- **Decimal, Hexadecimal and Binary Numbers**
  - Binary numbers are a code, and represent what the programmer intends for the code
  - Convert binary and hex numbers to unsigned decimal
  - Convert unsigned decimal to hex
  - Unsigned number line and wheel
  - Signed number line and wheel
  - Binary, Hex, Signed and Unsigned Decimal
  - Signed number representation --- 2's Complement form
  - Using the 1's complement table to find 2's complements of hex numbers
  - Overflow and Carry
  - Addition and subtraction of binary and hexadecimal numbers
  - The Condition Code Register (CCR): N, Z, V and C bits

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 programmer intends for the code.

0x72 Some possible meanings:
’r’ (ASCII)
INC MEM (hh ll) (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

$1 \text{ x } 2^6 + 1 \text{ x } 2^5 + 1 \text{ x } 2^4 + 1 \text{ x } 2^3 + 0 \text{ x } 2^2 + 1 \text{ x } 2^1 + 1 \text{ x } 2^0$

1 x 64 + 1 x 32 + 1 x 16 + 1 x 8 + 0 x 4 + 1 x 2 + 1 x 1

123_{10}

Hex to Unsigned Decimal

Convert Hex to Unsigned Decimal

$82D6_{16}$

$8 \text{ x } 16^3 + 2 \text{ x } 16^2 + 13 \text{ x } 16^1 + 6 \text{ x } 16^0$

8 x 4096 + 2 x 256 + 13 x 16 + 6 x 1

33494_{10}

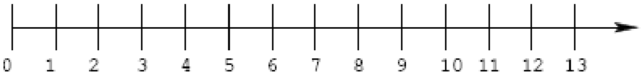
Unsigned Decimal to Hex

Convert Unsigned Decimal to Hex

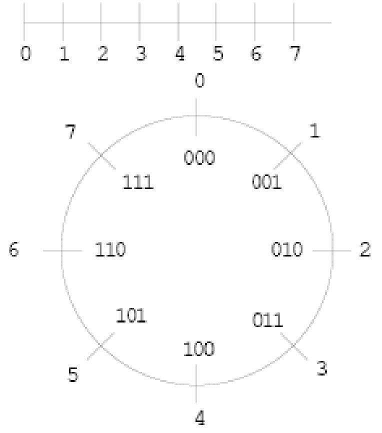
Division	Q	R	
		Decimal	Hex
721/16	45	1	1
45/16	2	13	D
2/16	0	2	2

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

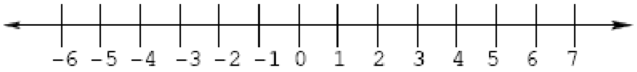
Unsigned Number Line: Numbers go from 0 to ∞



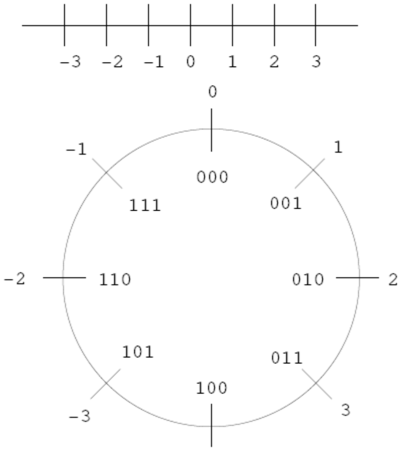
Unsigned Number Wheel: Numbers go from 0 to 2N − 1



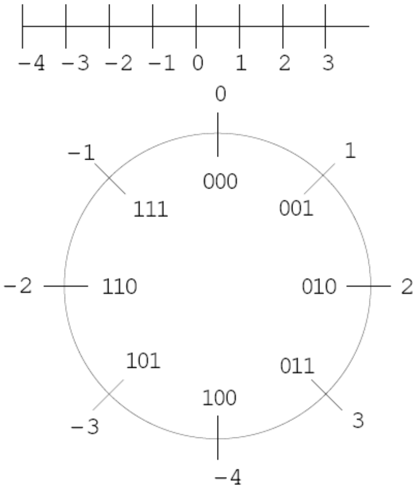
Signed Number Line: Numbers go from $-\infty$ to ∞



Number Wheel: What to do about 100_2

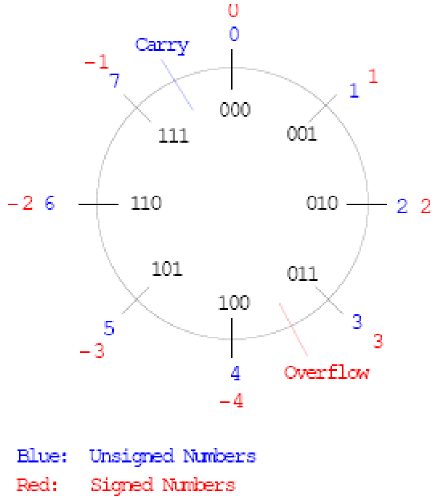


Number Wheel: Numbers go from $-2^{(N-1)}$ to $2^{(N-1)} - 1$



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.



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

Binary	**Hex**	**Decimal**	
		Unsigned	**Signed**
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 the most significant bit (MSB) is 0 (most significant hex digit 0–7), then the number is positive.
Get decimal equivalent by converting number to decimal, and use the + sign.

Example for 8–bit number:

3A $_{16}$ –> + (3 x 16^1 + 10 x 16^0) $_{10}$
+ (3 x 16 + 10 x 1) $_{10}$
+ 58 $_{10}$

If the most significant bit is 1 (most significant hex digit 8–F), then the 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 $_{16}$ –> - (5D) $_{16}$
- (5 x 16^1 + 13 x 16^0) $_{10}$
- (5 x 16 + 13 x 1) $_{10}$
- 93 $_{10}$

One’s complement table makes it simple to finding 2’s complements

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 complement.
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

1) Limit number of digits to specified word size.

4−bit word:

```
   1101
+  1011
1  1000
```

Keep only 4 bits in answer, carry is set

2) It does not matter if numbers are signed or unsigned − the mechanics are the same
Do the operation, then determine if carry and/or overflow bits are set.

4−bit word:

```
  1101 Neg
+ 1001 Neg
1 0110 Pos
```

Keep only 4 bits in answer, overflow is clear

Condition Code Register (CCR) gives information on the result of last operation

S	X	H	I	N	Z	V	C

Condition Code Register − 8 FFs

C − Carry : 1 −> last operation generated a carry
V − Overflow : 1 −> last operation generated an overflow
Z − Zero : 1 −> result zero, 0 −> result not zero
N − Negative : most significant bit of result
I − Interrupt mask
H − Half carry
X − Interrupt mask
S − Stop disable

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

- 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.