Numbering and coding systems

- Binary
- Hex
- Conversions binary/hex/decimal
- ASCII coding

Why do I need to know this?

Counting in binary

How many unique numbers can be represented by 4 bits?

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

Convert decimal to binary

Method 1: Use the weight of each position

Use the concept of weight to convert 39_{10} to binary.

Solution:

Weight:	32	16	8	4	2	1
	1	0	0	1	1	1
	32 +	0 +	0 +	4 +	2 +	1 = 39

Therefore, $39_{10} = 100111_2$.

Practice

Convert 43 to binary

Convert from binary to decimal

Using place value

$$110101_2 =$$

					Decimal	Binary
1×2^0	=	1×1	=		1	1
0×2^1	=	0×2	=		0	00
1×2^2	=	1×4	=		4	100
0×2^3	=	0×8	=		0	0000
1×2^4	=	1×16	=		16	10000
1×2^5	=	1×32	=		32	100000
					53	110101

Practice

Convert 1010101 to decimal

Convert from decimal to binary

Method 2: Repeated division by 2

Convert 25_{10} to binary.
Solution:

	Quotient	Remainder	
25/2 =	12	1	LSB (least significant bit)
12/2 =	6	0	
6/2 =	3	0	
3/2 =	1	1	
1/2 =	0	1	MSB (most significant bit)

Therefore, $25_{10} = 11001_2$.

Practice

Convert 36 to binary by repeated division by 2

Hex <--> Binary

Decimal	Binary	Hex
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Signed v. unsigned integers

Unsigned integers: use all bits for data

Signed integers: use 2's complement

2's complement

1. Write the number as a positive in binary
2. Invert each bit (1's complement)
3. Add 1

Observe the following steps.

```
1.      0000 0101              5 in 8-bit binary
2.      1111 1010              invert each bit
3       1111 1011              add 1 (which becomes FB in hex)
```

Therefore, –5 = $FB, the signed number representation in 2's complement for –5. D7 = N = 1 indicates that the number is negative.

2's complement shortcut

Write the positive number in binary

5 = 0000 0101

Starting at the LSB (least significant bit), copy each bit through the first one, then flip the remaining bits

-5 = 1111 1011

2's complement

How many unsigned numbers can we represent with n bits?
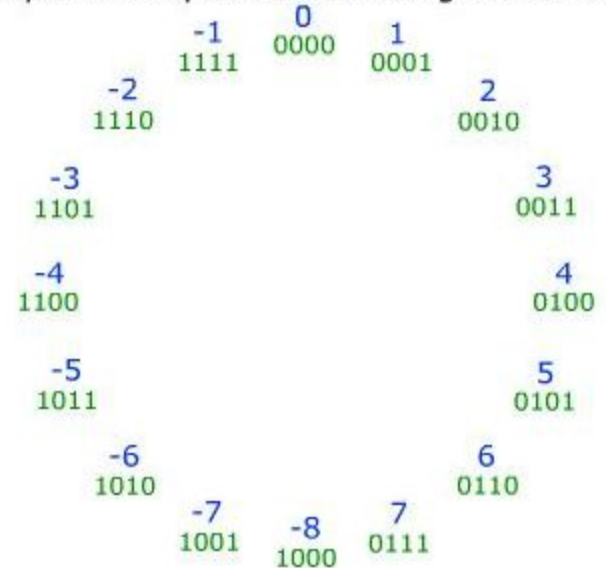
What is the range?

How many signed numbers?

What is the range?

Can tell +/- by MSB (most significant bit)

Terms to know: LSB and MSB

Two's Complement representation using 4 bit binary strings

Why is it called 2's complement?

Let's look at 2 and -2 in 4 bits:

    0010 and 1110

Adding these gives 10000 or 2^4

So the negation of x is $2^n - x$

Signed extension

When moving to a larger memory unit, extend the sign to the left.

Example:

- +2: 0000 0010 => 0000 0000 0000 0010
- −2: 1111 1110 => 1111 1111 1111 1110

Adding binary numbers

- -11 + 8

Adding binary numbers

1. 10 + 24
2. 5 + -6

What about characters?

ASCII (American Standard Code for Information Interchange)

Uses 7 bits per character (uses one byte)

MIPS uses ASCII

Unicode - used in Java, C++

ASCII

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C		
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Need to know ...

- How to convert between decimal and binary
- How to convert between hex and binary
- How to represent unsigned or signed integers
- How to add binary numbers

For next time

Download MARS

http://courses.missouristate.edu/KenVollmar/mars/

Windows 10 users with high resolution devices, try upgrading to Java 9

See Homework 1 in Class Discussion Forum