NUMERIC SYSTEMS USED IN NETWORKING

Decimal - Binary - Hexadecimal Table

Decimal	Binary	Hexadecimal
0	00000000	00
1	00000001	01
2	00000010	02
3	00000011	03
4	00000100	04
5	00000101	05
6	00000110	06
7	00000111	07
8	00001000	08
9	00001001	09
10	00001010	0A
11	00001011	0B
12	00001100	0C
13	00001101	0D
14	00001110	0E
15	00001111	0F
16	00010000	10
32	00100000	20
64	01000000	40
128	10000000	80
255	11111111	FF

ASCII Code

Keyboard	Binary Codes
A	01000001
B	01000010
C	01000011
D	01000100
E	01000101
F	01000110
G	01000111
H	01001000

128	64	32	16	8	4	2	1

The Letter A

0	1	0	0	0	0	0	1

Data Units

Units	Definition	Bytes*	Bits*	Examples
Bit (b)	Binary digit,a 1 or 0	1	1	On/Off; Open/Closed +5 Volts or 0 Volts
Byte (B)	8 bits	1	8	Represent the letter "X" as ASCII code
Kilobyte (KB)	1 kilobyte = 1024 bytes	1000	8,000	Typical Email = 2 KB 10-page report = 10 KB Early PCs = 64 KB of RAM
Megabyte (MB)	1 megabyte = 1024 kilobytes = 1,048,576 bytes	1 million	8 million	Floppy disks = 1.44 MBTypical RAM = 32 MBCDROM = 650 MB
Gigabyte (GB)	1 gigabyte = 1024 megabytes = 1,073741,824 bytes	1 billion	8 billion	Typical Hard Drive = 40 GB or greater
Terabyte (TB)	1 terabyte = 1024 gigabytes = 1,099,511,627,778 bytes	1 trillion	8 trillion	Amount of data theoreti-cally transmittable in optical fiber in one second

* Common or approximate bytes or bits

Base 10 Numbering System

Place Value	1000 100 10 1
Base$^{\text{Exponent}}$	$10^3 = 1000$ $10^2 = 100$ $10^1 = 10$ $10^0 = 1$
Number of Symbols	10
Symbols	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Rationale	Typical number of fingers equals ten

Base 2 Numbering System

Place Value	128 64 32 16 8 4 2 1
Base$^{\text{Exponent}}$	$2^7 = 128$ $2^3 = 8$ $2^6 = 64$ $2^2 = 4$ $2^5 = 32$ $2^1 = 2$ $2^4 = 16$ $2^0 = 1$
Number of Symbols	2
Symbols	0, 1
Rationale	Two-state (discrete binary) voltage systems made from transistors can be diverse, powerful, inexpensive, tiny and relatively immune to noise.

Decimal to Binary Conversion

128	64	32	16	8	4	2	1

Number	Divide	Result	Remainder
192	**/ 2 =**	96	0
96	**/ 2 =**	48	0
48	**/ 2 =**	24	0
24	**/ 2 =**	12	0
12	**/ 2 =**	6	0
6	**/ 2 =**	3	0
3	**/ 2 =**	1	1
1	**/ 2 =**	0	1

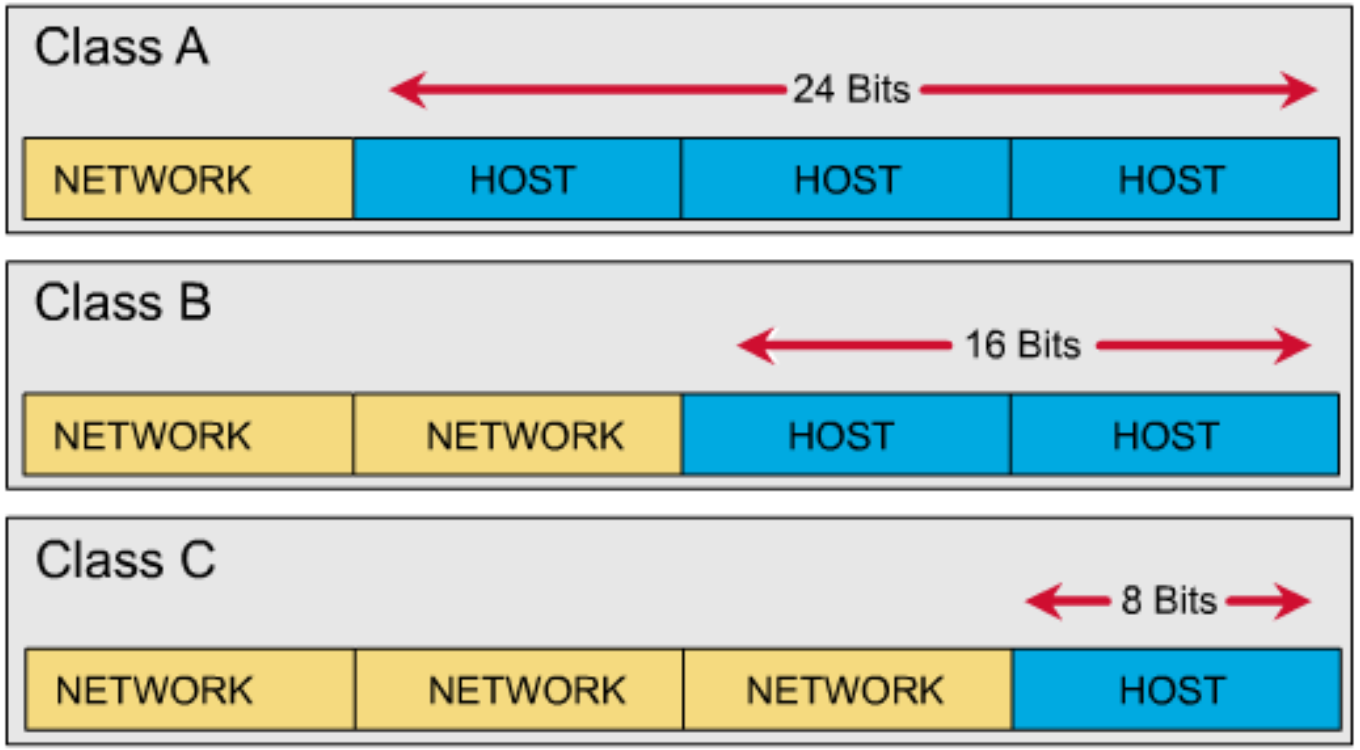
Binary to Decimal Conversion

128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0
1	0	0	1	1	0	0	1
1	1	1	1	1	1	1	1

Dotted Decimal Notation

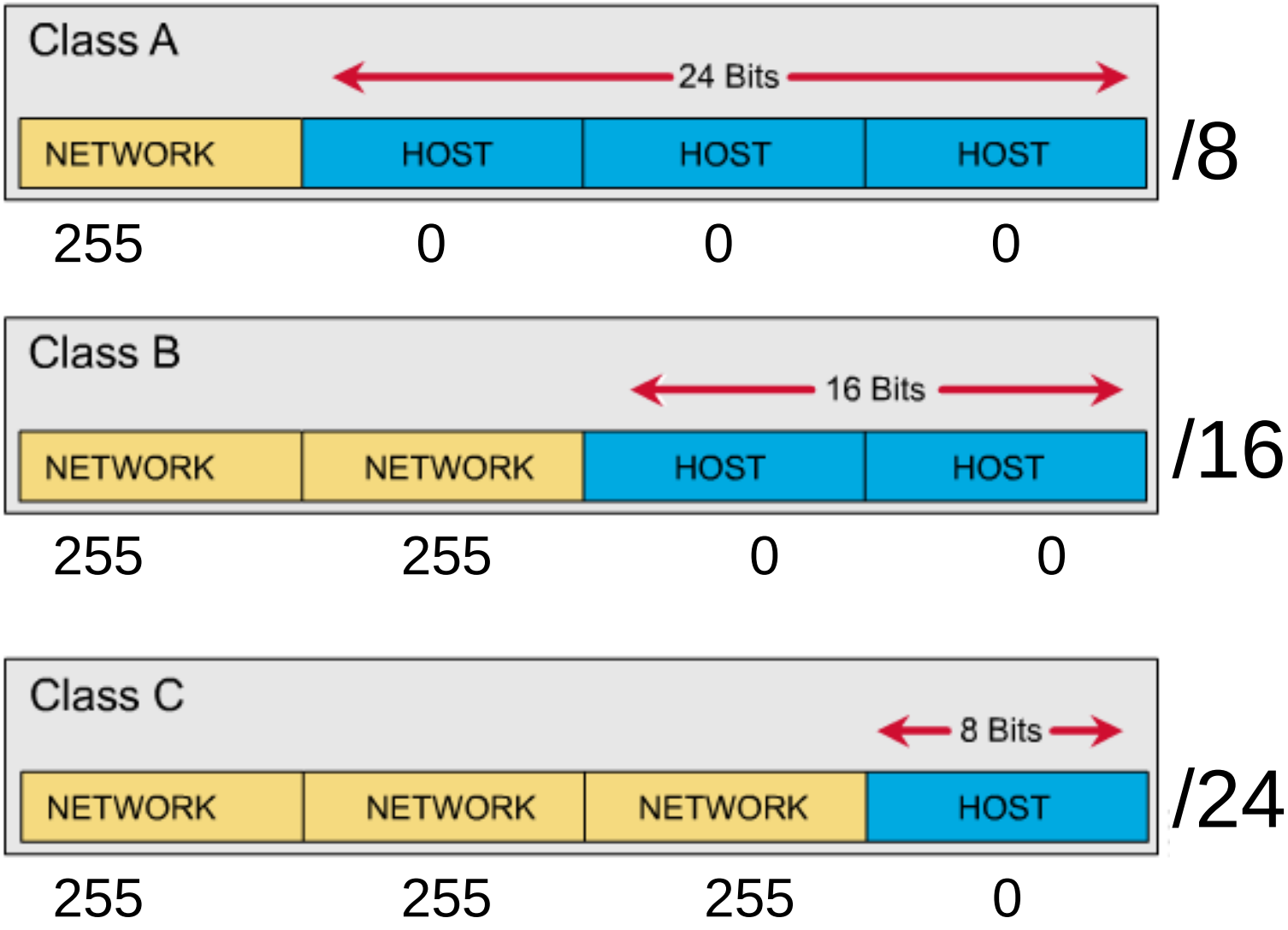
Binary	11001000		01110010		00000110		00110011
Decimal	200	.	114	.	6	.	51
	number	dot	number	dot	number	dot	number

IP Address Classes



Class "C" is the final commercial class of addresses. With eight bits for the host address, only two hundred fifty four hosts are allowed. Most smaller organizations use a class "C" or several class "C" addresses. As you'll see later, two addresses are always reserved: one for the network, and one for the broadcast address.

IP Address Classes

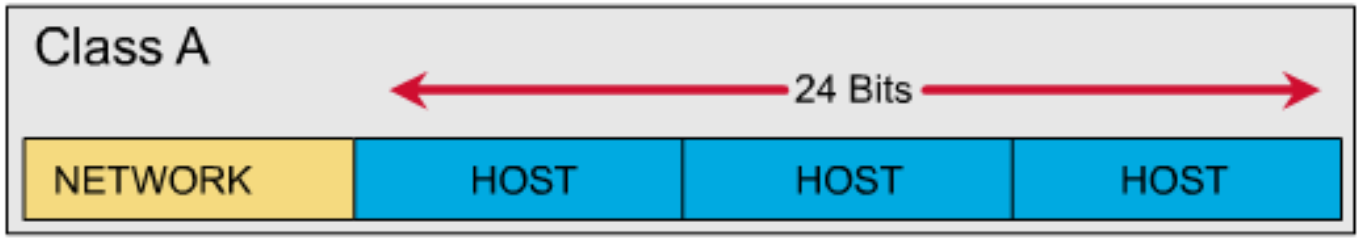


Address Classes

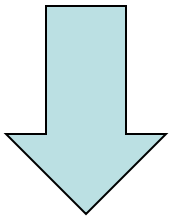
Cls	1st Octet Decimal Range	1st Octet High Order Bits	Network / Host ID (N=Network, H=Host)	Default Subnet Mask	Number of Networks	Hosts per Network (usable addresses)
A	1 – 126*	0	N.H.H.H	255.0.0.0	126 ($2^7 - 2$)	16,777,214 ($2^{24} - 2$)
B	128 – 191	1 0	N.N.H.H	255.255.0.0	16,382 ($2^{14} - 2$)	65,534 ($2^{16} - 2$)
C	192 – 223	1 1 0	N.N.N.H	255.255.255.0	2,097,150 ($2^{21} - 2$)	254 ($2^8 - 2$)
D	224 – 239	1 1 1 0	Reserved for Multicasting			
E	240 – 254	1 1 1 1 0	Experimental, used for research			

Binary to Decimal Conversion

IP Address Classes

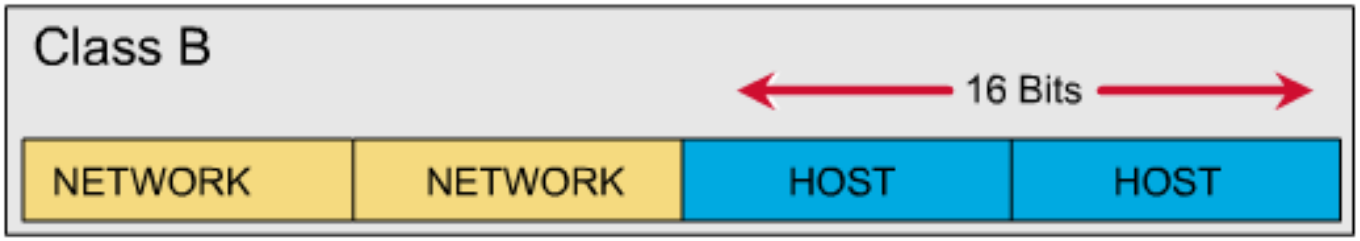


126.10.15.0



128	64	32	16	8	4	2	1
0	1	1	1	1	1	1	1

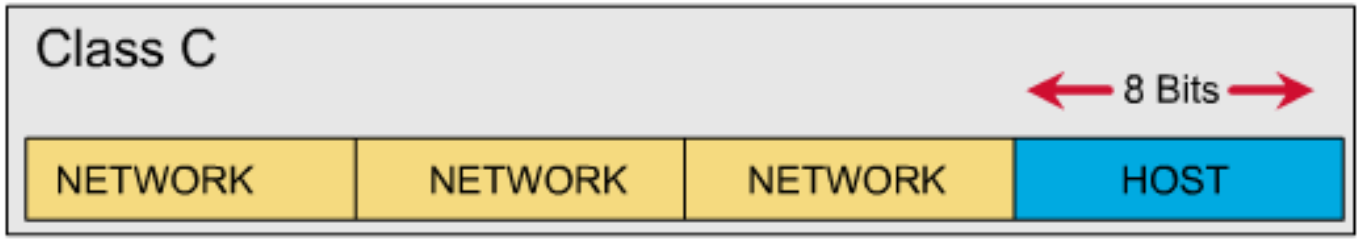
Binary to Decimal Conversion



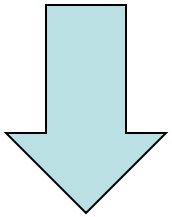
171.10.15.0

128	64	32	16	8	4	2	1
1	0	1	0	1	0	1	1

Binary to Decimal Conversion



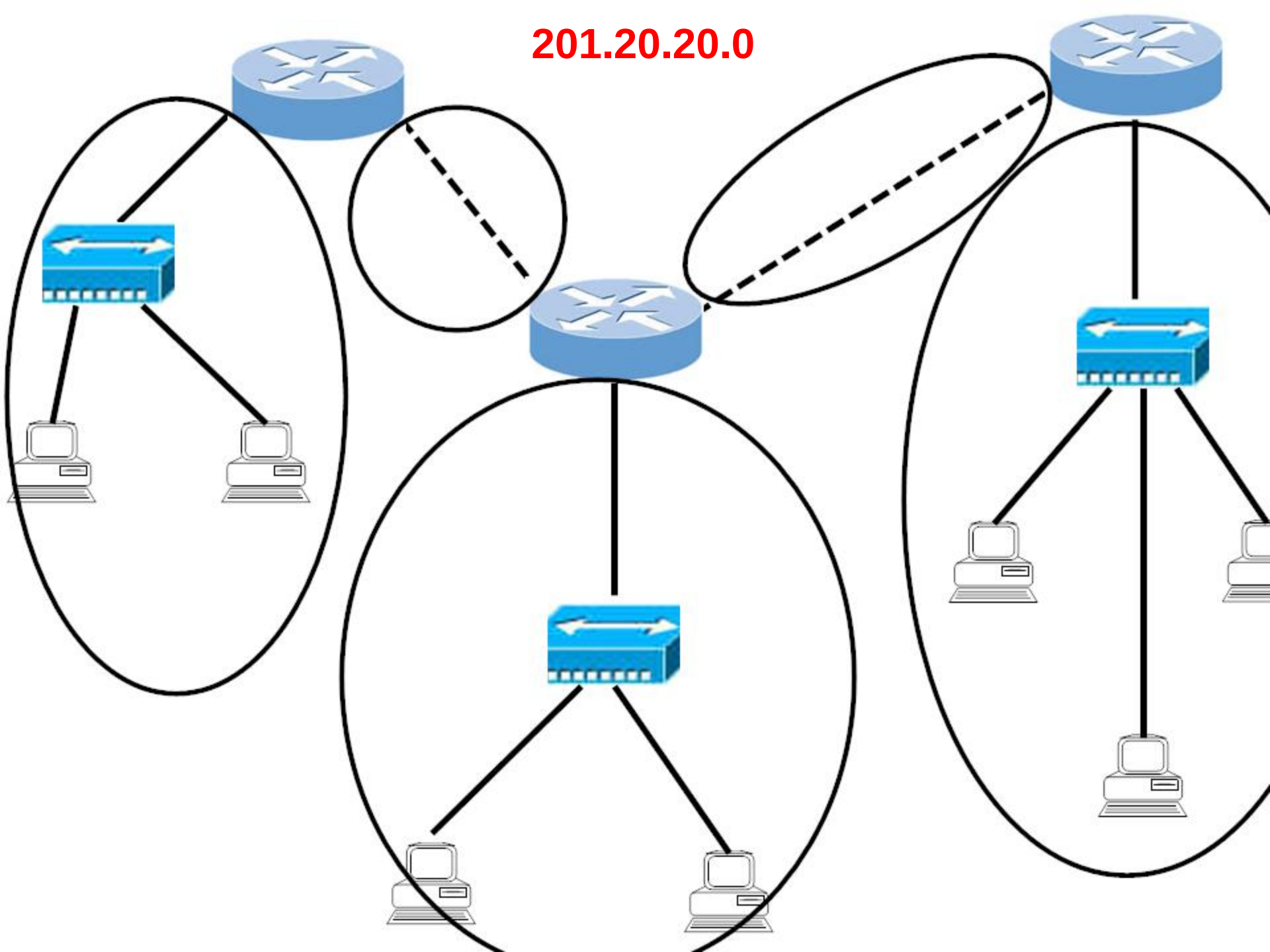
192.10.15.0



128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0

IP First Octet Address Ranges

High Order Bits	Octet in Decimal	Address Class
0	0 - 127	A
10	128 - 191	B
110	192 - 223	C

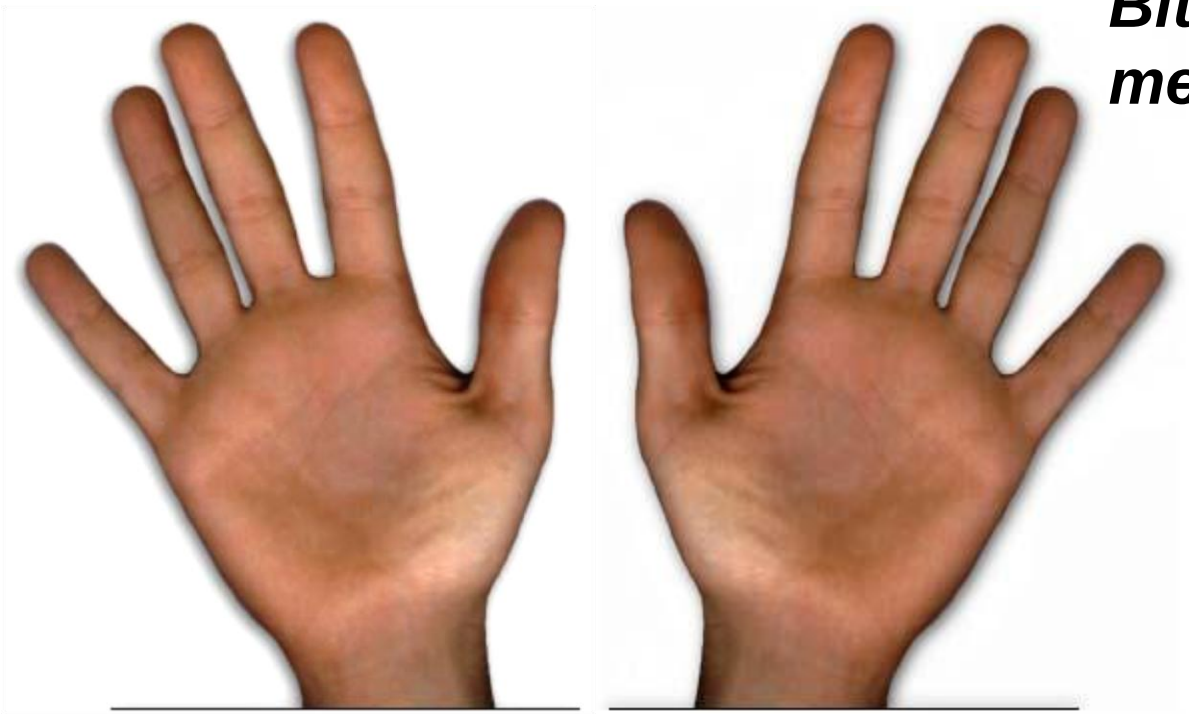

201.20.20.0

What class address	
How many subnets do you need	
How many bits do you have to borrow	
Add the bits you borrowed to find the subnet mask 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1	
How many bits are left for host addresses	
Count host bits to find number of hosts **per subnet** 128 64 32 16 8 4 2	

11111111.11111111.11111111.000**00000/27**

SUBNET MASK 255.255.255.224

Borrowing 3 Bits will give me 8 subnets

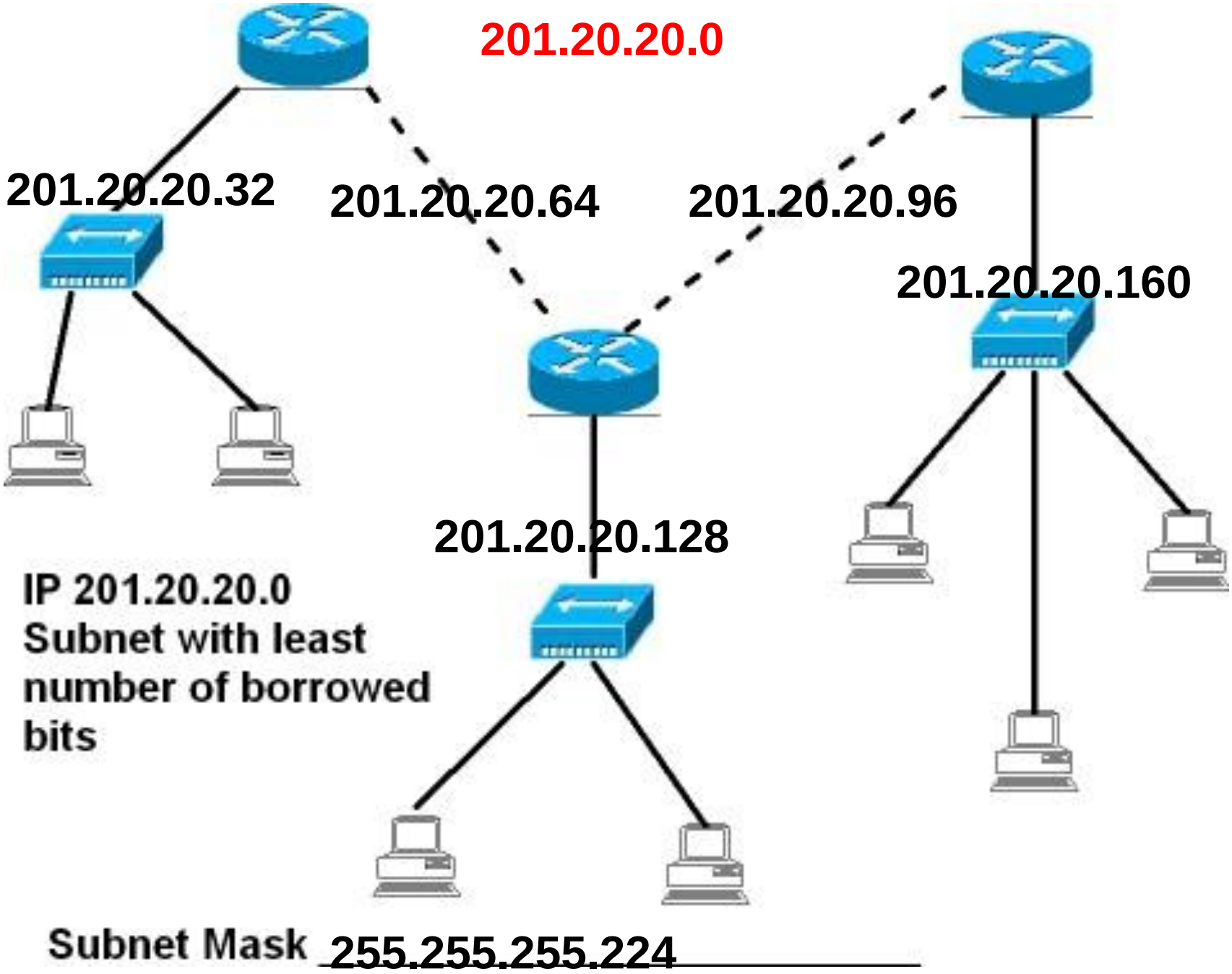


YOU MUST BORROW AT LEAST 2 BITS

YOU MUST LEAVE AT LEAST 2 BITS

YOU MUST BORROW 2 MORE BITS THAN YOU NEED

	SUBNET ADDR	BROADCAST ADDR
Range of first subnet (can't use)	0	
First Usable Subnet		
Second Usable subnet		
Third Usable subnet		
etc		


201.20.20.0
201.20.20.32
201.20.20.64
201.20.20.96
201.20.20.160
201.20.20.128
IP 201.20.20.0
Subnet with least number of borrowed bits
Subnet Mask 255.255.255.224

CLASS B SUBNETTING

You have an address of 185.15.0.0
You need 250 networks
You need 250 hosts

11111111.11111111.00000000.00000000/24

SUBNET 0	SUBNET 1	SUBNET 2
185.15.0.0	185.15.1.0	185.15.2.0
185.15.0.1	185.15.1.1	185.15.2.1
185.15.0.2	185.15.1.2	185.15.2.2
185.15.0.3	185.15.1.3	185.15.2.3
185.15.0.1	185.15.1.4	185.15.2.1
185.15.0.5	185.15.1.5	185.15.2.5
185.15.0.~ 255	185.15.1.~ 255	185.15.2.~ 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 60 subnets
You need at least 1000 hosts

11111111.11111111.11111100.00000000/22

Subnet 0
185.15.0.0 to 255
185.15.1.0 to 255
185.15.2.0 to 255
185.15.3.0 to 255

Subnet 1
185.15.4.0 to 255
185.15.5.0 to 255
185.15.6.0 to 255
185.15.7.0 to 255

Subnet 2
185.15.8.0 to 255
185.15.9.0 to 255
185.15.10.0 to 255
185.15.11.0 to 255

Subnet 3
185.15.12.0 to 255
185.15.13.0 to 255
185.15.14.0 to 255
185.15.15.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 30 subnets
You need at least 2000 hosts

11111111.11111111.11111000.00000000/21

Subnet 0	Subnet 1	Subnet 2
185.15.0.0 to 255	185.15.8.0 to 255	185.15.16.0 to 255
185.15.1.0 to 255	185.15.9.0 to 255	185.15.17.0 to 255
185.15.2.0 to 255	185.15.10.0 to 255	185.15.18.0 to 255
185.15.3.0 to 255	185.15.11.0 to 255	185.15.190 to 255
185.15.4.0 to 255	185.15.12.0 to 255	185.15.20.0 to 255
185.15.5.0 to 255	185.15.130 to 255	185.15.21.0 to 255
185.15.6.0 to 255	185.15.14.0 to 255	185.15.22.0 to 255
185.15.7.0 to 255	185.15.15.0 to 255	185.15.23.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000**/20**

Subnet 0
185.15.0.0 to 255
185.15.1.0 to 255
185.15.2.0 to 255
185.15.3.0 to 255
185.15.4.0 to 255
185.15.5.0 to 255
185.15.6.0 to 255
185.15.7.0 to 255

Subnet 0
185.15.8.0 to 255
185.15.9.0 to 255
185.15.10.0 to 255
185.15.11.0 to 255
185.15.12.0 to 255
185.15.130 to 255
185.15.14.0 to 255
185.15.15.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000/20

Subnet 1
185.15.16.0 to 255
185.15.17.0 to 255
185.15.18.0 to 255
185.15.19.0 to 255
185.15.20.0 to 255
185.15.21.0 to 255
185.15.22.0 to 255
185.15.23.0 to 255

Subnet 1
185.15.24.0 to 255
185.15.25.0 to 255
185.15.26.0 to 255
185.15.27.0 to 255
185.15.28.0 to 255
185.15.29.0 to 255
185.15.30.0 to 255
185.15.31.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000/20

Subnet 2	
185.15.32.0	to 255
185.15.33.0	to 255
185.15.34.0	to 255
185.15.35.0	to 255
185.15.36.0	to 255
185.15.37.0	to 255
185.15.38.0	to 255
185.15.39.0	to 255

Subnet 2	
185.15.40.0	to 255
185.15.41.0	to 255
185.15.42.0	to 255
185.15.43.0	to 255
185.15.44.0	to 255
185.15.45.0	to 255
185.15.46.0	to 255
185.15.47.0	to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need 250 networks
You need 250 hosts

11111111.11111111.00000000.00000000/24

SUBNET 0	SUBNET 1	SUBNET 2
185.15.0.0	185.15.1.0	185.15.2.0
185.15.0.1	185.15.1.1	185.15.2.1
185.15.0.2	185.15.1.2	185.15.2.2
185.15.0.3	185.15.1.3	185.15.2.3
185.15.0.1	185.15.1.4	185.15.2.1
185.15.0.5	185.15.1.5	185.15.2.5
185.15.0.~ 255	185.15.1.~ 255	185.15.2.~ 255

The last address will be 185.15.255.255

HEXIDECIMAL

Binary and Hexadecimal System

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

Only need 4 Hex positions:

4096 256 16 1

Converting Binary to Hexadecimal

Converting Binary Number to Hexadecimal Number

100100100010111110111110111001001

Converts to:

0001 0010 0100 0101 1111 0111 1101 1100 1001

Converts to:

1 2 4 5 F 7 D C 9

So:

100100100010111110111110111001001 binary

= 1245F7DC9 hexadecimal

Converting Hexadecimal Number to Binary Number

0x2102

Converts to:

2	1	0	2
0010	0001	0000	0010

So:

2102 hexadecimal converts to: 0010 0001 0000 0010 binary

Base 16 (Hexadecimal) System

Place Value	4096's 256's 16's 1's
Base Exponent	$16^3 = 4096$ $16^2 = 256$ $16^1 = 16$ $16^0 = 1$
Number of Symbols	16
Symbols	0, 1, 2, 3, 4, 5, 6, 7, 8, 9 A(=10), B(=11), C(=12), D(=13), E(=14), F(=15)
Rationale	Useful for computer engineering and programming purposes.

Hexadecimal is a *Base 16* numbering system

Hexadecimal is a *Base 16* numbering system that is used to represent MAC addresses.

It is referred to as Base 16 because it uses sixteen symbols;

combinations of these symbols can then represent all possible numbers.

Since there are only ten symbols that represent digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9), and the Base 16 requires six more symbols,

the extra symbols are the letters A, B, C, D, E, and F.

The position of each symbol, or digit, in a hex number represents the base number 16 raised to a power, or exponent, based on its position.

Moving from right to left, the first position represents 16^0, or 1;

the second position represents 16^1, or 16;

the third position, 16^2, or 256; and so on.

Example:
$4F6A = (4 \times 16^{3)} + (F[15] \times 16^{2)} + (6 \times 16^{1)} + (A[10] \times 16^0) =$ 20330 (decimal)

Example:

4F6A =

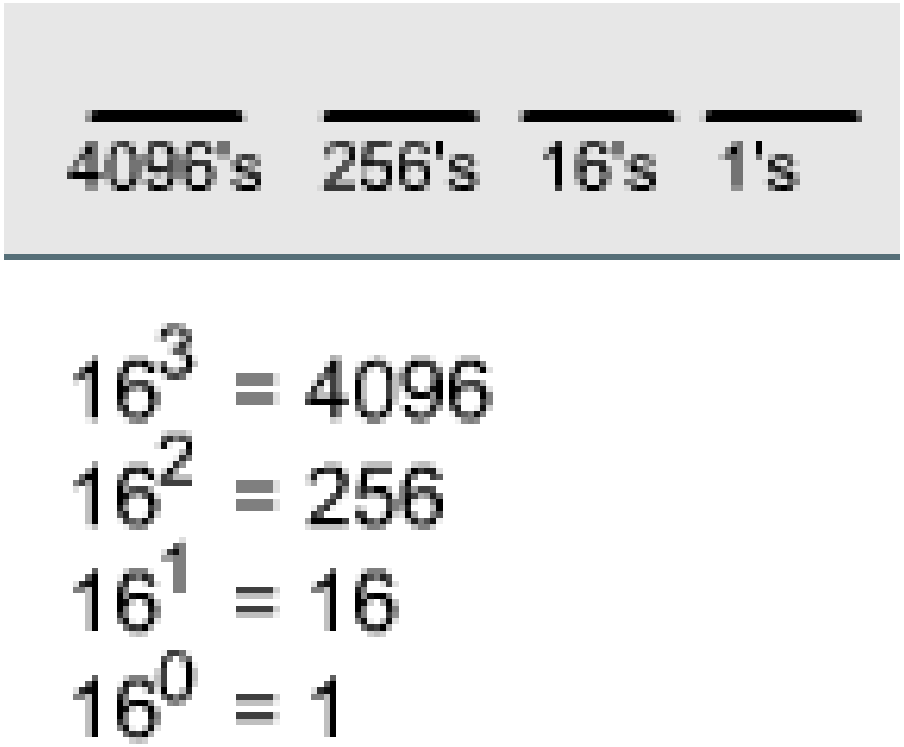
(4 x $16^{3)}$

+ (F[15] x $16^{2)}$

+ (6 x $16^{1)}$

+ (A[10] x 16^{0})

= 20330 (decimal)



Convert the decimal number 24032 to hex.

24032/16= 1502, with a remainder of 0

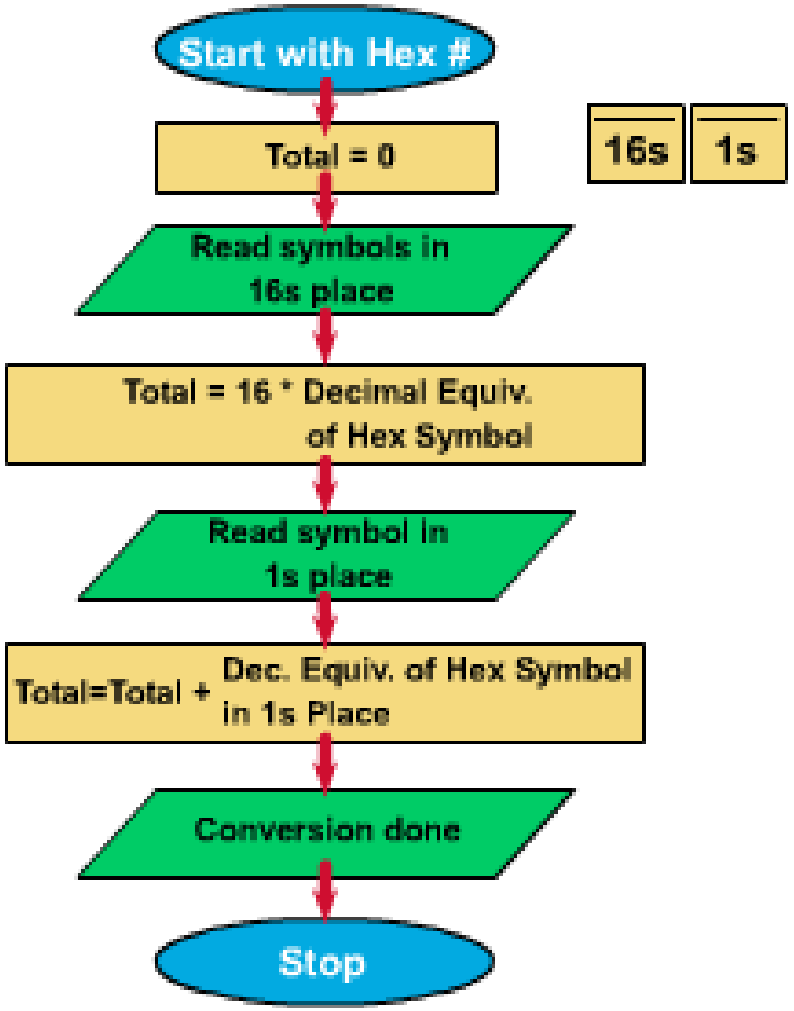
1502/16=93, with a remainder of 14 or E

93/16=5, with a remainder of 13 or D

5/16=0, with a remainder of 5

By collecting all the remainders backward, you have the hex number 5DE0.

Two Digit Hex to Decimal Conversion Algorithm



Decimal	Hex
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F

Convert hex 3F4B to a Decimal

(Work right to left)

3*	4096	=12288
F*	256	=3840
4*	16	=64
B*	1	=11
		=16203

Dec	Bin	Hex
0	00000000	00
1	00000001	01
2	00000010	02
3	00000011	03
4	00000100	04
5	00000101	05
6	00000110	06
7	00000111	01
8	00001000	08
9	00001001	09
10	00001010	0A
11	00001011	0B
12	00001100	0C
13	00001101	0D
14	00001110	0E
15	00001111	0F
16	00010000	10
32	00100000	20
64	01000000	40
128	10000000	80
255	11111111	FF

$15*16^1 = 240$

$15*16^0 = 15$

$= 255$

In this course,

the largest decimal number you have to deal with is 255;

the longest binary number you have to deal with is 8 bits (11111111); and

the largest hexadecimal number is 2 hex digits (FF

Mini Lab Assignment

- **Break into your groups**
- **Your group leader will assign each student a hex number and a decimal number**
- **Each student will go to the board and convert the hex number to decimal, and**
- **The decimal number to hex**
- **Use the white boards in the class to perform your calculations**