**Topic: Two’s complement (binary numbers)**

Reading Time: 20 mins

**·        Note\* Highlight important/core points while reading**

·        Read the content and write the answers given in the document in your words, to get the solid grip on topic.

**Two’s Complement (Binary Numbers)**

**What is Two’s Complement?**

Two’s complement is a method used to represent **positive and negative integers** in binary. It is the most common way computers store and process signed numbers.

In an **n-bit system**, the leftmost bit is called the **sign bit**:

* **0 → Positive number**
* **1 → Negative number**

For example, in an **8-bit system**:

* **01100100₂** = **+100₁₀** (positive because the leftmost bit is 0)
* **10011100₂** = **-100₁₀** (negative because the leftmost bit is 1)

**1. Writing Positive Binary Numbers in Two’s Complement Format**

To write a positive number in two’s complement format:

1. Convert the decimal number to binary.
2. Ensure the number has the correct number of bits (e.g., **8-bit** system requires 8 bits).
3. Add a **0** as the leftmost (sign) bit.

**Example (8-bit system)**

Convert **+13₁₀** to **two’s complement format**:

1. **13₁₀ → 1101₂**
2. Add leading zeros to make **8 bits**: **00001101₂**
3. Since the leftmost bit is **0**, it remains **positive**.

**2. Converting Positive Denary Numbers to Two’s Complement Binary**

Example: Convert **+25₁₀** to two’s complement format (8-bit).

1. Convert **25₁₀ → 11001₂**
2. Add leading zeros to make **8 bits**: **00011001₂**

So, **+25₁₀ in two’s complement = 00011001₂**

**3. Converting Positive Binary Numbers in Two’s Complement to Denary**

To convert a **positive binary number** to decimal:

1. The leftmost bit is **0**, so the number is positive.
2. Convert the binary to decimal normally.

Example: Convert **00101110₂** (8-bit) to decimal.

1. Leftmost bit is **0**, so the number is **positive**.
2. Convert **00101110₂ → (0×128) + (0×64) + (1×32) + (0×16) + (1×8) + (1×4) + (1×2) + (0×1) = 46₁₀**

So, **00101110₂ = 46₁₀**

**4. Writing Negative Binary Numbers in Two’s Complement Format and Converting to Denary**

To write a **negative number** in two’s complement format:

1. Convert the absolute value to binary.
2. Make it an **8-bit binary number**.
3. **Invert all bits (flip 0s to 1s and 1s to 0s).**
4. **Add 1** to the result.

**Example: Convert -25₁₀ to Two’s Complement (8-bit)**

1. **|25|₁₀ → 11001₂**
2. **Make 8-bit:** **00011001₂**
3. **Invert bits:** **11100110₂**
4. **Add 1:**

 11100110

+  00000001

    ------------

   11100111₂

So, **-25₁₀ in two’s complement = 11100111₂**

**5. Converting Negative Two’s Complement Numbers to Denary**

To convert a **negative** two’s complement number back to decimal:

1. **Check if the leftmost bit is 1** (if yes, the number is negative).
2. **Invert all bits** (flip 1s to 0s and 0s to 1s).
3. **Add 1** to the result.
4. Convert the result to decimal and add a **negative sign (-)**.

**Example: Convert 11101100₂ (8-bit) to Decimal**

1. Leftmost bit is **1** → The number is **negative**.
2. Invert bits: **00010011₂**
3. Add **1**:

    00010011

+  00000001

   ------------

   00010100₂

1. **00010100₂ = 20₁₀**
2. Add **negative sign** → **-20₁₀**

So, **11101100₂ = -20₁₀**

**A-Rated Questions/Answers By Examiner**

**Q1: What is the leftmost bit used for in two’s complement?**

**Answer:** The leftmost bit is the **sign bit**:

* 0 → Positive number
* 1 → Negative number

**Q2: Convert +18₁₀ to an 8-bit two’s complement binary number.**

**Answer:**

1. **18₁₀ → 10010₂**
2. Add leading zeros to make 8-bit: **00010010₂**

**Q3: Convert 11011000₂ (8-bit) to decimal using two’s complement rules.**

**Answer:**

1. Leftmost bit is **1**, so the number is negative.
2. Invert bits: **00100111₂**
3. Add **1**:

    00100111

+  00000001

     ------------

   00101000₂ = 40₁₀

1. Add **negative sign** → **-40₁₀**

So, **11011000₂ = -40₁₀**

**Q4: Convert -12₁₀ to two’s complement (8-bit).**

**Answer:**

1. **|12|₁₀ → 1100₂**
2. Make it **8-bit**: **00001100₂**
3. Invert bits: **11110011₂**
4. Add **1**:

    11110011

+  00000001

     ------------

   11110100₂

So, **-12₁₀ in two’s complement = 11110100₂**

**Q5: How do you convert a two’s complement negative binary number back to denary?**

**Answer:**

1. **Check if the leftmost bit is 1** (negative number).
2. **Invert all bits** (flip 1s to 0s and 0s to 1s).
3. **Add 1**.
4. Convert the result to decimal and **add a negative sign (-)**.

### Write your Answers on your Notebook and Verify it on Next Screen

**Q6: Convert 10110101₂ (8-bit) to decimal using two’s complement rules.**

**Q7: What is the two’s complement representation of -1 in an 8-bit system?**

**Q8: Convert 11001100₂ (8-bit) to decimal using two’s complement rules.**

**Q9: Convert 10101101₂ (8-bit) to decimal using two’s complement rules.**

**Q10: Convert 10011001₂ (8-bit) to decimal using two’s complement rules.**

**6. Answer:**

1. **Leftmost bit is 1** → The number is **negative**.
2. **Invert bits**: 01001010₂.
3. **Add 1**:

       01001010

* 00000001

**7. Answer:**

* **|1|₁₀ → 00000001₂**
* **Invert bits**: **11111110₂**
* **Add 1**:

11111110

* 00000001

**8. Answer:**

* **Leftmost bit is 1**, so the number is **negative**.
* **Invert bits**: **00110011₂**
* **Add 1**:

00110011

* 00000001

**9. Answer:**

* **Leftmost bit is 1**, so the number is **negative**.
* **Invert bits**: **01010010₂**
* **Add 1**:

01010010

* 00000001

**10. Answer:**

1. **Leftmost bit is 1**, so the number is **negative**.
2. **Invert bits**: **01100110₂**
3. **Add 1**:

01100110

* 00000001