G.C.E. O/L Grade 10 ICT · Lesson 3

3.3 Binary ↔ Decimal, Octal and Hexadecimal Conversions

Now we go the other way. You will convert **binary to decimal** using place values, and convert **binary ↔ octal** and **binary ↔ hexadecimal** quickly by **grouping bits in 3s and 4s**. Finally you will convert **octal ↔ hexadecimal** through binary. Only positive whole numbers are used.

1. Binary → decimal (place value method)

Write the place values (1, 2, 4, 8 ...) under each bit from the right. Add the place values where the bit is **1**.

Worked example 1: 101101_2 → decimal

Digit	1	0	1	1	0	1
Place value	$2^5 = 32$	$2^4 = 16$	$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$
Digit × place value	1 × 32 = 32	0 × 16 = 0	1 × 8 = 8	1 × 4 = 4	0 × 2 = 0	1 × 1 = 1

💡 32 + 0 + 8 + 4 + 0 + 1 = **45_{10}**

The same method works for octal and hex → decimal: multiply each digit by its place value and add.

Worked example 2: $3A7_{16}$ → decimal

Digit	3	A	7
Place value	$16^2 = 256$	$16^1 = 16$	$16^0 = 1$
Digit × place value	3 × 256 = 768	10 × 16 = 160	7 × 1 = 7

💡 768 + 160 + 7 = **935_{10}**

2. Binary ↔ octal (groups of 3)

Because $8 = 2^3$, **one octal digit = exactly 3 bits**. Group the bits in threes **from the right**; add 0s on the left if needed. Change each group to one digit.

Octal	0	1	2	3	4	5	6	7
Binary	000	001	010	011	100	101	110	111

Worked example 3: 1101011_2 → octal

Group	001	101	011
Value	1	5	3

💡 1101011_2 = **153_8** (two 0s were added on the left to make 001).

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Worked example 4: 572_8 → binary

Digit	5	7	2
Bits	101	111	010

💡 572_8 = **101111010_2**

3. Binary ↔ hexadecimal (groups of 4)

Because 16 = 2^4, **one hex digit = exactly 4 bits** (a nibble). Group from the right in fours.

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

Worked example 5: 1011111010_2 → hexadecimal

Group	0010	1111	1010
Value	2	F	A

💡 1011111010_2 = **$2FA_{16}$**

Worked example 6: $9C_{16}$ → binary

Digit	9	C
Bits	1001	1100

💡 $9C_{16}$ = **10011100_2**

4. Octal ↔ hexadecimal (via binary)

There is no direct grouping between 8 and 16. Go through binary: **octal → binary (3 bits each) → regroup in 4s → hex**, and the reverse for hex → octal.

Worked example 7: 357_8 → hexadecimal

Digit	3	5	7
Bits	011	101	111

Group	1110	1111
Value	E	F

💡 357_8 = 11101111_2 = **EF_{16}** (check: both equal 239_{10}).

Worked example 8: $2B_{16}$ → octal

Digit	2	B
Bits	0010	1011

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Group	101	011
Value	5	3

💡 $2B_{16} = 101011_2 = \mathbf{53_8}$

💡 **Common mistakes:** grouping from the LEFT instead of the right; forgetting leading 0s; writing 10 instead of A in hex.

Key Words

Grouping – Splitting a binary number into groups of 3 or 4 bits from the right.

Nibble – A group of 4 bits = one hexadecimal digit.

Triad – A group of 3 bits = one octal digit.

Leading zero – A 0 added on the left to complete a group; it does not change the value.

Place value method – Multiply each digit by its place value and add to get decimal.

Binary to decimal – Add the place values where the bit is 1.

Binary to octal – Group bits in 3s from the right and convert each group.

Binary to hexadecimal – Group bits in 4s from the right and convert each group.

Octal to binary – Write each octal digit as 3 bits.

Hexadecimal to binary – Write each hex digit as 4 bits.

Octal to hexadecimal – Convert octal to binary, then regroup in 4s.

Positive integer – A whole number greater than zero (no fractions, no minus sign).

Sample Q&A

1. Convert 11010_2 to decimal.

Answer: $16 + 8 + 2 = 26_{10}$.

2. Why do we group bits in 3s for octal?

Answer: Because $8 = 2^3$, so each octal digit is exactly 3 bits.

3. Convert 11110110_2 to hexadecimal.

Answer: 1111 | 0110 → F | 6 → $F6_{16}$.

4. Convert 47_8 to binary.

Answer: 4 → 100, 7 → 111 → 100111_2.

5. From which side do you start grouping bits?

Answer: From the right (the LSB). Add leading 0s on the left if the last group is short.

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6. How do you convert octal to hexadecimal?

> **Answer:** Change each octal digit to 3 bits, then regroup the bits in 4s from the right and change each group to a hex digit.

MCQ

1. What is 101101_2 in decimal?

A. 45
B. 90
C. 54
D. 43

2. What is 1111_2 in decimal?

A. 16
B. 1111
C. 15
D. 4

3. What is 1100100_2 in decimal?

A. 100
B. 200
C. 98
D. 50

4. What is 1101011_2 in octal?

A. 513
B. 153
C. 651
D. 326

5. What is 1011111010_2 in hexadecimal?

A. 2EA
B. 2FA0
C. 2FA
D. BE2

6. What is 572_8 in binary?

A. 101011010
B. 111101010
C. 101111001
D. 101111010

7. What is $9C_{16}$ in binary?

A. 10010011
B. 11001001
C. 10011100
D. 10011010

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8. When converting binary to hexadecimal, bits are grouped in:

A. Eights from the left
B. Fours from the left
C. Threes from the right
D. Fours from the right

9. What is 357_8 in hexadecimal?

A. 357
B. EF
C. FE
D. DF

10. What is $2B_{16}$ in octal?

A. 53
B. 52
C. 35
D. 43

11. What is $3A7_{16}$ in decimal?

A. 937
B. 935
C. 3107
D. 967

12. What is 11110110_2 in hexadecimal?

A. 6F
B. F5
C. F6
D. E6

13. One hexadecimal digit is equal to how many bits?

A. 4
B. 8
C. 16
D. 3

14. What is 75_8 in decimal?

A. 117
B. 57
C. 75
D. 61

15. Which binary number equals $7F_{16}$?

A. 11110111
B. 1111111
C. 1111111111
D. 01110000

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Structured Questions

1. Convert 10110011_2 to (i) decimal (ii) octal (iii) hexadecimal. Show working. (6 marks) *(6 marks)*

> (i) 128+32+16+2+1 = 179_{10}
> (ii) 010 110 011 → 263_8
> (iii) 1011 0011 → $B3_{16}$

2. Convert 645_8 to binary and then to hexadecimal. (4 marks) *(4 marks)*

> 6→110, 4→100, 5→101 → 110100101_2. Regroup: 0001 1010 0101 → $1A5_{16}$.

3. Convert $A5_{16}$ to (i) binary (ii) octal (iii) decimal. (3 marks) *(3 marks)*

> (i) 1010 0101 → 10100101_2 (ii) 010 100 101 → 245_8 (iii) 10×16+5 = 165_{10}

4. A student converted 1101101_2 to hex as 1101 101 → D5. (i) What mistake was made? (1 mark) (ii) Give the correct answer. (2 marks) *(3 marks)*

> (i) Grouped from the left instead of the right. (ii) 0110 1101 → $6D_{16}$.

5. Arrange in ascending order after converting to decimal: 1110_2, 17_8, 10_{16}. (3 marks) *(3 marks)*

> 1110_2 = 14, 17_8 = 15, 10_{16} = 16 → 1110_2, 17_8, 10_{16}.

6. Convert $1F_{16}$ to octal using binary. Show both steps. (3 marks) *(3 marks)*

> 1→0001, F→1111 → 11111_2. Regroup in 3s: 011 111 → 37_8.

Summary

- Binary → decimal: add place values where the bit is 1.
- Octal/hex → decimal: digit × place value, then add.
- 1 octal digit = 3 bits ($8 = 2^3$).
- 1 hex digit = 4 bits ($16 = 2^4$), called a nibble.
- Always group from the right; add leading 0s on the left.
- Octal/hex → binary: write each digit as 3 or 4 bits.
- Octal ↔ hex: go through binary and regroup.
- Check answers by converting both to decimal.

MCQ answer key – 3.3

1. **A** – 32+8+4+1 = 45.
2. **C** – 8+4+2+1 = 15.
3. **A** – 64+32+4 = 100.
4. **B** – 001 101 011 → 1 5 3.
5. **C** – 0010 1111 1010 → 2 F A.
6. **D** – 5→101, 7→111, 2→010.
7. **C** – 9→1001, C→1100.
8. **D** – $16 = 2^4$; start at the LSB.
9. **B** – $357_8 = 11101111_2 = EF_{16}$.
10. **A** – $2B = 101011_2 = 101\ 011 = 53_8$.

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11. **B** – 3×256 + 10×16 + 7 = 935.
12. **C** – 1111 0110 → F6.
13. **A** – 16 = 2^4 → 4 bits.
14. **D** – 7×8 + 5 = 61.
15. **B** – 7→0111, F→1111 → 1111111.

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