Two's Complement

- To get the Two's complement of a binary value
  - *1.) Invert the bits*
    - *i.e. 010010 -> 101101*
    - *Make sure there is an extra bit available for the sign of the number!*
  - *2.) Add +1*
    - *i.e. 101101 + 1 -> 101110*

Two's Complement – Conversion to Decimal

- Unsigned conversion was just adding together the power of twos

$$\begin{array}{r} 2^7\ 2^4\ 2^1 2^0 \\ 0100100111 = 2^7 + 2^4 + 2^1 + 2^0 = 147 \end{array}$$

- Two's Complement just needs a slight tweak for the sign bit
  - *Sign bit (MSB) becomes -2^{n-1}*

$$\begin{array}{r} -2^8\ 2^7\ 2^4\ 2^1 2^0 \\ 0100100111 = 0*-2^8 + 2^7 + 2^4 + 2^1 + 2^0 = 147 \\ -2^8\ 2^7\ 2^4\ 2^1 2^0 \\ 1100100111 = 1*-2^8 + 2^7 + 2^4 + 2^1 + 2^0 = -256 + 147 \\ = -109 \end{array}$$

Two's Complement – Conversion to Decimal (Option #2)

- Can take the two's complement and then convert as well

$$-2^8\ 2^7\ 2^4\ 2^1 2^0$$
$$1\ 1\ 0\ 0\ 1\ 0\ 0\ 1\ 1 = -109$$

- Two's Complement
  - *Invert 110010011 -> 001101100*
  - *Add 1 -> 001101101*

$$2^6 2^5\ 2^3 2^2\ 2^0$$
$$0\ 1\ 1\ 0\ 1\ 1\ 0\ 1 = 2^6 + 2^5 + 2^3 + 2^2 + 2^0 =$$
$$64 + 32 + 8 + 4 + 1 = 109$$

Put negative sign back -109

Two's Complement – Decimal to binary

- Easiest way is to treat as positive number and then perform two's complement
- 1.) Get magnitude

$$-32 = 32$$

- 2.) Convert to binary

$$32 = 2^5 = 0100000$$

Leave a bit for the sign bit!

- 3.) Perform Two's complement

invert **add-one**

$$0100000 \rightarrow 1011111 \rightarrow = 1100000 = -2^6 + 2^5 = -64 + 32 = -32$$