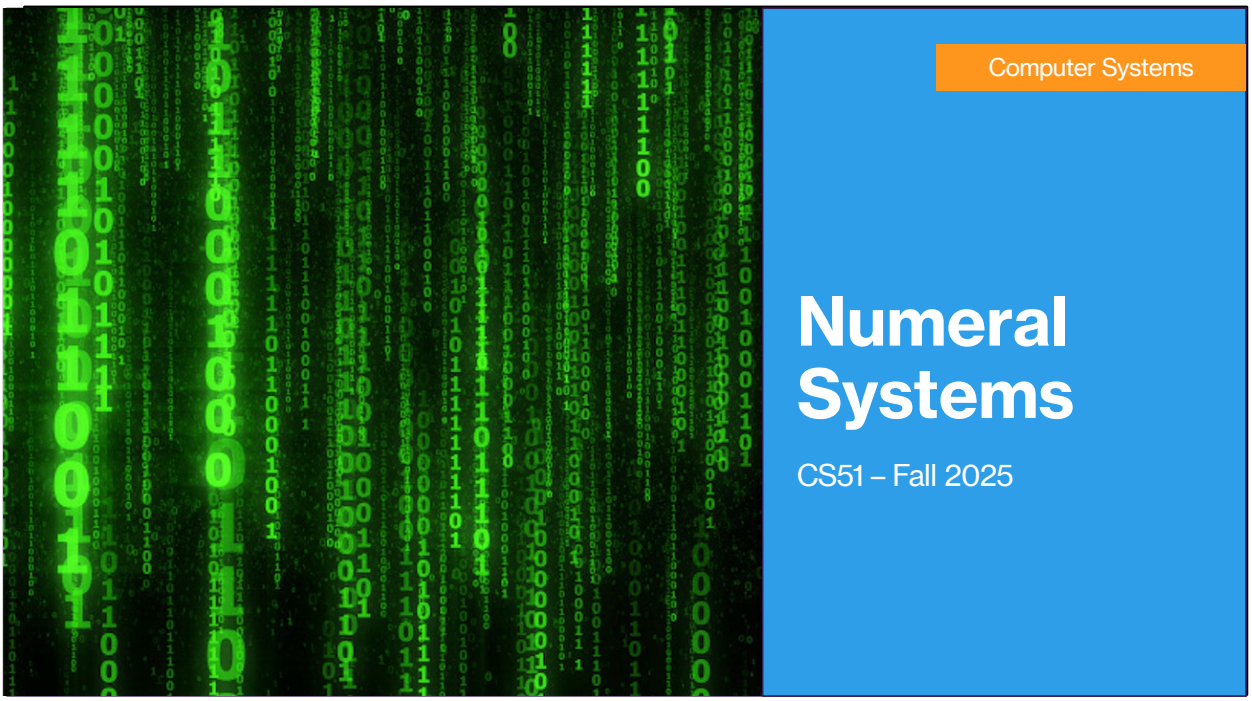


Last time we talked about how physical components like transistors allow us to represent data in computers in one of two binary states, 0 or 1, False or True etc. Working with binary data is just one example of a numeral system.

Decimal numbers

- We are used to numbers that use ten digits: $0, 1, 2, 3, 4, 5, 6, 7, 8, 9$.
- This arithmetic is called **base 10** (denoted as a subscript) and such numbers are called **decimal**.
- $d_n d_{n-1} \ldots d_2\, d_1 d_0$ represents the integer $d_n 10^n + d_{n-1} 10^{n-1} + \ldots + d_2\, 10^2 + d_1 10^1 + d_0 10^0$
- For example, the number 9247_{10} can be written as the sum of each of its digits multiplied by the weight of the corresponding column:

$10^3 = 1000$	$10^2 = 100$	$10^1 = 10$	$10^0 = 1$
9	2	4	7

  - $9247_{10} = 9{\times}10^3 + 2{\times}10^2 + 4{\times}10^1 + 7{\times}10^0$
- An n-digit decimal number is one of 10^n possibilities. For non-negative numbers, this provides a **range** of $0, 1, 2, 3, \ldots, 10^n - 1$. For example, with 3 digits, we can represent $0, \ldots, 999$.

2

Although computer scientists love binary data, we are not used to them in everyday life. Instead, we are accustomed to talking about numbers that use ten digits, 0,…9, which we combine to form longer numbers. This type of arithmetic is called base 10 or decimal (deci means one tenth). To avoid confusion, we will use subscripts to indicate the base of a number. If we take a decimal number we can break it down as the sum of individual digits that are multiplied with increasingly larger powers of 10. Starting with the right-most digit, that would be multiplied with 1 or 10^0. The second to last would be multiplied with 10 or 10^1. Third from the right, would be multiplied with 100 or 10^2 and so on. Notice that each column is 10 times larger than the one on the right. If we have a non-negative decimal number with n digits we know it has to be one of 0,1,…, 10^n-1. For example, with 3 digits, it can be 0, 1, 2,3, … 999.

Binary numbers

- We combine **bits**, that is binary digits that are either 0 or 1, to form **binary numbers**. This arithmetic is called base 2 and each column is twice as large as the one on its right.
- $b_n b_{n-1} \ldots b_2 b_1 b_0$ represents the integer $b_n 2^n + b_{n-1} 2^{n-1} + \ldots + b_2 2^2 + b_1 2^1 + b_0 2^0$
- For example, the binary number 10100111_2 can be written as:

$2^7 = 128$	$2^6 = 64$	$2^5 = 32$	$2^4 = 16$	$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$
1	0	1	0	0	1	1	1

  - $1\times2^7 + 0\times2^6 + 1\times2^5 + 0\times2^4 + 0\times2^3 + 1\times2^2 + 1\times2^1 + 1\times2^0$
  - This is equal to the decimal representation $128 + 32 + 4 + 2 + 1 = 167_{10}$
- The left-most bit is the **most significant bit** (MSB). The right-most is the **least significant bit** (LSB).
- An n-digit binary number is one of 2^n possibilities: $0, 1, 2, 3, \ldots, 2^n - 1$.
- We need at least $\log_2 n$ bits to represent information with n values.

3

The same idea can apply with binary variables. We say that a binary digit, a 0 or a 1, is a bit. We combine bits to form binary numbers. This arithmetic is called base 2 or binary. We can break down binary numbers as we did with decimals but the columns will now be powers of 2 and each column will be twice as large as the one to its right. We can use this to convert a binary number to a decimal number. If we have a binary number with n digits, it can be one of 0, 1, 2, …, 2^n-1. We need at least $\log_2 n$ bits to represent information with n values.

Binary numbers and their decimal equivalents

1-bit binary	2-bit binary	3-bit binary	4-bit binary	Decimal equivalent
0	00	000	0000	0
1	01	001	0001	1
	10	010	0010	2
	11	011	0011	3
		100	0100	4
		101	0101	5
		110	0110	6
		111	0111	7
			1000	8
			1001	9
			1010	10
			1011	11
			1100	12
			1101	13
			1110	14
			1111	15

4

Here is what that would look like if we take binary numbers with 1, 2, 3, or 4 bits. You can also see the decimal equivalent. With 1 bit, we can represent 2 values, with 2 bits 4, with 3 bits 8 and 4 bits 16, and so on.

PRACTICE TIME

- Convert the following binary numbers to their decimal representation:
  - 10011011_2
  - 1100011_2
  - 100010_2

5

Let's practice, by converting the following binary numbers to their decimal representation.

PRACTICE TIME - ANSWER

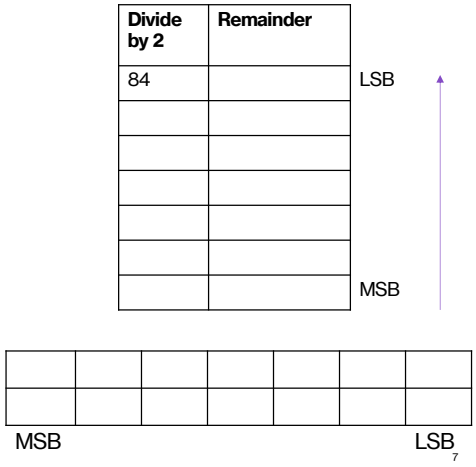
- Convert the following binary numbers to their decimal representation:
  - $10011011_2 = 1\times2^7 + 0\times2^6 + 0\times2^5 + 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0 = 128 + 16 + 8 + 2 + 1 = 155_{10}$
  - $1100011_2 = 1\times2^6 + 1\times2^5 + 0\times2^4 + 0\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0 = 99_{10}$
  - $100010_2 = 1\times2^5 + 0\times2^4 + 0\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0 = 32 + 2 = 34_{10}$

6

Did you get this?

Decimal to binary conversion

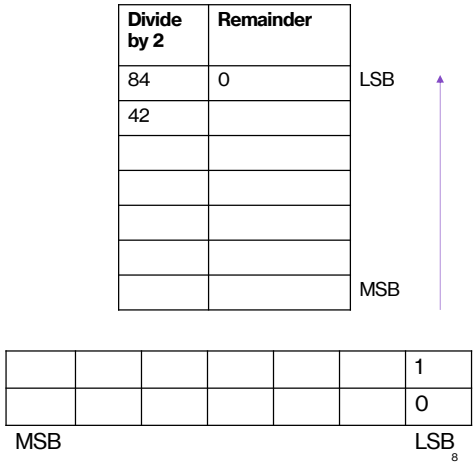
- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.



How do we go from decimal numbers to binary? We repeatedly divide the number by 2 and the remainder goes to each column from right to left. Let' see how we can convert the decimal number 84 to binary. We start by writing 84 and we divide it by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.



84/2 = 42 with a remainder of 0. So 0 goes in the 1s column. We next divide 42 by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.

Divide by 2	Remainder	
84	0	LSB
42	0	
21		
		MSB

					2	1
					0	0

MSB LSB

42/2 – 21 with a remainder of 0. So 0 goes to the 2s column. We next divide 21 by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.
  - $\frac{21}{2} = 10$ with a remainder of 1, so there is a 1 going to the 4s column.

Divide by 2	Remainder	
84	0	LSB
42	0	
21	1	
		MSB

				4	2	1
				1	0	0

MSB LSB

$_{10}$

21/2 = 10 with a remainder of 1. So 1 goes to the 4s column. We next divide 10 by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.
  - $\frac{21}{2} = 10$ with a remainder of 1, so there is a 1 going to the 4s column.
  - $\frac{10}{2} = 5$ with a remainder of 0, so there is a 0 in the 8's column.

Divide by 2	Remainder	
84	0	LSB
42	0	
21	1	
10	0	
5		
		MSB

			8	4	2	1
			0	1	0	0

MSB LSB

11

10/2 = 5 with a remainder of 0 so 0 goes to the 8s column and we next divide 5 by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.
  - $\frac{21}{2} = 10$ with a remainder of 1, so there is a 1 going to the 4s column.
  - $\frac{10}{2} = 5$ with a remainder of 0, so there is a 0 in the 8's column.
  - $\frac{5}{2} = 2$ with a remainder of 1, so there is a 1 going to the 16's column.

Divide by 2	Remainder	
84	0	LSB
42	0	
21	1	
10	0	
5	1	
2		
		MSB

		16	8	4	2	1
		1	0	1	0	0

MSB LSB

12

5/2=2 with a remainder of 1. So 1 goes to the 16s column. We next divide 2 by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.
  - $\frac{21}{2} = 10$ with a remainder of 1, so there is a 1 going to the 4s column.
  - $\frac{10}{2} = 5$ with a remainder of 0, so there is a 0 in the 8's column.
  - $\frac{5}{2} = 2$ with a remainder of 1, so there is a 1 going to the 16's column.
  - $\frac{2}{2} = 1$, with a remainder of 0, so 0 goes in the 32's column.

Divide by 2	Remainder	
84	0	LSB
42	0	
21	1	
10	0	
5	1	
2	0	
1		MSB

	32	16	8	4	2	1
	0	1	0	1	0	0

MSB LSB

13

2/2 = 1, with a remainder of 0. So 0 goes in the 32s column. We next divide 1 by 2.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.
  - $\frac{21}{2} = 10$ with a remainder of 1, so there is a 1 going to the 4s column.
  - $\frac{10}{2} = 5$ with a remainder of 0, so there is a 0 in the 8's column.
  - $\frac{5}{2} = 2$ with a remainder of 1, so there is a 1 going to the 16's column.
  - $\frac{2}{2} = 1$, with a remainder of 0, so 0 goes in the 32's column.
  - $\frac{1}{2} = 0$, with a remainder of 1, so 1 goes in the 64's column.

Divide by 2	Remainder	
84	0	LSB
42	0	
21	1	
10	0	
5	1	
2	0	
1	1	MSB

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

MSB LSB

14

½=0 with a remainder of 1, so 1 goes in the 64s column.

Decimal to binary conversion

- Repeatedly divide the number by 2. The remainder goes to each column, from right to left.
- Example: Convert the decimal number 84_{10} to binary.
  - $\frac{84}{2} = 42$ with a remainder of 0, so 0 goes in the 1's column.
  - $\frac{42}{2} = 21$ with a remainder of 0, so 0 goes in the 2's column.
  - $\frac{21}{2} = 10$ with a remainder of 1, so there is a 1 going to the 4s column.
  - $\frac{10}{2} = 5$ with a remainder of 0, so there is a 0 in the 8's column.
  - $\frac{5}{2} = 2$ with a remainder of 1, so there is a 1 going to the 16's column.
  - $\frac{2}{2} = 1$, with a remainder of 0, so 0 goes in the 32's column.
  - $\frac{1}{2} = 0$, with a remainder of 1, so 1 goes in the 64's column.
- Putting this all together, $84_{10} = 1010100_2$.

Divide by 2	Remainder	
84	0	LSB
42	0	
21	1	
10	0	
5	1	
2	0	
1	1	MSB

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

MSB LSB

15

Putting this all together, $84_{10} = 1010100_2$.

PRACTICE TIME

- Convert the following decimal numbers to their binary representation.
  - 125_{10}
  - 339_{10}
  - 75_{10}

16

Practice converting the following decimal numbers to binary.

PRACTICE TIME - ANSWER

- Convert the following decimal numbers to their binary representation.
  - $125_{10} = 1111101_2$ $339_{10} = 101010011_2$ $75_{10} = 1001011_2$

Divide by 2	Remainder	
125	1	LSB
62	0	
31	1	
15	1	
7	1	
3	1	
1	1	MSB

Divide by 2	Remainder	
339	1	LSB
169	1	
84	0	
42	0	
21	1	
10	0	
5	1	
2	0	
1	1	MSB

Divide by 2	Remainder	
75	1	LSB
37	1	
18	0	
9	1	
4	0	
2	0	
1	1	MSB

17

This is what you should have gotten.

Hexadecimal numbers

- We also use a **hexadecimal** (or hex) notation where the arithmetic is base 16.
- Each digit is one of $0, 1, 2, 3, 4, 5, 6, 7, 8, 9, \mathrm{A}, \mathrm{B}, \mathrm{C}, \mathrm{D}, \mathrm{E}, \mathrm{F}$
  - (i.e. A for 10, B for 11, C for 12, D for 13, E for 14, and F for 15).
- $h_n h_{n-1} \ldots h_2 h_1 h_0$ represents the integer $h_n 16^n + h_{n-1} 16^{n-1} + \ldots + h_2 16^2 + h_1 16^1 + h_0 16^0$
- For example, the hex number $FACE_{16}$ can be written as:

$16^3 = 4096$	$16^2 = 256$	$16^1 = 16$	$16^0 = 1$
15	10	12	14

  - $15\times16^3 + 10\times16^2 + 12\times16^1 + 14\times16^0$
  - This is equal to the decimal representation $61440 + 2560 + 192 + 14 = 64206_{10}$
- An n-digit hex number is one of 16^n possibilities: $0, 1, 2, 3, \ldots, 16^n - 1$.
- Hex numbers are sometimes preceded by 0x to be distinguished from decimal numbers, e.g., 0x15 is 15_{16} which is equal to 21_{10} and not 15_{10}.

18

Writing long binary numbers can be both tedious and prone to errors. For this reason, computer scientists also like working in base 16 or with hexadecimal/hex notation (we saw that a group of 4 bits can represent 2^4=16 possibilities). Hexadecimal numbers use the digits 0 to 9 along with the letters A to F which are used for 10 to 15, respectively.

Equivalence across number systems

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

19

This table shows the first 16 numbers as represented in the three systems we have seen so far.

PRACTICE TIME

- Convert the following hexadecimal numbers to their decimal representation.
  - $32A_{16}$
  - $D1CE_{16}$
  - $1B7F_{16}$
  - 47_{16}

20

Let's practice by converting the hexadecimal numbers to decimal.

ANSWER

- Convert the following hexadecimal numbers to their decimal representation.
  - $32A_{16} = 3\times16^2 + 2\times16^1 + 10\times16^0 = 810_{10}$
  - $D1CE_{16} = 13\times16^3 + 1\times16^2 + 12\times16^1 + 14\times16^0 = 53710_{10}$
  - $1B7F_{16} = 1\times16^3 + 11\times16^2 + 7\times16^1 + 15\times16^0 = 7039_{10}$
  - $47_{16} = 4\times16^1 + 7\times16^0 = 71_{10}$

21

Is this what you got?

Decimal to hexadecimal conversion

- Similarly to converting from decimal to binary, we will now repeatedly divide by 16 and the remainder is converted to hexadecimal and goes to the corresponding column from right to left.
- Example: Convert the decimal number 333_{10} to hexadecimal.

Divide by 16	Remainder	
333		LSB
		MSB

22

Similarly to converting from decimal to binary, we will now repeatedly divide by 16 and the remainder is converted to hexadecimal and goes to the corresponding column from right to left.
Let's see an example of converting the decimal number 333 to hex. We start by dividing it by 16.

Decimal to hexadecimal conversion

- Similarly to converting from decimal to binary, we will now repeatedly divide by 16 and the remainder is converted to hexadecimal and goes to the corresponding column from right to left.
- Example: Convert the decimal number 333_{10} to hexadecimal.
  - $\frac{333}{16} = 20$ with a remainder of $13_{10} = D_{16}$ which goes in the 1's column.

Divide by 16	Remainder	
333	$13_{10} = D_{16}$	LSB
20		
		MSB

		1
		D

23

333/16=20 with a remainder of 13 (in decimal) or D in hex. So we put D in the 1s column. We next divide 20 by 16.

Decimal to hexadecimal conversion

- Similarly to converting from decimal to binary, we will now repeatedly divide by 16 and the remainder is converted to hexadecimal and goes to the corresponding column from right to left.
- Example: Convert the decimal number 333_{10} to hexadecimal.
  - $\frac{333}{16} = 20$ with a remainder of $13_{10} = D_{16}$ which goes in the 1's column.
  - $\frac{20}{16} = 1$ with a remainder of 4, so 4 goes in the 16's column.

Divide by 16	Remainder	
333	$13_{10} = D_{16}$	LSB
20	$4_{10} = 4_{16}$	
1		MSB

	16	1
	4	D

24

20/16= 1 with a remainder of 4 (same in decimal and hex), so 4 goes in the 16's column. We next divide 1 by 16.

Decimal to hexadecimal conversion

- Similarly to converting from decimal to binary, we will now repeatedly divide by 16 and the remainder is converted to hexadecimal and goes to the corresponding column from right to left.
- Example: Convert the decimal number 333_{10} to hexadecimal.
  - $\frac{333}{16} = 20$ with a remainder of $13_{10} = D_{16}$ which goes in the 1's column.
  - $\frac{20}{16} = 1$ with a remainder of 4, so 4 goes in the 16's column.
  - $\frac{1}{16} = 0$ with a remainder of 1, so there is a 1 going to the 256s column.

Divide by 16	Remainder	
333	$13_{10} = D_{16}$	LSB
20	$4_{10} = 4_{16}$	
1	$1_{10} = 1_{16}$	MSB

256	16	1
1	4	D

25

$\frac{1}{16} = 0$ with a remainder of 1 (same in decimal and hex), so there is a 1 going to the 256s column.

Decimal to hexadecimal conversion

- Similarly to converting from decimal to binary, we will now repeatedly divide by 16 and the remainder is converted to hexadecimal and goes to the corresponding column from right to left.
- Example: Convert the decimal number 333_{10} to hexadecimal.
  - $\frac{333}{16} = 20$ with a remainder of $13_{10} = D_{16}$ which goes in the 1's column.
  - $\frac{20}{16} = 1$ with a remainder of 4, so 4 goes in the 16's column.
  - $\frac{1}{16} = 0$ with a remainder of 1, so there is a 1 going to the 256s column.
  - Putting this all together, $333_{10} = 14D_{16}$.

Divide by 16	Remainder	
333	$13_{10} = D_{16}$	LSB
20	$4_{10} = 4_{16}$	
1	$1_{10} = 1_{16}$	MSB

256	16	1
1	4	D

26

Putting this all together, $333_{10} = 14D_{16}$.

PRACTICE TIME

- Convert the following decimal numbers to their hexadecimal representation.
  - 2546_{10}
  - 1457_{10}
  - 269_{10}
  - 47_{10}

27

Let's practice by converting the following decimal numbers to their hex representation.

ANSWER

- Convert the following decimal numbers to their hexadecimal representation.
  - $2546_{10} = 9F2$ $1457_{10} = 5B1$ $269_{10} = 10D$ $47_{10} = 2F$

Divide by 16	Remainder
2546	$2_{10} = 2_{16}$
159	$15_{10} = F_{16}$
9	$9_{10} = 9_{16}$

Divide by 16	Remainder
1457	$1_{10} = 1_{16}$
91	$11_{10} = B_{16}$
5	$5_{10} = 5_{16}$

Divide by 16	Remainder
269	$13_{10} = D_{16}$
16	$0_{10} = 0_{16}$
1	$1_{10} = 1_{16}$

Divide by 16	Remainder	
47	$15_{10} = F_{16}$	LSB
2	$2_{10} = 2_{16}$	MSB

28

Is this what you got?

Binary to hexadecimal conversion

- We read the binary digits in groups of four and convert each group to its corresponding hexadecimal number. If needed, prepend leading 0s to make the number of bits a multiple of 4.
- Example: Convert the binary number 110011100010000_2 to its hexadecimal representation.
  - Prepend a 0 to turn the number of digits to 16 (4 blocks of 4), i.e. we need to convert $0110\ 0111\ 0001\ 0000_2$
  - $0110_2 = 6_{16}$
  - $0111_2 = 7_{16}$
  - $0001_2 = 1_{16}$
  - $0000_2 = 0_{16}$
  - Putting this all together, $110011100010000_2 = 6710_{16}$.

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

29

To convert from binary to hex, we read the binary digits in groups of four and convert each group to its corresponding hexadecimal number. If needed, prepend leading 0s to make the number of bits a multiple of 4.

PRACTICE TIME

- Convert the following binary numbers to their hexadecimal representation.
  - 10010011_2
  - 101100110101_2
  - 11111011101110010_2

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

30

Can you give it a try?

ANSWER

- Convert the following binary numbers to their hexadecimal representation.
  - $1001\ 0011_2 = 93_{16}$
  - $1011\ 0011\ 0101_2 = B35_{16}$
  - $11111011101110010_2 = 0001\ 1111\ 0111\ 0111\ 0010 = 1F772_{16}$

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

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Hexadecimal to binary conversion

- We replace each hex digit with the four binary bits that correspond to its value.
- Example: Convert the hexadecimal number $CAFE_{16}$ to its binary representation.
  - $C_{16} = 1100_2$
  - $A_{16} = 1010_2$
  - $F_{16} = 1111_2$
  - $E_{16} = 1110_2$
  - Putting this all together, $CAFE_{16} = 1100101011111110_2$.

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

32

To go from hex to binary, we replace each hex digit with the four binary bits that correspond to its value.

PRACTICE TIME

- Convert the following hexadecimal numbers to their binary representation.
  - $\mathrm{F00D}_{16}$
  - $2B3BAD_{16}$
  - $\mathrm{DEADC0DE}_{16}$

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

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Let's try it

ANSWER

- Convert the following hexadecimal numbers to their binary representation.
  - $\mathrm{F00D}_{16} = 1111000000001101_2$
  - $2B3BAD_{16} = 00101011001110111010110 1_2$
  - $\mathrm{DEADC0DE}_{16} = 11011110101011011110000001101111 0_2$

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

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Fun, huh?

Practice Problem

- For each row, fill in the missing entries by converting the given number from its representation to every other equivalent representation.

Binary	Decimal	Hexadecimal
	39_{10}	
100111010_2		
		$BADE_{16}$
	47_{10}	
101100111_2		
		$C0FFEE_{16}$

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Practice Problem - ANSWER

- For each row, fill in the missing entries by converting the given number from its representation to every other equivalent representation.

Binary	Decimal	Hexadecimal
100111_2	39_{10}	27_{16}
100111010_2	314_{10}	$13A_{16}$
1011101011011110_2	47838_{10}	$BADE_{16}$
101111_2	47_{10}	$2F_{16}$
101100111_2	359_{10}	167_{16}
$11000000111111111101110_2$	12648430_{10}	$C0FFEE_{16}$