unsigned Integers (positive numbers) with Fixed # of Bits

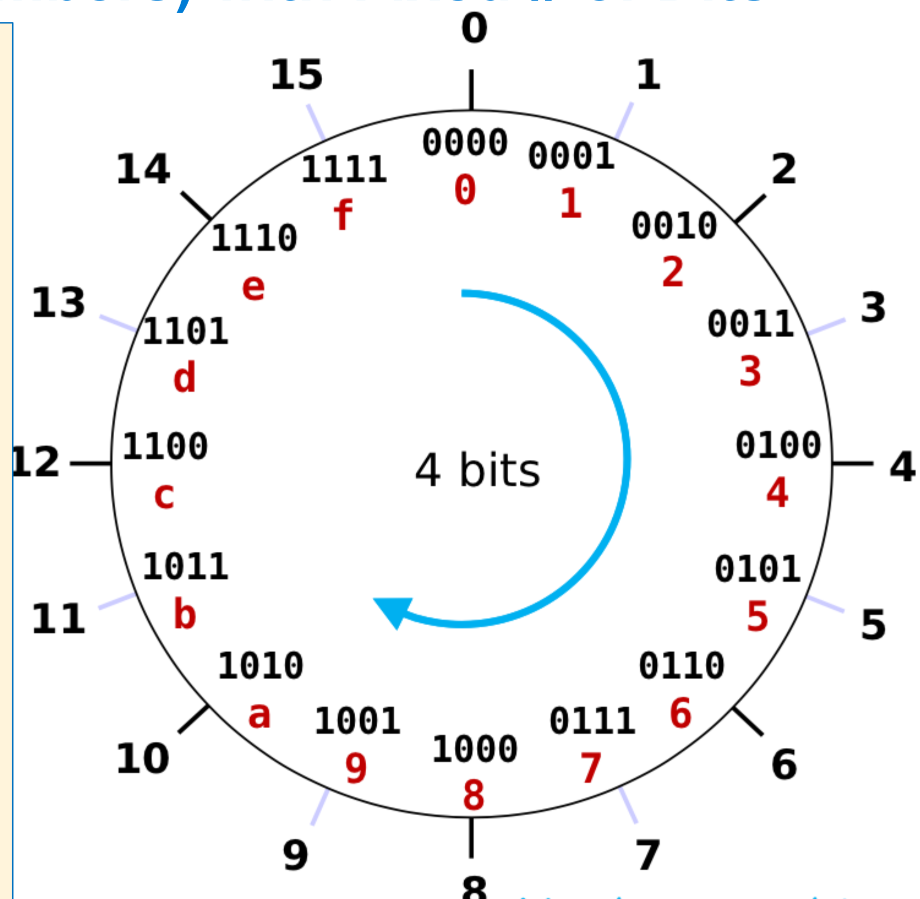
- 4 bits is 2^4 = ONLY 16 distinct values
- **Modular** (C operator: %) or clock math
  - Numbers start at 0 and “wrap around” after 15 and go back to 0
- Keep adding 1

  wraps (clockwise)

  0000 -> 0001 … -> 1111 -> 0000
- Keep subtracting 1

  wraps (counter-clockwise)

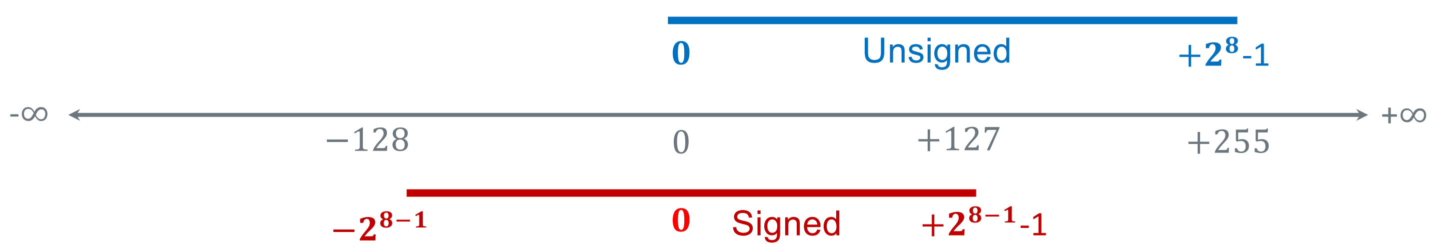
  1111 -> 1110 … -> 0000 -> 1111
- Addition and subtraction use normal "carry" and "borrow" rules, just operate in binary



Numbers get bigger in this direction

Problem: How to Encode Both Positive and Negative Integers

- How do we represent the negative numbers within a fixed number of bits?
    - Allocate some bit patterns to negative and others to positive numbers (and zero)
- 2^n distinct bit patterns to encode positive and negative values
- **Unsigned values:** $0 \ldots 2^n{-}1$ ← -1 comes from counting 0 as a "positive" number
- **Signed values:** $-2^{n-1} \ldots 2^{n-1}{-}1$ (dividing the range in ~ half including 0)
- **On a number line (below):** 8-bit integers – signed and unsigned (*e.g.*, **`char in C`**)



Same “width” (same number of encodings), just shifted in value

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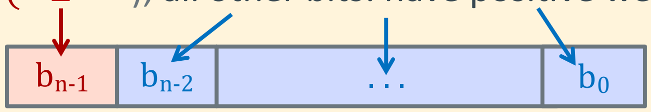
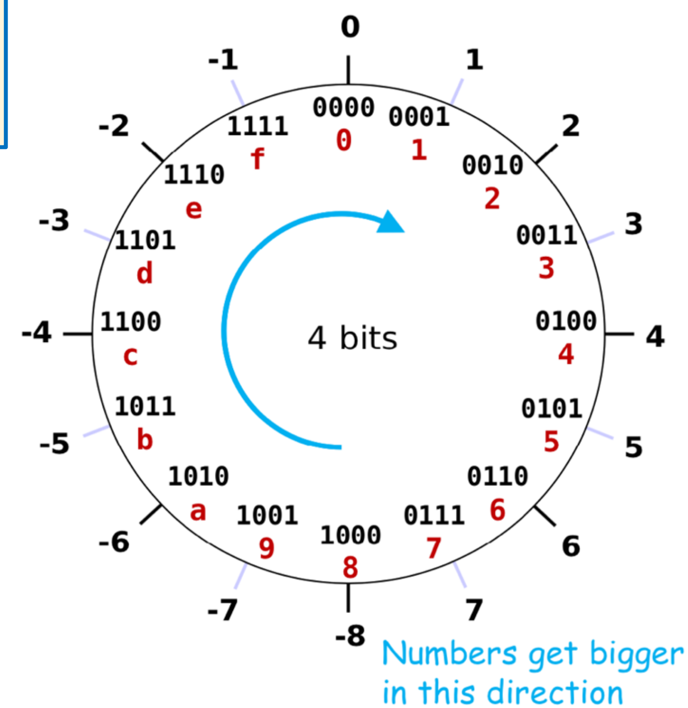
Two's Complement: The MSB Has a *Negative Weight*

$$2's\ Comp = -b_{n-1}2^{n-1} + b_{n-2}2^{n-2} + \ldots + b_1 2^1 + b_0 2^0$$

b_{n-1} weight is (-2^{n-1}), all other bits: have positive weights $(+2^i)$



- 4-bit (w = 4) weight $= -2^{4-1} = -2^3 = -8$
  - 1010_2 **unsigned**:
    $1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0 =$ **10**
  - 1010_2 **two's complement**:
    $-1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0 = -8 + 2 =$ **–6**
  - -8 in **two's complement:**
    $1000_2 = -2^3 + 0 = -8$
  - -1 in **two's complement:**
    $1111_2 = -2^3 + (2^3 - 1) = -8 + 7 =$ **-1**



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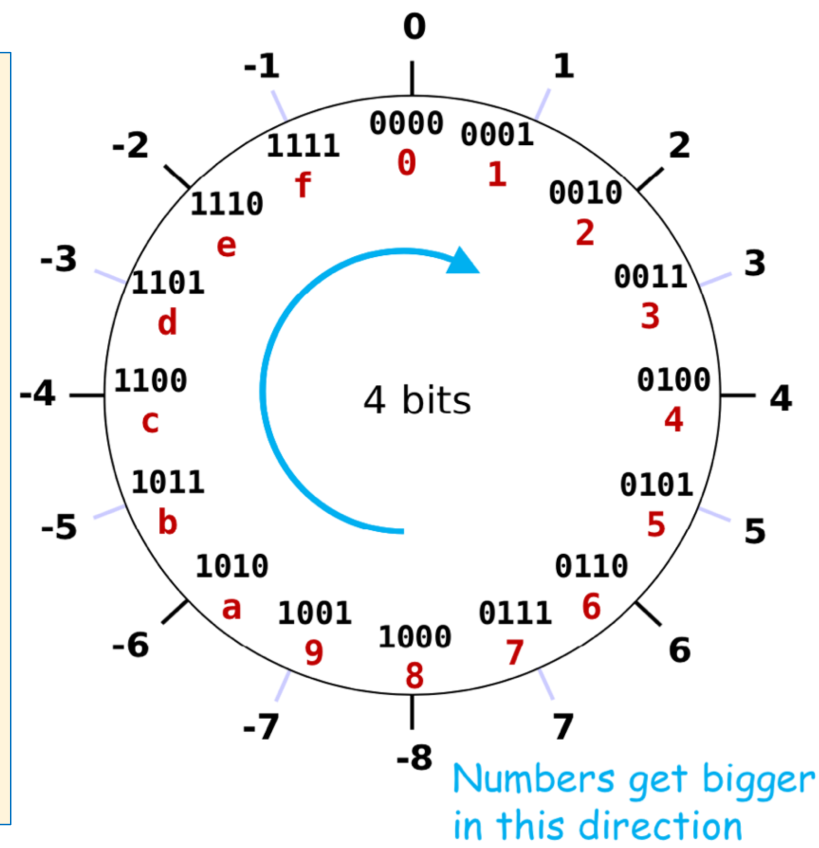
2's Complement Signed Integer Method

- Positive numbers encoded same as unsigned numbers
- All negative values have a one in the leftmost bit
- All positive values have a zero in the leftmost bit
  - This implies that 0 is a positive value
- Only one zero
- **For n bits, Number range is $-(2^{n-1})$ to $+(2^{n-1}$ - 1)**
  - Negative values "go 1 further" than the positive values
- Example: the range for 8 bits:
  -128, -127, .. 0, .. 126, **+127**
- Example the range for 32 bits:
  -2147483648 .. 0, .. **+2147483647**
- *Arithmetic is the same as with unsigned binary!*



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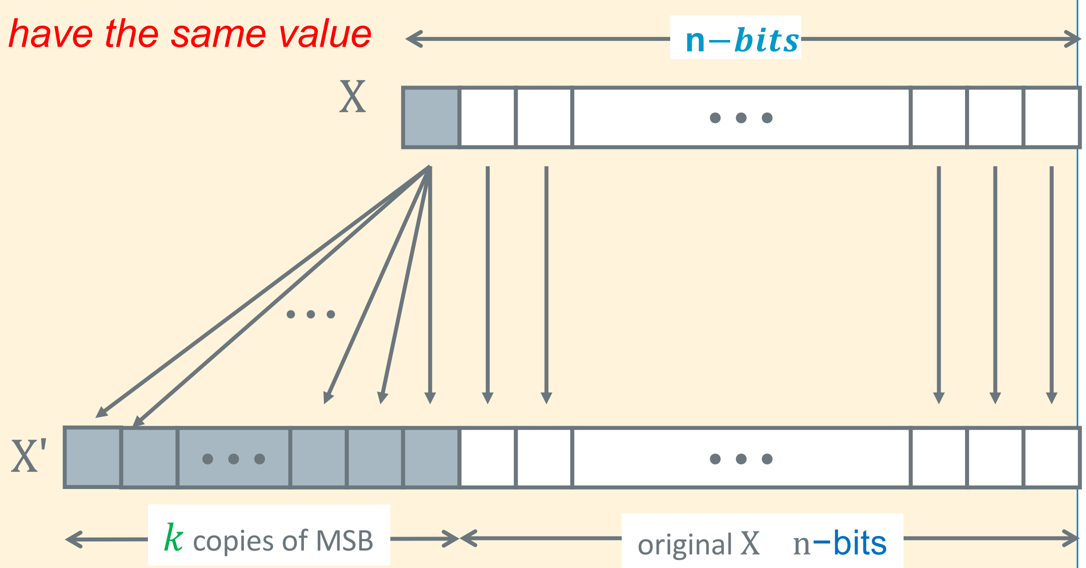
Sign Extension (how type promotion works)

- Sometimes you need to work with integers encoded with different number of bits

  8 bits (char) -> (16 bits) **`short`** -> (32 bits) **`int`**

- **Sign extension increases the number of bits: n-bit** wide signed integer X, ***EXPANDS*** to a ***wider*** n−bit + k-bit signed integer X' where *both have the same value*



Unsigned

- Just add leading zeroes to the left side

Two's Complement Signed:

- If positive, add leading zeroes on the left
  - Observe: Positive stay positive
- If negative, add leading ones on the left
  - Observe: Negative stays negative

x

Example: Two’s Complement Sign or bit Extension - 1

- Adding 0's in front of a positive numbers does not change its value

```
     7    =    0111
extend to
8 bits
           00000111
Number is still 7
```

```
     1    =    0001
extend to
8 bits
           00000001
Number is still 1
```


x

Example: Two's Complement Sign or bit Extension -2

- Adding 1's if front of a negative number does not change its value

```
     7 = 0111
invert = 1000
add 1  +    1
    -7   1001
```

```
  -7      =     1001
extend to
8 bits
            11111001
```

```
1001 = -8 + 1 = -7
11111001 =
(-128 + 64 + 32 + 16 + 8) + 1
= -8 + 1 = -7
```

```
     7 = 00000111
invert = 11111000
add 1  +        1
    -7   11111001
```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Sign Extension in C: Type casts

- Convert from smaller to larger integral data types
- C and Java automatically performs sign extension
- Example (on pi-cluster with 32-bit int)

```
#include <stdlib.h>
#include <stdio.h>
int main(void)
{
    signed char c = -1;
    signed int i = c;
    unsigned char d = 1;
    unsigned int j = d;
    printf("c decimal = %hd\n", c);
    printf("c = 0x%hhx\n", c);
    printf("i decimal = %d\n", i);
    printf("i = 0x%x\n", i);
    printf("\nd decimal = %hd\n", d);
    printf("d = 0x%hhx\n", d);
    printf("j decimal = %d\n", j);
    printf("j = 0x%x\n", j);
    return EXIT_SUCCESS;
}
```

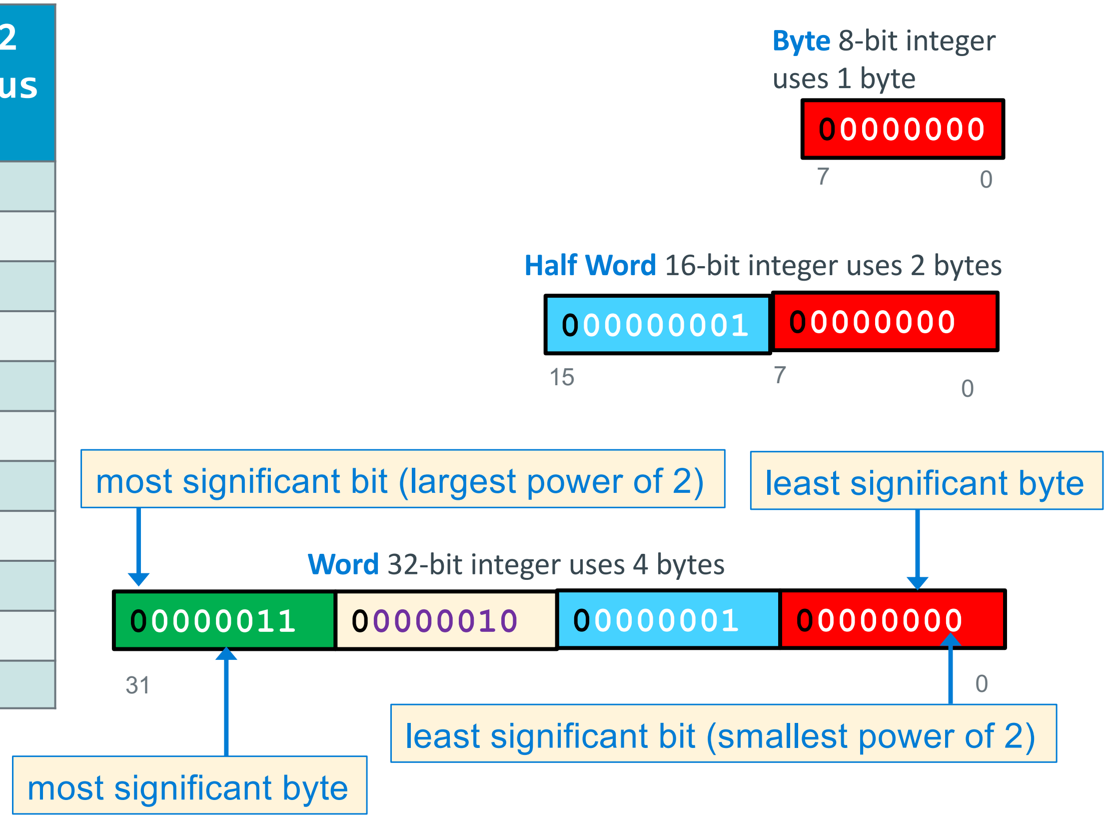
```
%./a.out
c decimal = -1
c = 0xff
i decimal = -1
i = 0xffffffff

d decimal = 1
d = 0x1
j decimal = 1
j = 0x1
```


x

Different Type of Numbers each have a Fixed # of Bits
Spanning one or more contiguous bytes of memory

C Data Type	AArch-32 contiguous Bytes
char (arm unsigned)	1
short int	2
unsigned short int	2
int	4
unsigned int	4
long int	4
long long int	8
float	4
double	8
long double	8
pointer *	4



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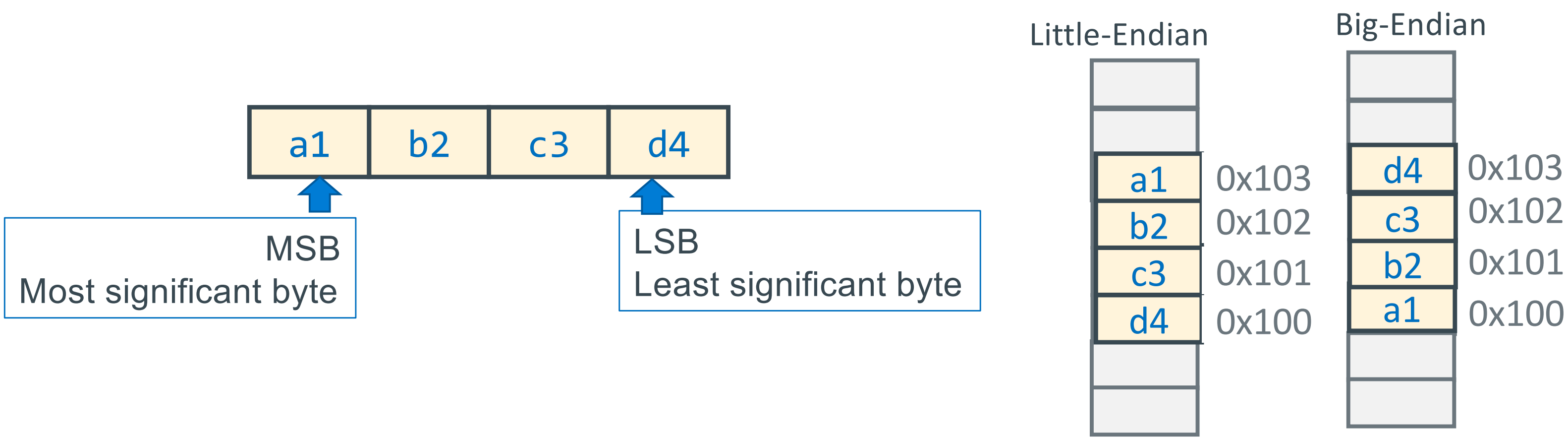
Byte Ordering of Numbers In Memory: Endianness

- Two different ways to place multi-byte integers in a byte addressable memory
- Big-endian: Most Significant Byte ("big end") starts at the *lowest (starting)* address
- Little-endian: Least Significant Byte ("little end") starts at the *lowest (starting)* address
- Example: 32-bit integer with 4-byte data



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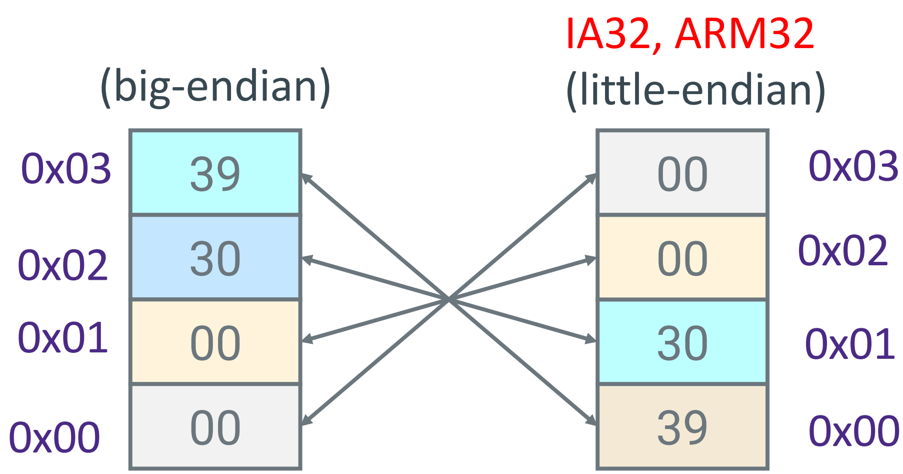
Byte Ordering Example

```
Decimal:   12345
Binary:     0011  0000  0011  1001
Hex:          3     0     3     9
```

```
int x = 12345;
// or x = 0x00003039;  // show all 32 bits
```



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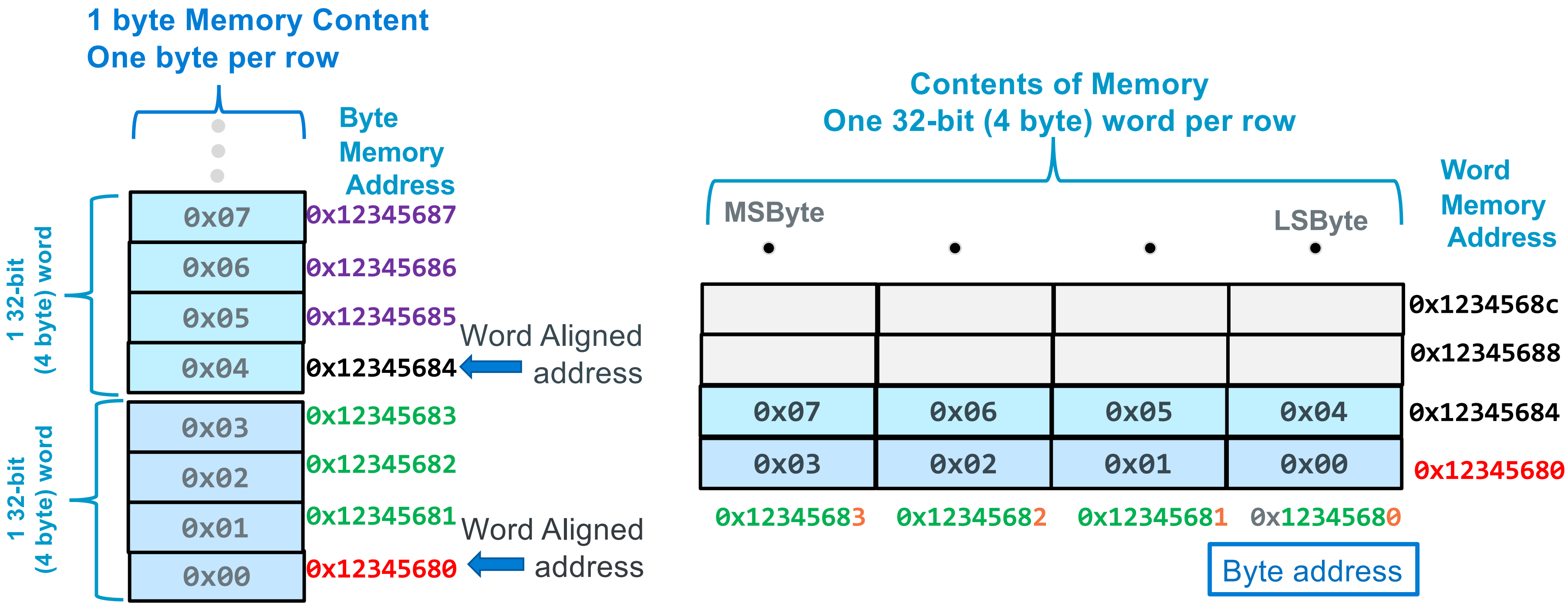
Byte Addressable Memory Shown as 32-bit words



Observation
32-bit aligned addresses
rightmost 2 bits of the address are always 0

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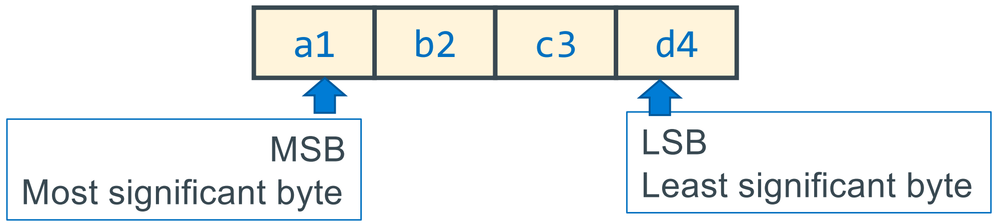
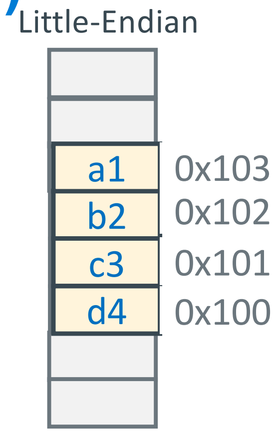
Using pointers to examine byte order (on pi-cluster)



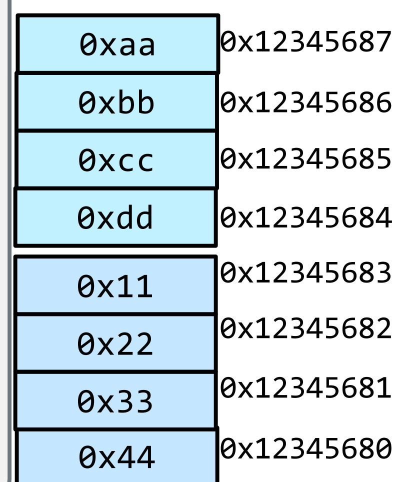



```c
#include <stdio.h>
#include <stdlib.h>
#define SZ 2
int main()
{
    unsigned int foo[SZ] = {0x11223344, 0xaabbccdd};
    unsigned char *chptr = (unsigned char *)foo;

    // print from MSB to LSB – high to low memory)
    for (int i = sizeof(foo)-1; i >= 0; i--)
        printf("byte %d: %x\n", i, *(chptr + i));

    return EXIT_SUCCESS;
}
```

```
$ ./a.out
byte 7: aa
byte 6: bb
byte 5: cc
byte 4: dd
byte 3: 11
byte 2: 22
byte 1: 33
byte 0: 44
```



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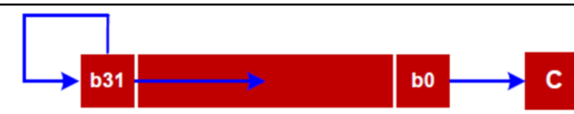
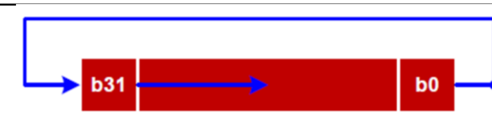
Shift and Rotate Instructions

<inst>	Rd	Rm	const5
	destination	operand 1	operand 2 constant

Number of bit to shift or rotate: const 5 bits

<inst>	Rd	Rm	Rs
	destination	operand 1	operand 2

Number of bit to shift or rotate: Rs

Instruction	Syntax	Operation	Notes	Diagram
Logical Shift Left int x; or unsigned int x x << n;	lsl R_d, R_m, *const5* lsl R_d, R_m, R_s	$R_d \leftarrow R_m$ << *const5* $R_d \leftarrow R_m$ << R_s	Zero fills shift: 0 - 31	
Logical Shift Right unsigned int x; x >> n;	lsr R_d, R_m, *const5* lsr R_d, R_m, R_s	$R_d \leftarrow R_m$ >> *const5* $R_d \leftarrow R_m$ >> R_s	Zero fills shift: 1 – 32	
Arithmetic Shift Right int x; x >> n;	asr R_d, R_m, *const5* asr R_d, R_m, R_s	$R_d \leftarrow R_m$ >> *const5* $R_d \leftarrow R_m$ >> R_s	Sign extends shift: 1 - 32	
Rotate Right unsigned int x; x = (x>>n)|(x<<(32-n));	ror R_d, R_m, *const5* ror R_d, R_m, R_s	$R_d \leftarrow R_m$ ror *const5* $R_d \leftarrow R_m$ ror R_s	right rotate rot: 0 - 31	

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Shift Operations in C

- n is number of bits to shift a variable x of width w bits
- Shifts by `n < 0` or `n ≥ w` are *undefined*
- Left shift (`x << N`) – **Multiplies by 2^N**
  - Shift N bits left, Fill with `0`s on right
- **In C:** behavior of >> is determined by compiler
  - gcc: it depends on data type of `x` (signed/unsigned)
- Right shift (`x >> N`) - **Divides by 2^N**
  - Logical shift (for unsigned variables)
    - Shift N bits right, Fill with 0s on left
  - Arithmetic shift (for signed variables) – Sign Extension
    - Shift N bits right while **Replicating** the most significant bit on left
    - Maintains sign of `x`
- **In Java:** logical shift is **>>>** and arithmetic shift is >>

x

Arithmetic Shift Right Example: Testing Sign

```
asr r2, r0, 31

r0 0xab ab ab 77  // bit 31 is a one
r2 0xff ff ff ff // see the sign extend
```

Test for sign
-1 if r0 negative

```
int i;
//code
if ((i>>31) == -1) {
  // code neg #
}
```

```
  asr r2, r0, 31
  cmp r2, -1
  bne .Lendif
  //code neg #
.Lendif:
```


x

Arithmetic Shift Right Example: Testing SIgn

```
asr r2, r0, 31

r0 0x7b ab ab 77  // bit 31 is a zero
r2 0x00 00 00 00 // see the sign extend
```

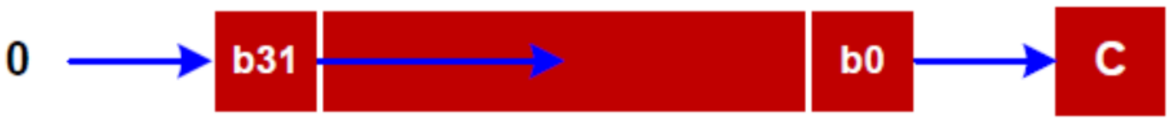
Test for sign
0 if r0 positive

```
int i;
//code
if ((i>>31) == 0) {
  // code pos #
}
```

```
  asr r2, r0, 31
  cmp r2, 0
  bne .Lendif
  //code positive #
.Lendif:
```


x

Logical Shift & Rotate Operations




```
lsr r2, r0, 8

r0 0xab ab ab 77
r2 0x00 ab ab ab
```


```
lsl r2, r0, 8

r0 0xab ab ab 77
r2 0xab ab 77 00
```

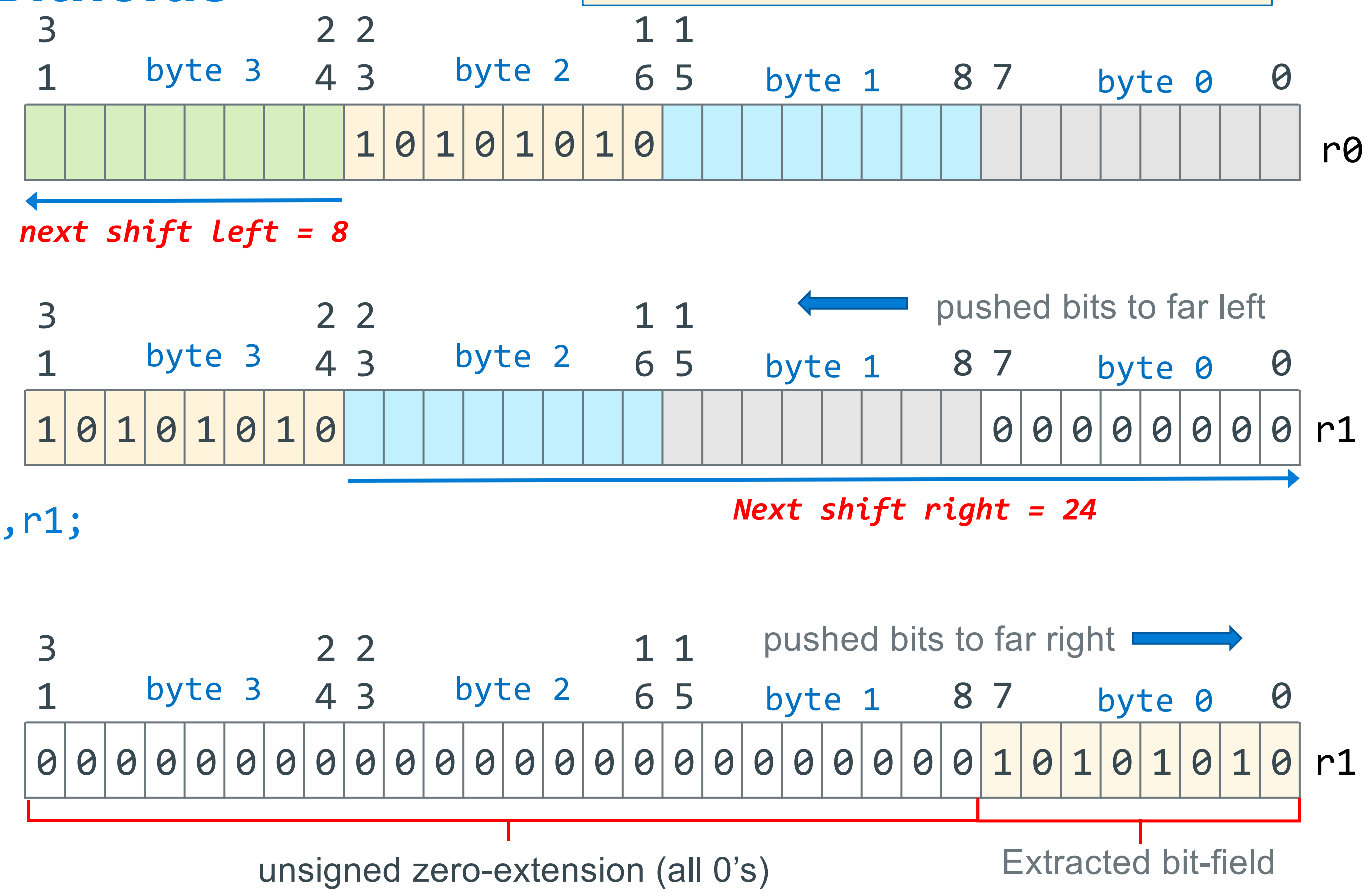

```
ror r2, r0, 8

r0 0xab ab ab 77
r2 0x77 ab ab ab
```


x

Extracting/Isolating Unsigned Bitfields

Hint: Useful for PA7

- Move byte 2 in r0 to byte 0 in r1




```
lsl  r1, r0, 8
```

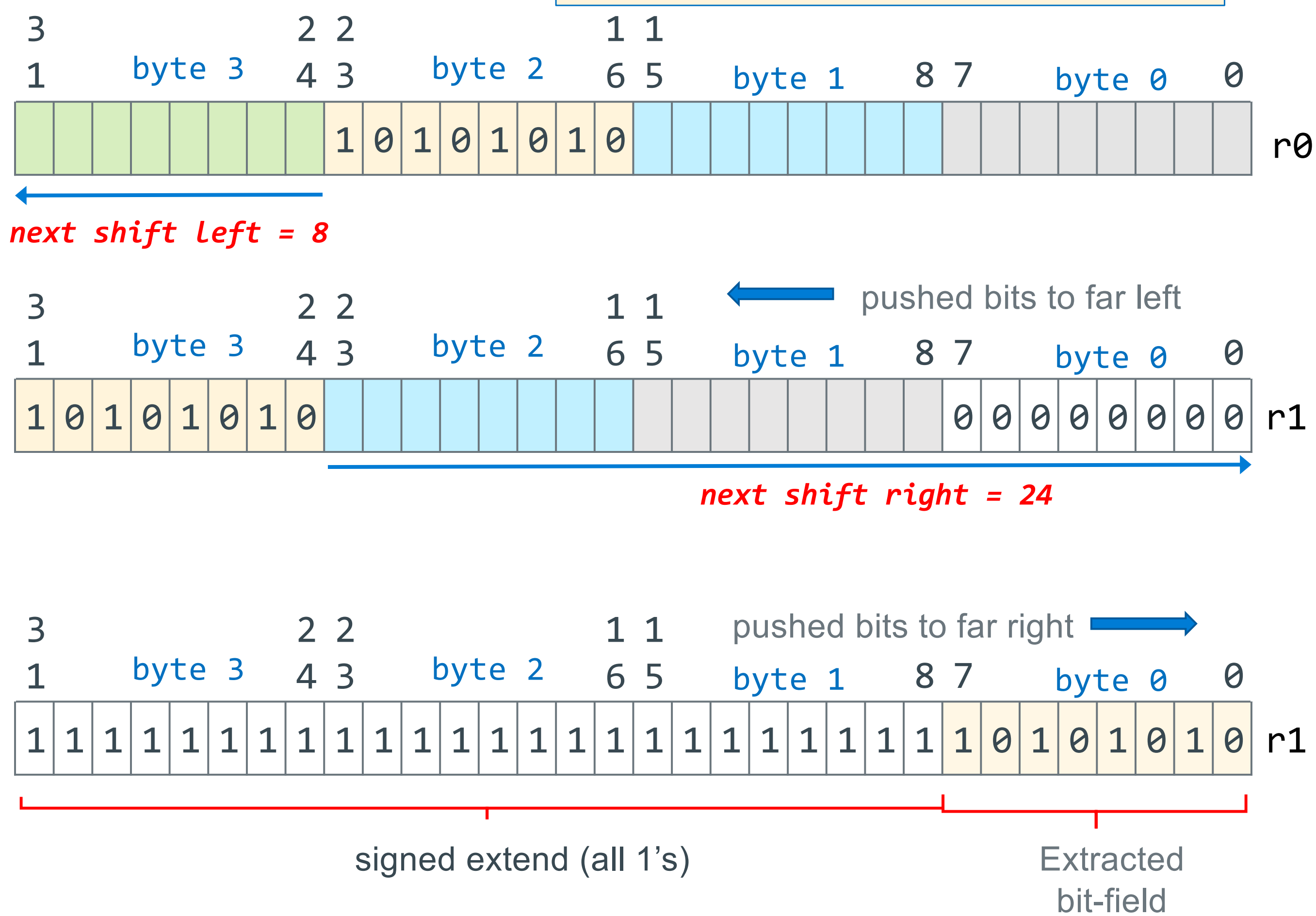
```
unsigned int r0,r1;
r1 = r0 << 8;
```

```
lsr  r1, r1, 24
r1 = r1 >> 24;
```


x

Extracting Signed Bitfields

- Move byte 2 in r0 to byte 0 in r1




```
lsl  r1, r0, 8
int r0,r1;
r1 = r0 << 8;
```

```
asr  r1, r1, 24
r1 = r1 >> 24;
```


x

Inserting Bitfields – Inserting Source Field into Destination Field

Task: Insert source into destination

a	b	a | b
0	0	0
0	1	1
1	0	1
1	1	1

Approach

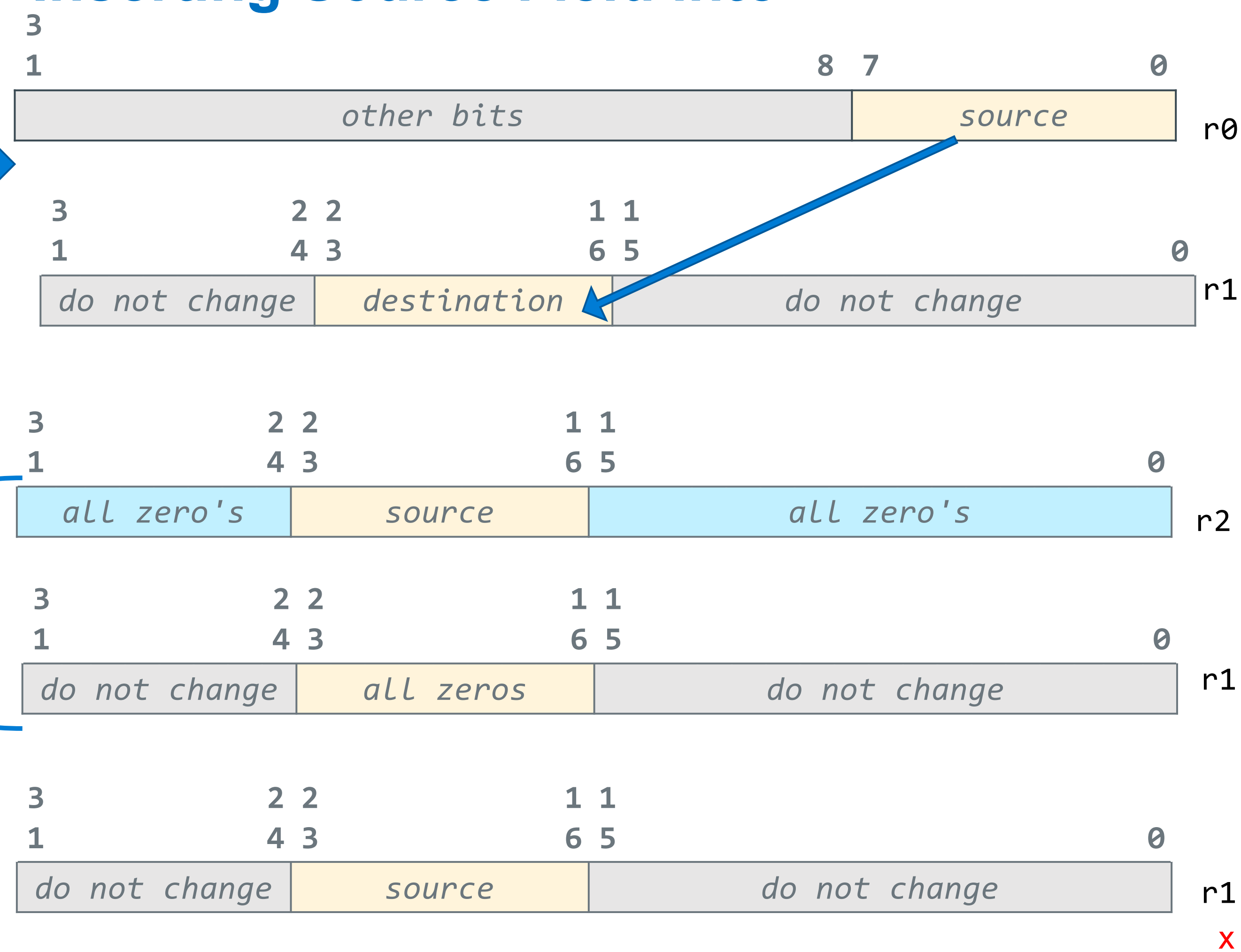
(1) isolate source field

(2) clear destination field

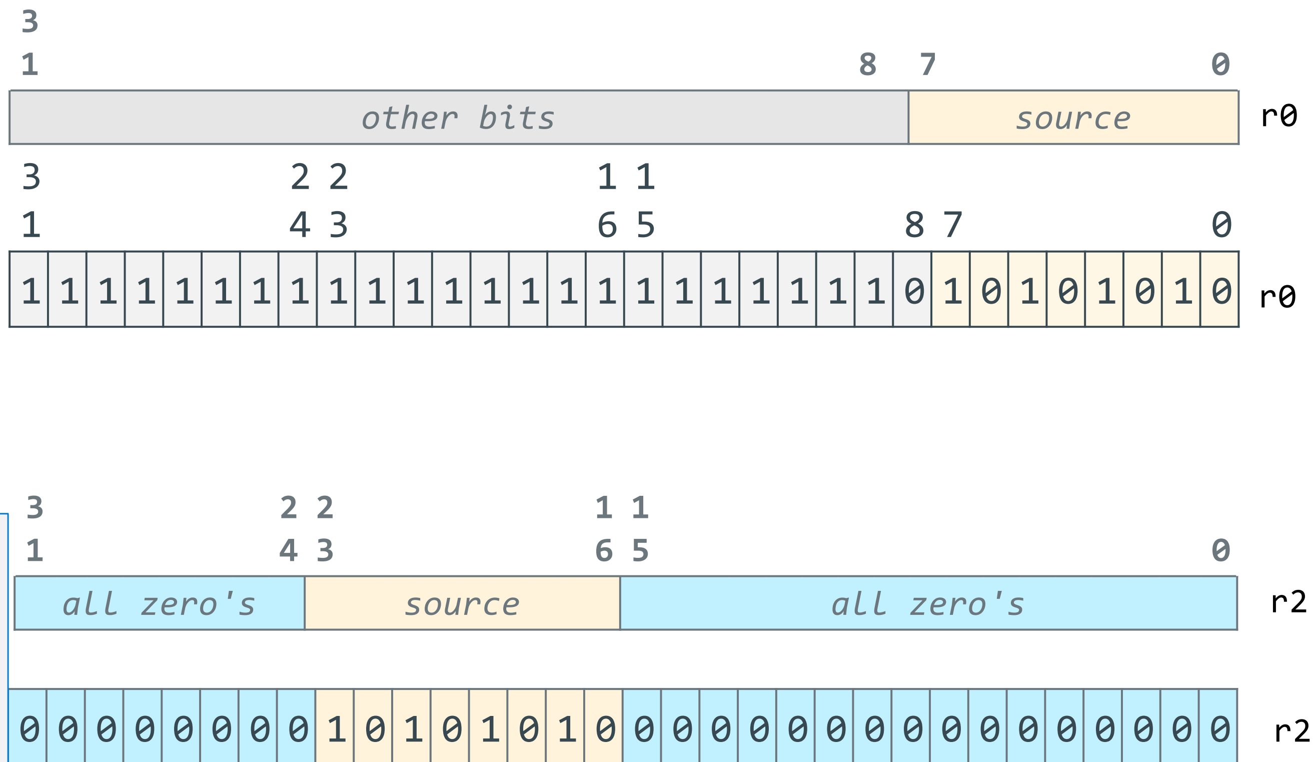
(3) Bitwise or together

```
orr    r1, r1, r2
r1 =   r1 | r2;
```

results in



Inserting Bitfields – Isolating the Source Field




```
isolate source field

lsl    r2, r0, 24
lsr    r2, r2, 8

r2 = r0 << 24;
r2 = r2 >> 8;
```


x

Inserting Bitfields – Clearing the Destination Field

31 … 24	23 … 16	15 … 0	
do not change	*destination*	*do not change*	r1
1 0 1 0 1 0 1 0	1 1 1 0 1 1 1 1	1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0	r1

```
clear the
destination field
ror    r1, r1, 24
r1=(r1>>24)|(r1<<8);
```

1 1 1 0 1 1 1 1	1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0	1 0 1 0 1 0 1 0	r3

```
lsl    r1, r1, 8
r1 = r1 << 8;
```

1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0	1 0 1 0 1 0 1 0	0 0 0 0 0 0 0 0	r1

31 … 24	23 … 16	15 … 0	
do not change	*all zeros*	*do not change*	
1 0 1 0 1 0 1 0	0 0 0 0 0 0 0 0	1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0	r1

```
ror    r1, r1, 16
r1= (r1>>16)|(r1<<16);
```


x

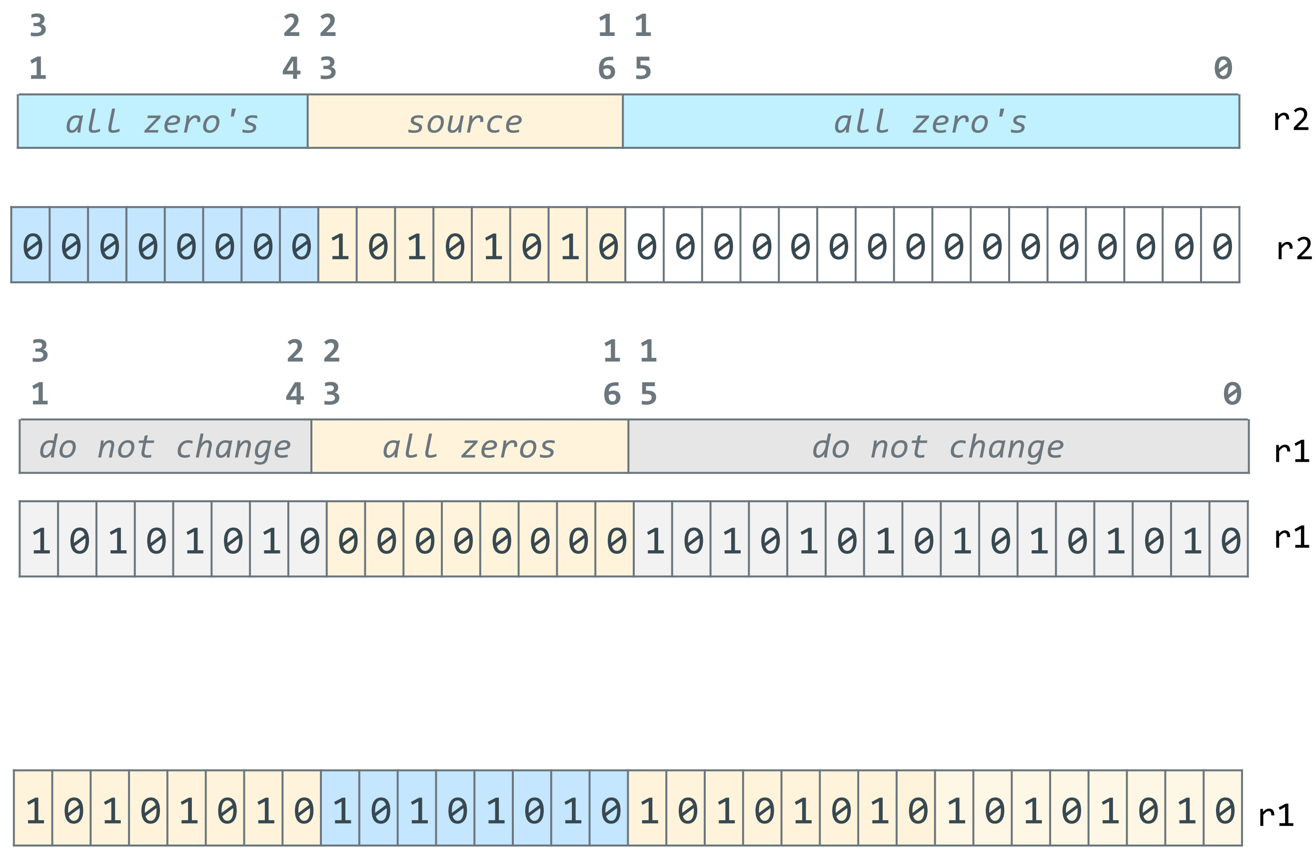
Inserting Bitfields – Combining Isolated Source and Cleared Destination

isolated source

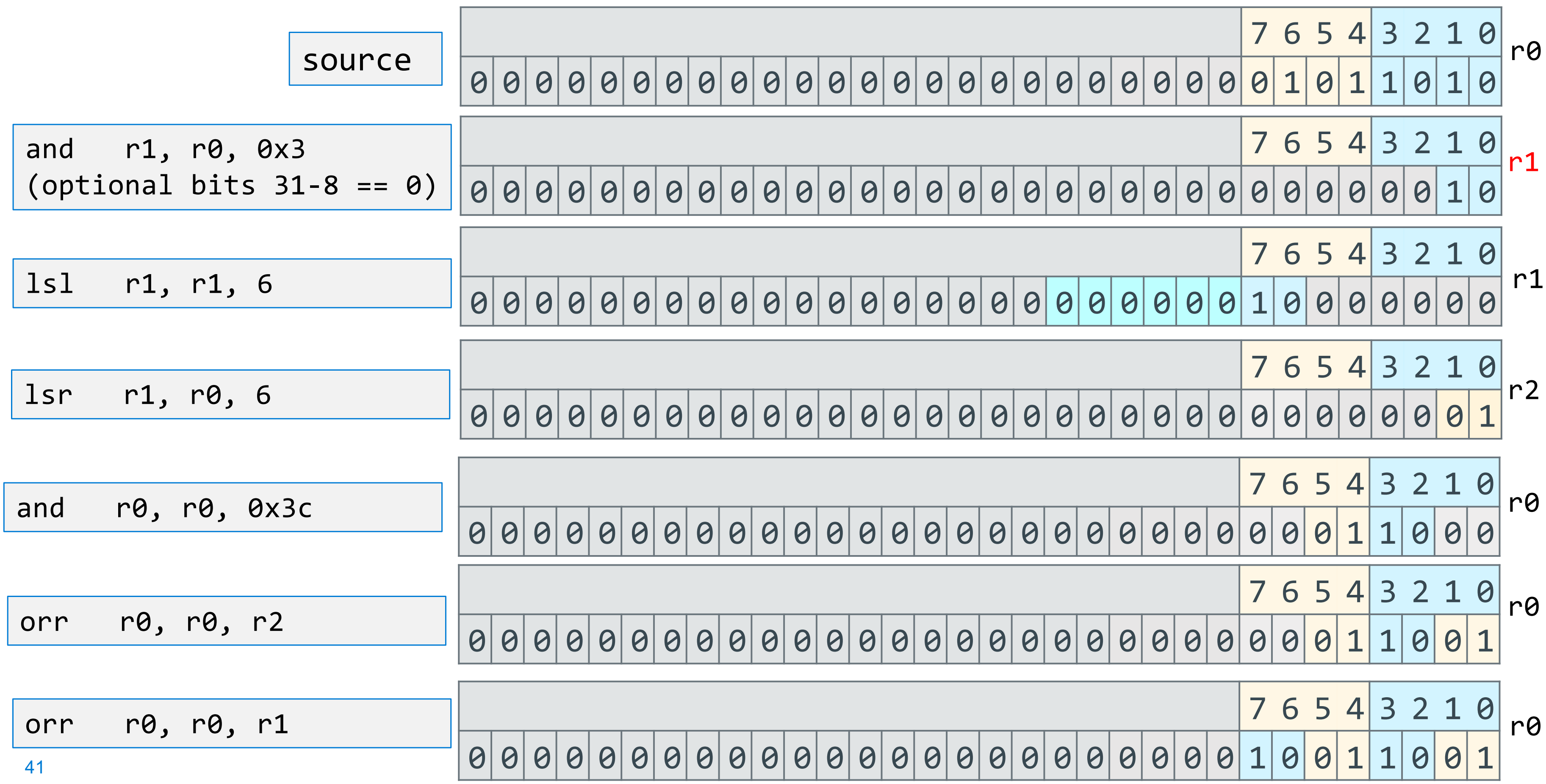
field cleared in destination

inserted field

```
orr    r1, r1, r0
r1 = r1 | r0;
```



Example: Swapping bits7,6 with bits 1,0



x

Masking Summary

Select a field: Use `and` with a mask of one's surrounded by zero's to select the bits that have a 1 in the mask, all other bits will be set to zero

selects this field when used with and

0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0 0 0 0 0	selection mask

Clear a field: Use `and` with a mask of zero's surrounded by one's to select the bits that have a 1 in the mask, all other bits will be set to zero

clears this field when used with and

1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	clear a field mask

Isolate a field: Use `lsr, lsl, rot` to get a field surrounded by zeros

0 0 0 0 0 0 0 0	*source*	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

lsl to get this edge into msb

lsr to get this edge into lsb

Insert a field: Use `orr` with fields surrounded by zeros

0 0 0 0 0 0 0 0	*source*	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Keep these bits	0 0 0 0 0 0 0 0	Keep these bits

x