Binary, Hex and Decimal Numbers (4-bit representation)

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

What does a number represent?

Binary numbers are a code, and represent what the programme intends for the code.

0x72 **Some possible codes:**

- **'r' (ASCII)**
- **INC (HC12 instruction)**
- **2.26V (Input from A/D converter)**
- **114_{10} (Unsigned number)**
- **114_{10} (Signed number)**
- **Set temperature in room to 69 F**
- **Set cruise control speed to 120 mph**

Binary to Unsigned Decimal:

Convert Binary to Unsigned Decimal

1111011_2

$1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$

$1 \times 64 + 1 \times 32 + 1 \times 16 + 1 \times 8 + 0 \times 4 + 1 \times 2 + 1 \times$

123_{10}

Hex to Unsigned Decimal

Convert Hex to Unsigned Decimal

$82D6_{16}$

$8 \times 16^3 + 2 \times 16^2 + 13 \times 16^1 + 6 \times 16^0$

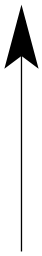
$8 \times 4096 + 2 \times 256 + 13 \times 16 + 6 \times 1$

33494_{10}

Unsigned Decimal to Hex

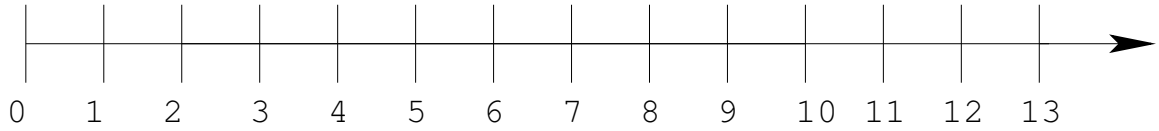
Convert Unsigned Decimal to Hex

Division	Q	R	
		Decimal	Hex
721/16	45	1	1
45/16	2	13	D
2/16	0	2	2



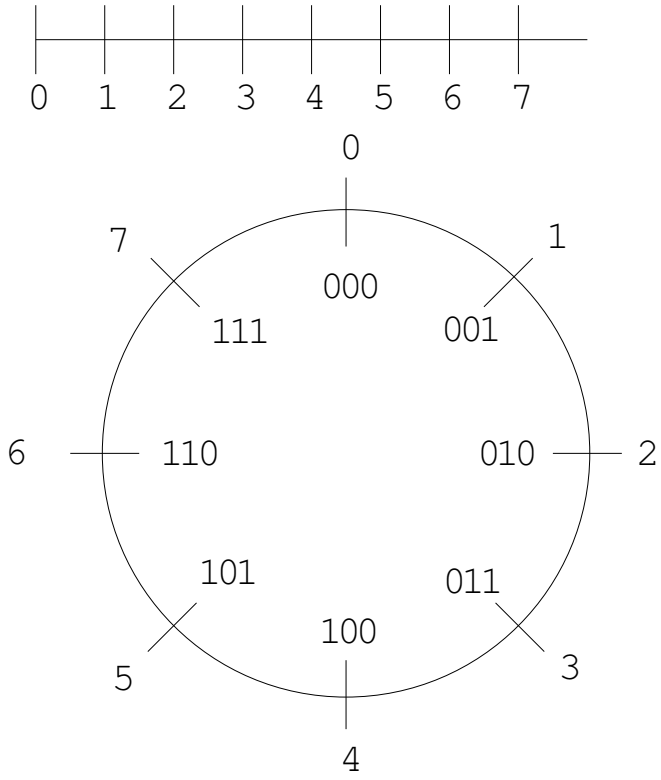
$$721_{10} = 2D1_{16}$$

Unsigned Number Line: Numbers go from 0 to ∞

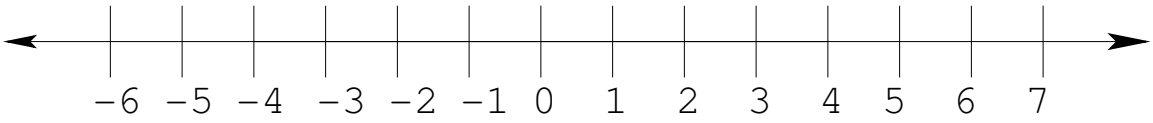


Unsigned Number Line

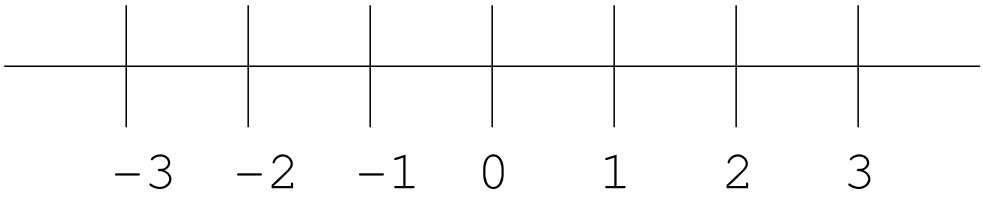
Unsigned Number Wheel: Numbers go from 0 to $2^N - 1$

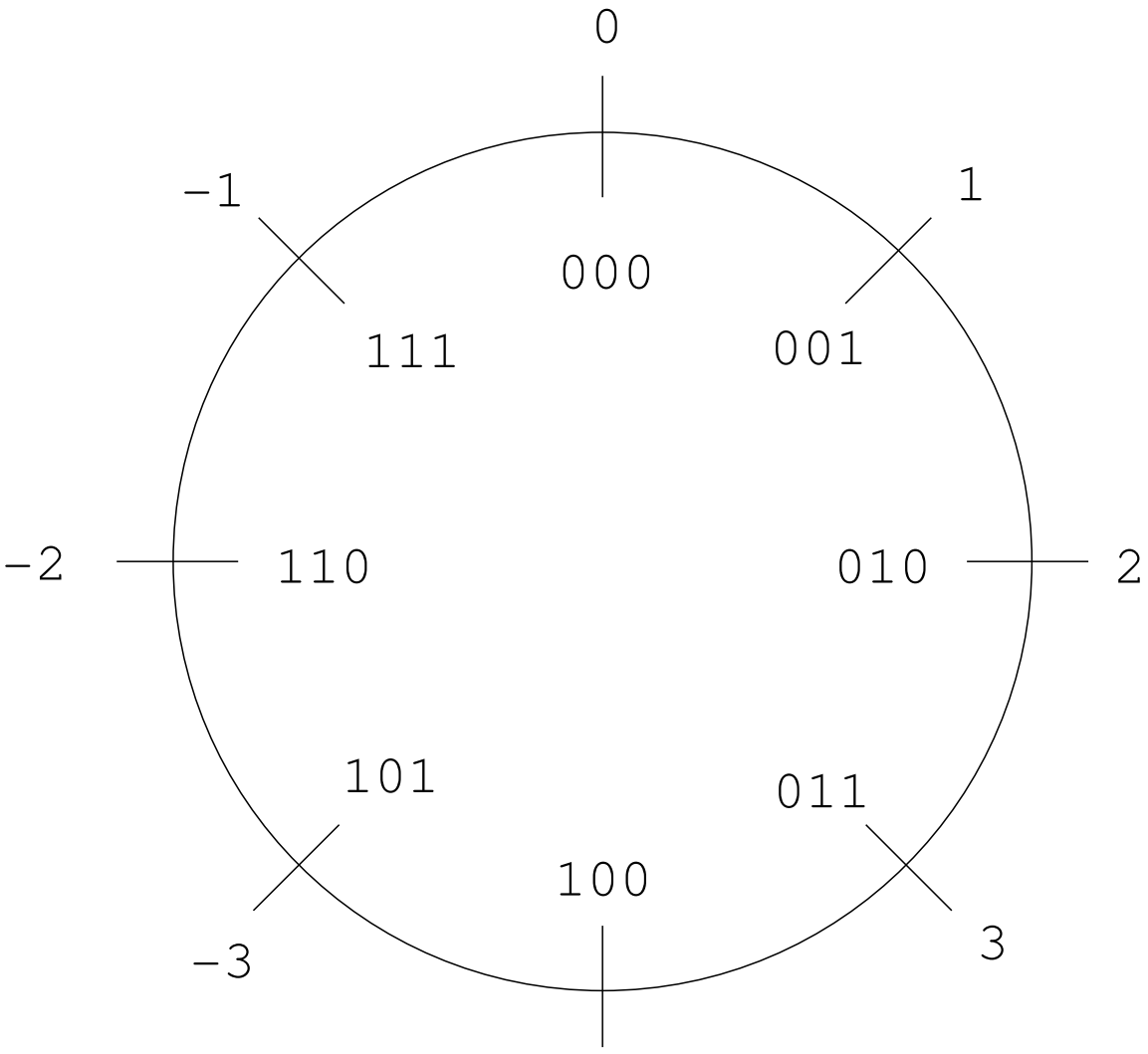


Signed Number Line: Numbers go from $-\infty$ to ∞

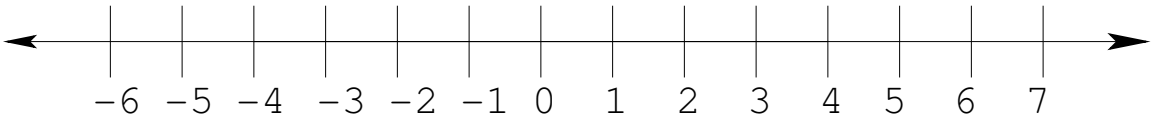


Number Wheel: What to do about 100_2

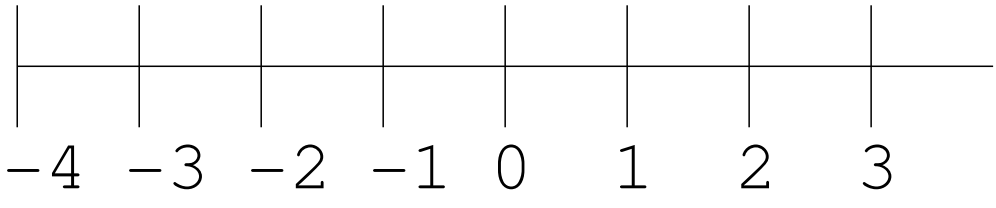


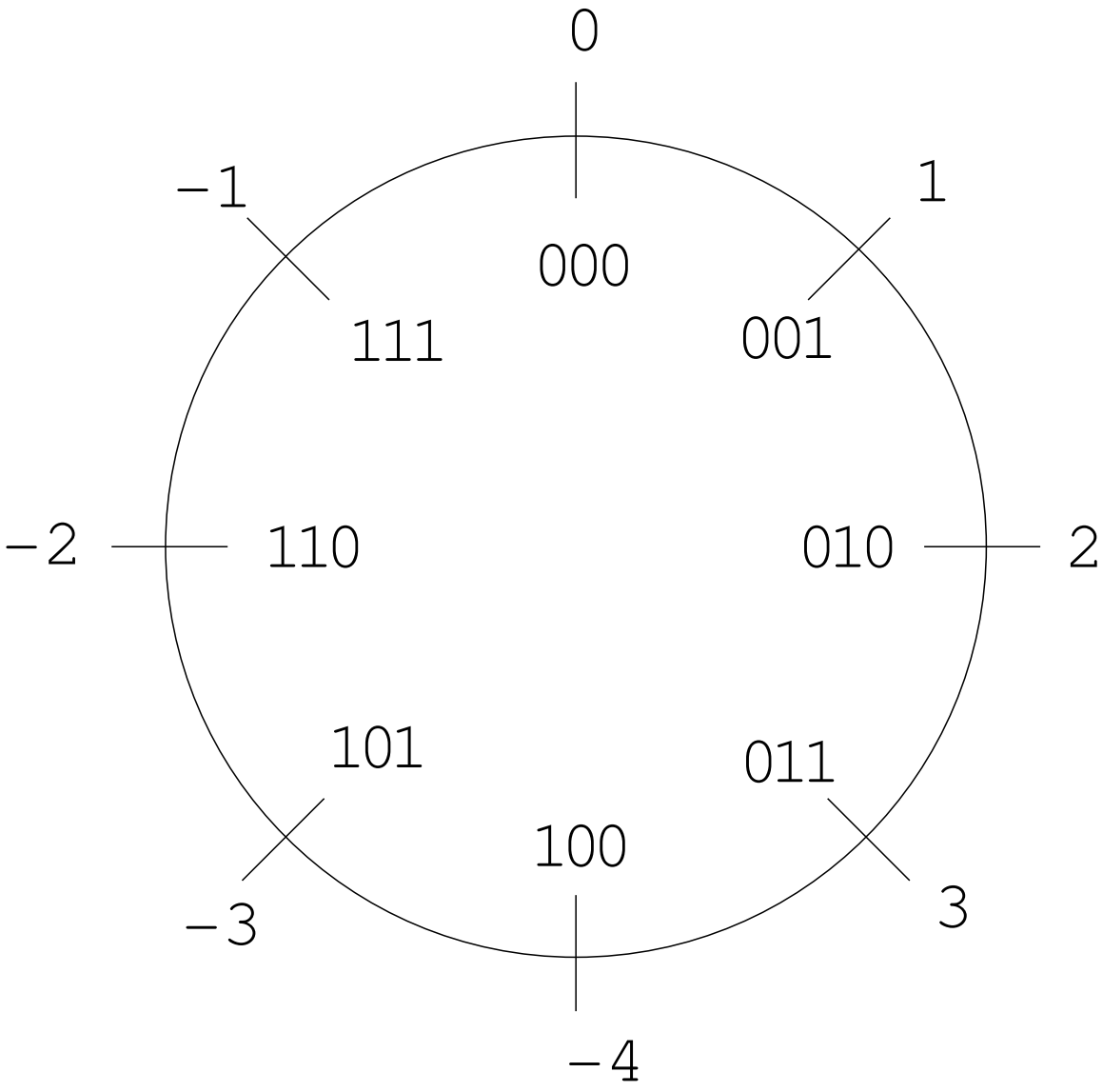


Signed Number Line: Numbers go from $-\infty$ to ∞



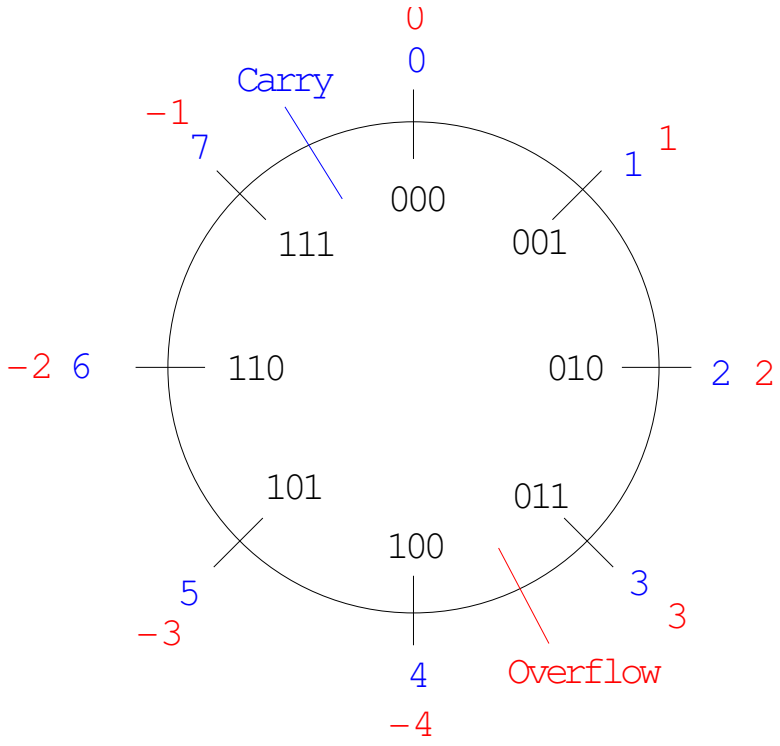
Number Wheel: Numbers go from $-2^{(N-1)}$ to $2^{(N-1)}-1$





Number Wheel: Carry and Overflow

- Carry applies to unsigned numbers — when adding or subtracting, result is incorrect.
- Overflow applies to signed numbers — when adding or subtracting, result is incorrect.



Blue: Unsigned Numbers

Red: Signed Numbers

Binary, Hex and Decimal (Signed & Unsigned) Numbers (4-bit representatio

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

Signed Number Representation in 2's Complement Form:

If most significant bit is 0 (most significant hex digit 0–7), number is positive. Get decimal equivalent by converting number to decimal, and using + sign.

Example for 8–bit number:

$$3A_{16} \rightarrow +\ (\ 3 \times 16^{1} + 10 \times 16^{0})_{10}$$
$$+\ (\ 3 \times 16 + 10 \times 1\ )_{10}$$
$$+\ 58_{10}$$

If most significant bit is 1 (most significant hex digit 8–F), number is negative. Get decimal equivalent by taking 2's complement of number, converting to decimal, and using – sign.

Example for 8–bit number:

$$A3_{16} \rightarrow -\ (\ 5D\ )_{16}$$
$$-\ (\ 5 \times 16^{1} + 13 \times 16^{0})_{10}$$
$$-\ (\ 5 \times 16 + 13 \times 1\ )_{10}$$
$$-\ 93_{10}$$

One's Complement Table Makes It Simple To Find 2's Complements

One's Complement Table

0	F
1	E
2	D
3	C
4	B
5	A
6	9
7	8

To take two's complement, add one to one's complemen

Take two's complement of D0C3 :

2F3C + 1 = 2F3D

- Overflow and Carry assume you have a fixed word size
- A carry is generated when you add two unsigned numbers together, and the result is too large to fit in the fixed word size.
- A carry is generated when you subtract two unsigned numbers, and the result should be negative.
- An overflow is generated when you add or subtract two signed numbers, and the fixed-length answer has the wrong sign.

Addition and Subtraction of Binary and Hexadecimal Numbers

ADDITION AND SUBTRACTION OF BINARY AND HEXADECIMAL NUMBER

1) Limit number of digits to specified word size.

4–bit word:

```
   1101
+ 1011
-------
 1 1000
```

Keep only 4 bits in answer

2) Does not matter if numbers are signed or unsigned – mechanics the same

Do the operation, then determine if carry and/or overflow bits are set.

4–bit word:

```
   1101      Neg
+ 1011       Neg
-------
 1 1000      Neg
```

Carry is set, overflow is clear

Condition Code Register Gives Information On Result Of Last Operation

S	X	H	I	N	Z	V	C

Condition Code Register – 8 FFs

N – Negative : most significant bit of result

Z – Zero : 1 -> result zero, 0 -> result not zero

V – Overflow : 1 -> last operation generated an overfl

C – Carry : 1 -> last operation generated a carry

Note: Not all HC12 instructions change CCR bits. A bit in the CCR is the result of the last executed instruction which affects that bit. For example, consider the following instruction sequence:

```
aba                 ; Add B to A
staa $0900          ; Store A in address $0900
```

The ABA instruction will change the H, N, Z, V and C bits of the CCR. The STAA instruction will change the N and Z bit, and clear the V bit. After the two instructions, the H and C bits will reflect the result of the ABA instruction; the N and Z bits will reflect the result of the STAA instruction (was the number stored negative or zero), and the V bit will be 0.

Overflow occurs only under certain addition and subtraction operations.

S	X	H	I	N	Z	V	C

Condition Code Register – 8 FFs

```
N - Negative : most significant bit of result
Z - Zero     : 1 -> result zero, 0 -> result not zero
V - Overflow : 1 -> last operation generated an overfl
C - Carry    : 1 -> last operation generated a carry
```

- If you add a positive and a negative number, on overflow never occurs.
- If you subtract two positive numbers, an overflow never occurs.
- If you subtract two negative numbers, and overflow never occurs.