Denary, Binary, Hexadecimal System

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Introduction

The binary and hexadecimal system are the ‘language’ of computers and with which programs and information are encoded. Understanding this, helps us understand how computers work.

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INTRODUCTION

Types of number- or ‘language’-
systems in computers

TYPES OF NUMBER SYSTEM

There are three types of number system that we'll explain and two of which are used in computers:

- Denary
- Binary
- Hexadecimal

Denary is the number system we use. Binary and hexadecimal are used in computers, and you've actually seen them before-explained in the 'Application' section. Over the next 3 slides we'll brief over each one.

Denary system

The denary number system is a base-10 number system, meaning that each position have a power of ten. In other words, each place value -remember kindergarten- has a power of 10. Like for the number 219:

As you can see, each position have a value of a power of 10.

The denary system use 10 ‘symbols’ to represent all values, these are 0-9.

10^2=100	10^1= 10	10^0= 1
200	10	9

Binary System

The binary number system is a base-2 number system, meaning each position -or place value- has a power of 2. Look at the binary number: 10010.

Why these headings? When we learn how to convert binary to denary, it will make sense. For now, it gives the binary number its value.

Also notice that binary numbers only have 2 ‘symbols’: 1 and 0. The binary number system only uses 2 ‘symbols’ to represent all values.

Binary numbers are primarily used in computers, as computers use ‘switches’ in an ON or OFF position (1 for ON and 0 for OFF) to store information and solve problems. Plus, it makes technology easier to manipulate

A binary digit or a bit is the basic unit of computer storage. 4 bits make a ‘nibble’ and 8 bits make a byte.

2^4=16	2^3=8	2^2= 4	2^1=2	2^0=1
1	0	0	1	0

Hexadecimal System

The hexadecimal system is a base-16 system. Each position-or place value- has a power of 16. It uses 16 different 'symbols' to represent all values: 0- F. Wait... F?!

The table at the next slide show what these symbols represent in denary and binary. Don't memorise: in the next section, we'll see how to convert between binary and hexadecimal. Let's look at hex 21F9 to see the powers:

If you see the table, you'll notice that, 4 bits- or nibble- represent a single hex digit. Why? We'll explore the answer in the application section.

16^4= 65536	16^3= 4096	16^2= 256	16^0= 1
2	1	F	9

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

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CONVERSION

How to convert between number systems

Convert denary to binary: Method 1

There are two methods to convert denary to binary. Let's use the number 53:

Method 1:

2^8= 256	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) List out powers of 2- starting from power of 0:
2) Subtract the highest value of a power of 2-closest to 53- from 53. 32 (2^5) is the highest power of 2 next to 53. So 53-32= 21. Do this until you reach zero.

   53-32=21 . The next highest value of a power of 2 closest to 21 is 16 (2^4) so:

   21-16= 5. The next highest value of a power of 2 closest to 5 is 4 so:

   5-4= 1. The next highest value of a power of 2 is 1 so:

   1-1 =0.

Method 1: Continued

3) Now, we highlight the power of 2 we used and note their position

4) We'll place 1's were the highlighted powers are and 0's were there is no highlight so:

000110101 is binary of 53

2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1
0	0	0	1	1	0	1	0	1

To check, we add the values of the power of 2 where 1's are:

32+16+4+ 1 = 53! We are correct!

2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1

Example 2: Number 165

So, to convert all we have to do is find the values of power of 2 in a number and put ones in their place values. Let's internalize it with another example with number 165

2^8= 256	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) List out powers of 2 and their values:
2) Subtract the highest value of the powers of 2 closest to 165 until you reach zero:
- 128 is closest to 165 so: 165-128= 37.
- 32 is closest to 37 so: 37-32 = 5
- 4 is closest to 5 so: 5-4 = 1
- 1 is closest to 1 so: 1-1 =0
3) Highlight the powers we used and add 1's to their positions and put 0's for the powers that we didn't use. The binary of 165 is 010100101. To check, add values where the 1's are placed: 128+ 32+ 4+ 1 = 165. We are correct!

2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1
0	1	0	1	0	0	1	0	1

Method 2: Division

Instead of subtracting, we can divide instead. Let's use 53 again:

1) List out powers of 2 and their values
2) Divide 53 with 2 . Put 1 for answers with remainders and ignore the decimal and move on with the whole number and 0 if the answers have no remainders until zero is reached

- 53/2 = 26.5 Remainder 1
- 26/2 = 13 No remainder 0
- 13/2 = 6.5 Remainder 1
- 6/2 = 3 No remainder 0
- 3/2 = 1.5 Remainder 1
- ½ =0.5 Remainder 1 STOP!

3) To get the answer write the binary number from BOTTOM to TOP so: 110101. To check the answer find the sum of the value of the power of two in the position it's in:

32+16+4+1 = 53. Also, if we compare it with the first method it's the same!

2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1
0	0	0	1	1	0	1	0	1

Example 2: Number 208

1) Divide 208 by 2 until you get 0. Put 0 for no remainders and 1 for answers with remainders. Ignore remainders and move on with the whole number
- 208/2 = 104 No remainder 0
- 104/2= 52   No remainder 0
- 52/2 = 26   No remainder   0
- 26/2 = 13 No remainder   0
- 13/2 = 6.5 Remainder   1
- 6/2 = 3 No remainder 0
- 3/2 = 1.5 Remainder 1
- 1 / 2 = 0.5 Remainder 1 STOP

2) To get the binary number write from BOTTOM TO TOP : 11010000. To check, add the values of the powers of 2 where 1 is. 128+64+16= 208 We are correct!

2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1
0	1	1	0	1	0	0	0	0

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If you have noticed..

Method 1 is useful for small numbers and method 2 is effective with big numbers. Plus, you've already learned how to change binary to denary! As a recap how....

Convert binary to denary

	2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1
1010101	0	0	1	0	1	0	1	0	1

1) Draw a table of the powers of 2 and its values and align the binary along with the place value
2) Add the values of the power of 2, where there are 1's : 64+16+4+1= 85
3) The denary is 85!

100010

1) Draw a table of the powers of 2 and align the binary along the place values
2) Add the values of the power of 2 where the 1's are: 32+2 = 34
3) The denary is 34

2^8= 256	2^7=128	2^6=64	2^5=32	2^4=16	2^3=8	2^2=4	2^1=2	2^0=1
0	0	0	1	0	0	0	1	0

Convert denary to hexadecimal

56

1) Divide the number by 16 until you get to 0. Note the remainder and remove the decimal and take the whole number to continue dividing.
2) Multiply the remainder with 16 and convert it to hex with the table in slide 11

   56/16= 3.5 Remainder: 0.5   16*0.5=8   HEx: 8

   3/16=0.1875   Remainder: 0.1875   16*0.1875 = 3 Hex:3 (You obviously need a calculator)

3) Write the hex value from BOTTOM to TOP: 38 is the hex value of 56

Convert hex to denary (to check)

16^1=16	16^0= 1
3	8

To check, you have to convert hex to denary. So the hex value 38:

1) Place the hex value with the position of the powers of 16 with their values:
2) Multiply the values of the power of 16 with the hex digit in their position and add them:

(1*8) +(3*16) = 8+ 48 = 56

3) So our hex digit is correct!

Example 2: Convert denary to hex

216

1) Divide the number from 16. Multiply remainders by 16 and convert it by hex. Take the whole numbers to use to continue dividing, till you reach 0
   - 216/16 = 13.5 Remainder = 0.5   16*0.5=6   Hex = 8
   - 13/16= 0.8125   Remainder = 0.8125   16*0.8125 = 13   hex=D
2) Write the hex numbers from BOTTOM to TOP: D8
3) The hex is D8

Hex to denary

F68

1) Place the hex digit with the position of the powers of 16
2) Multiply the hex digit with the value of the powers of 16 in its position and add them. F is 15 to denary

(8*1)+ (16*6)+(15*256)= 8+96+3840=3944

The denary is 3944

16^2=256	16^1=16	16^0= 1
F	6	8

Binary to hexadecimal

Binary to hexadecimal is VERY easy

10010001

1) Group the byte into a group of 4 bits from right to left: 1001 0001
2) Convert each nibble into hex.

   1001= 5 (denary)= 5(hex

   0001=1 (denary = 1 (hex)

3) The hex value is 51

Binary to hexadecimal

111101110

1) Group the byte into 4 bits from right to left : 111101111. There's an extra bit. Just add zeros to make it a nibble: 000111101111.
2) Convert each nibble into hex:

   0001= 1 (denary)= 1(hex)

   1110=14 (denary)=E (hex)

   1111= 15 (denary) = F(hex)

3) Write the hex number in order with the nibble: 1EF

Hexadecimal to binary

This is also really easy:

45B

1) Take each hex digit and convert it to binary:

   4= 4 (denary)= 0100

   5= 5 (denary)= 0101

   B= 11(denary)= 1011

2) The binary value is 010001011011

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APPLICATION

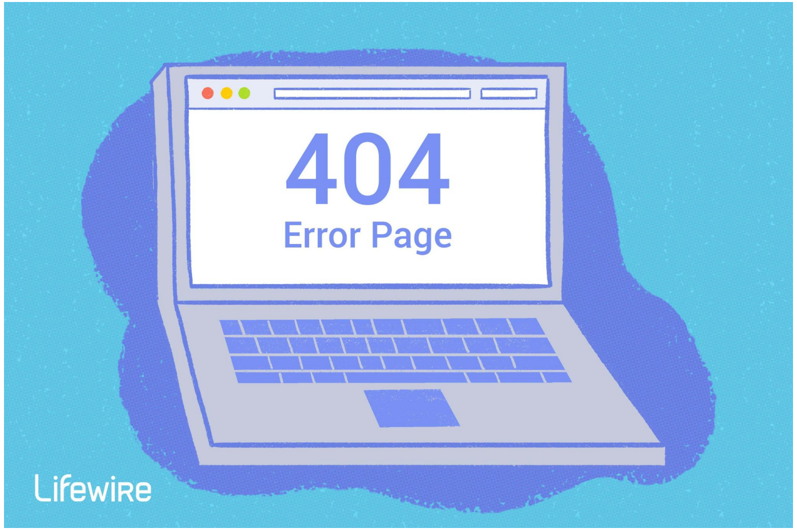
The use of the hexadecimal system

Why the hexadecimal system?

Although computers don't store info in hexadecimal, they're useful to us. Remember how a nibble represent a hex digit? Well, the hexadecimal system enables us to represent binary in a short, concise form. They can be fitted in a screen and are useful to programmers and IT as hexadecimal is easy to memorize and interpret.

Error codes

Error codes include the memory location of errors in code and express the nature of an error. They are often shown in hexadecimal. You might have already seen one: the 404 error code. It means that the server of the website isn't found



MAC Address

MAC address stands for Media Access Control and is known as the physical address of any device. It is often a 48-bit address. In hexadecimal, its a 6 groups of 2 hew digits. Like: 00-14-29-B0-F9-D3. The first three groups is the identity number of the manufacturer -like Apple, hp, Samsung- and the last three groups is the serial number of the device. Since it's rarely changes, it can identify where the device is wherever it is in the globe

IP Address(v4 and v6)

IP Addresses are also known as logic address and they uniquely identify a device using the Internet. Version 4 is made up of 32 bits like 192.02.03 in denary. However version 6, is made out of 128-bits in hexadecimal like 2001:4B58:EF65:A001. In Ipv4, there is a point, while in IPv6 has a colon.

Ipv6 has been created to form more addresses as they are more devices especially in IoT(internet of things) and we have runned out of the 4.3 billion addresses in Ipv4.

HTML colour codes

HTML (Hypertext Markup Language) is a markup language that determines the presentation, processing and definitions of text including colors.
When choosing colours in a hex form it can appear like this- #FF5689. Each color has a red,blue and green component. A pair of hex digit in a colour code, determines the intensity of each color component.
#FF0000 - is red
#00FF00 is blue
#0000FF is green.
The first pair represent the red, the second pair blue, and third pair green.

Operations with binary numbers

For some additional knowledge, check out this video on how addition of binary numbers take place:
https://www.youtube.com/watch?v=C5EkxfNEMjE

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TEST

Test your knowledge on this topic! A calculator is helpful

Convert from denary to binary

1) 12
2) 78
3) 180
4) 90
5) 100

Write your answers in an 8-bit form like (00001111)

Convert from binary to denary

1) 01101010
2) 00001100
3) 11111100
4) 00011111
5) 10100101

Convert from binary to hex

1) 011110001
2) 011010101
3) 01111000001
4) 101010101000
5) 11110111011110

Convert hex to denary

1) 2AF
2) E1
3) 51
4) 78
5) 4B5

Questions

1) What is a ‘bit’
2) Why do you think programmers like working with hexadecimal numbers?
3) Why do computers use the binary number system
4) Describe 3 uses of the hexadecimal system
5) Describe the difference between IP address v4 and IP address v6.

No answers for this one!

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Answers

Don’t peek unless you’ve attempted all the questions!

Convert denary to binary-answers

1) 12 - 00001100
2) 78 - 00100111
3) 180-10110100
4) 90-01011010
5) 100-01100100

Convert binary to denary-answers

1) 01101010- 106
2) 00001100- 12
3) 11111100- 248
4) 00011111-31
5) 10100101-164

Convert binary to hex-answers

1) 011110001- 71
2) 011010101- 0D5
3) 01111000001-3C1
4) 101010101000- AA8
5) 11110111011110- 3DDE

Convert hex to denary- answers

1) 2AF- 687
2) E1- 225
3) 51- 81
4) 78- 120
5) 4B5- 1205

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Thank you!

I hope this sparks your curiosity and knowledge on computers and its inner workings!