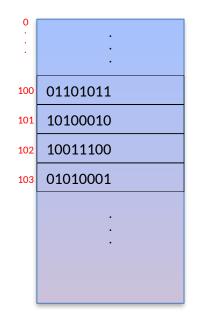# Positional Number Systems

Digital Data

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

0	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

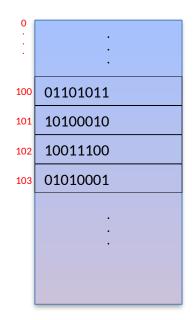# Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

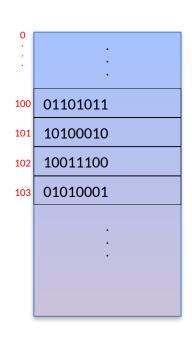|	
0 . . .	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers

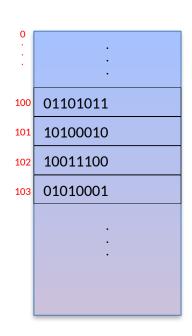|	
0	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary

0	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
    - Numbers: Represented in binary
    - Text

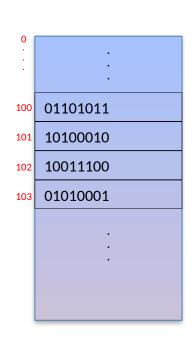|	
0	⋮
⋮	⋮
⋮	⋮
100	01101011
101	10100010
102	10011100
103	01010001
	⋮
	⋮
	⋮

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text
  - Images

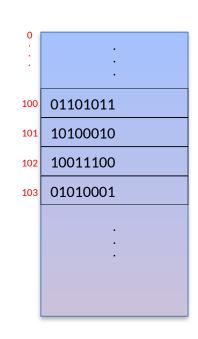|	
0	⋮
100	01101011
101	10100010
102	10011100
103	01010001
	⋮

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text
  - Images

  - Video

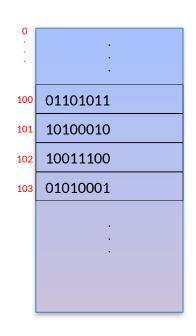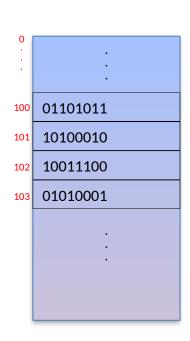|	
0	
:	:
:	:
100	01101011
101	10100010
102	10011100
103	01010001
	:
	:
	:

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text
  - Images

  - Video
  - Audio

0	. . .
	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

72

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

72 101

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

72 101

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124		
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

72 101 108 108

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124	|
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	[backspace]

Hello World!

72 101 108 108 111 32 87 111 114 108 100 33

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text
  - Images

  - Video
  - Audio

0	⋮
	⋮
100	01101011
101	10100010
102	10011100
103	01010001
	⋮

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text: Each character is mapped to a number
  - Images

  - Video
  - Audio

0	. . .
	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

Digital Data

Digital Data

(120, 100, 200)

Digital Data

(120, 100, 200)

(255, 0, 210)

Digital Data

(120, 100, 200)

(255, 0, 210)

(0, 130, 0)

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text: Each character is mapped to a number
  - Images

  - Video
  - Audio

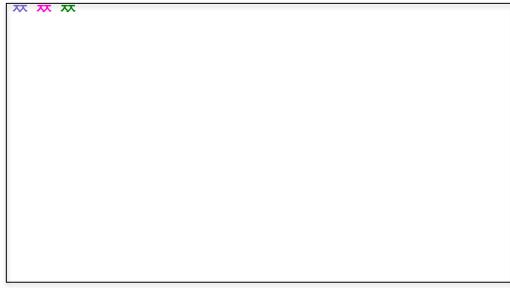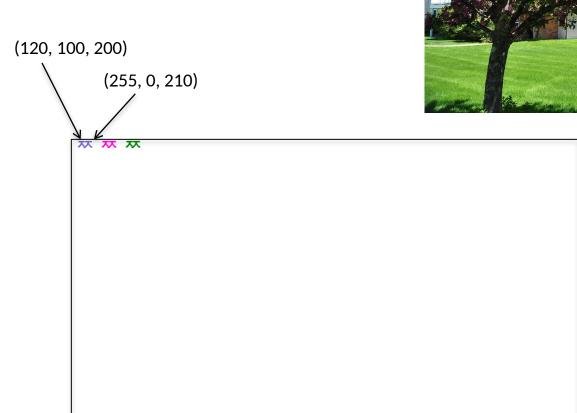|	
0	. . .
	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text: Each character is mapped to a number
  - Images: Matrix of pixels' colors. Each color is represented as (R,G,B) levels
  - Video
  - Audio

0	. . .
	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
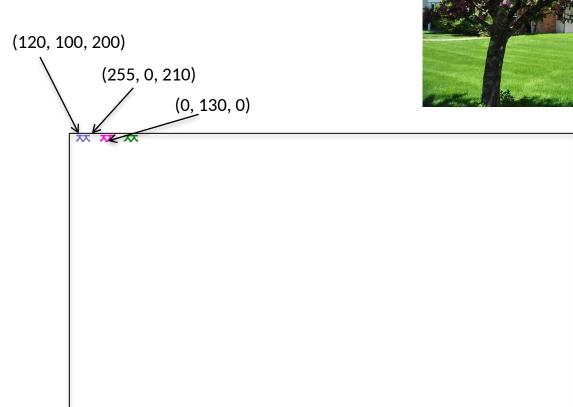 - Text: Each character is mapped to a number
  - Images: Matrix of pixels' colors. Each color is represented as (R,G,B) levels
  - Video: Sequence of images
  - Audio

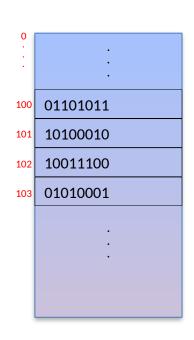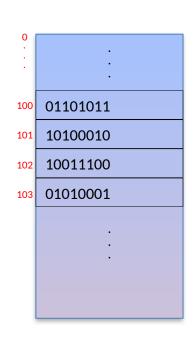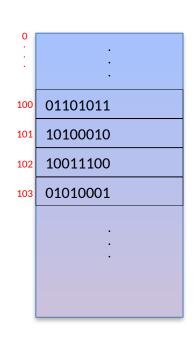| 0	. . .
	. . .
100	01101011
101	10100010
102	10011100
103	01010001
	. . .

Digital Data

- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers

- Kinds of data:
  - Numbers: Represented in binary
  - Text: Each character is mapped to a number
  - Images: Matrix of pixels' colors. Each color is represented as (R,G,B) levels
  - Video: Sequence of images
  - Audio: Sampled voltage levels

0	
100	01101011
101	10100010
102	10011100
103	01010001

Lets Count

Lets Count

Decimal (base 10)

Lets Count
Decimal (base 10)

0

Lets Count

Decimal (base 10)

0
1

Lets Count
Decimal (base 10)

0

1

2

Lets Count

Decimal (base 10)

0

1

2

3

Lets Count
Decimal (base 10)

0

1

2

3

4

5

6

7

8

9

Lets Count

Decimal (base 10)

0

1

2

3

4

5

6

7

8

9

10

Lets Count

Decimal (base 10)

0	11
1	12
2	...
3	19
4	
5	
6	
7	
8	
9	
10	

Lets Count

Decimal (base 10)

0	11
1	12
2	...
3	19
4	20
5	
6	
7	
8	
9	
10	

Lets Count
Decimal (base 10)

0	11
1	12
2	...
3	19
4	20
5	21
6	...
7	
8	
9	
10	

Lets Count

Decimal (base 10)

0	11
1	12
2	...
3	19
4	20
5	21
6	...
7	99
8	
9	
10	

Lets Count
Decimal (base 10)

0	11
1	12
2	...
3	19
4	20
5	21
6	...
7	99
8	100
9	
10	

Lets Count

Decimal (base 10)

0	11
1	12
2	...
3	19
4	20
5	21
6	...
7	99
8	100
9	101
10	...

Lets Count

Decimal (base 10)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

0	11
1	12
2	…
3	19
4	20
5	21
6	…
7	99
8	100
9	101
10	…

Lets Count

base 5

Lets Count

base 5

0

Lets Count

base 5

0
1

Lets Count

base 5

0

1

2

Lets Count

base 5

0

1

2

3

Lets Count

base 5

0

1

2

3

4

Lets Count
base 5

0

1

2

3

4

10

Lets Count

base 5

0

1

2

3

4

10

11

12

13

14

Lets Count

base 5

0

1

2

3

4

10

11

12

13

14

20

Lets Count

base 5

0	21
1	22
2	...
3	
4	
10	
11	
12	
13	
14	
20	

Lets Count
base 5

0	21
1	22
2	...
3	
4	100
10	
11	
12	
13	
14	
20	

Lets Count
base 5

0	21
1	22
2	...
3	44
4	100
10	
11	
12	
13	
14	
20	

Lets Count
base 5

0	21
1	22
2	...
3	44
4	100
10	101
11	...
12	
13	
14	
20	

Lets Count

base 5

Digits: 0, 1, 2, 3, 4

0	21
1	22
2	...
3	44
4	100
10	101
11	...
12	
13	
14	
20	

Lets Count

Octal (base 8)

Lets Count

Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

Lets Count

Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0

Lets Count

Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0

1

Lets Count
Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0

1

2

3

4

5

6

7

Lets Count

Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0

1

2

3

4

5

6

7

10

Lets Count

Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0	13
1	14
2	15
3	16
4	17
5	
6	
7	
10	
11	
12	

Lets Count
Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0	13
1	14
2	15
3	16
4	17
5	20
6	
7	
10	
11	
12	

Lets Count
Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0	13
1	14
2	15
3	16
4	17
5	20
6	21
7	...
10	
11	
12	

Lets Count
Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0	13
1	14
2	15
3	16
4	17
5	20
6	21
7	...
10	
11	100
12	

Lets Count
Octal (base 8)

Digits: 0, 1, 2, 3, 4, 5, 6, 7

0	13
1	14
2	15
3	16
4	17
5	20
6	21
7	...
10	77
11	100
12	...

Lets Count

Binary (base 2)

Lets Count

Binary (base 2)

Digits: 0, 1

Lets Count

Binary (base 2)

Digits: 0, 1

0

Lets Count

Binary (base 2)

Digits: 0, 1

0

1

Lets Count
Binary (base 2)

Digits: 0, 1

0

1

10

Lets Count
Binary (base 2)

Digits: 0, 1

0

1

10

11

Lets Count

Binary (base 2)

Digits: 0, 1

0

1

10

11

100

Lets Count

Binary (base 2)

Digits: 0, 1

0

1

10

11

100

101

Lets Count
Binary (base 2)

Digits: 0, 1

0

1

10

11

100

101

110

Lets Count

Binary (base 2)

Digits: 0, 1

0

1

10

11

100

101

110

111

Lets Count
Binary (base 2)

Digits: 0, 1

0

1

10

11

100

101

110

111

1000

Lets Count

Binary (base 2)

Digits: 0, 1

0

1

10

11

100

101

110

111

1000

1001

Lets Count
Binary (base 2)

Digits: 0, 1

0

1

10

11

100

101

110

111

1000

1001

1010

...

Lets Count

Hexadecimal (base 16)

Lets Count
Hexadecimal (base 16)

0

Lets Count
Hexadecimal (base 16)

0
1

Lets Count

Hexadecimal (base 16)

0
1
2

Lets Count

Hexadecimal (base 16)

0   9

1

2

3

4

5

6

7

8

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0   9

1

2

3

4

5

6

7

8

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9
1	a
2	
3	
4	
5	
6	
7	
8	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9
1	a
2	b
3	
4	
5	
6	
7	
8	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9
1	a
2	b
3	c
4	d
5	e
6	f
7	
8	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9
1	a
2	b
3	c
4	d
5	e
6	f
7	10
8	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12
1	a	13
2	b	...
3	c	19
4	d	
5	e	
6	f	
7	10	
8	11	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12
1	a	13
2	b	...
3	c	19
4	d	1a
5	e	
6	f	
7	10	
8	11	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12
1	a	13
2	b	...
3	c	19
4	d	1a
5	e	1b
6	f	...
7	10	1f
8	11	

Lets Count
Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12
1	a	13
2	b	...
3	c	19
4	d	1a
5	e	1b
6	f	...
7	10	1f
8	11	20

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12	21
1	a	13	22
2	b	...	...
3	c	19	2f
4	d	1a	
5	e	1b	
6	f	...	
7	10	1f	
8	11	20	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12	21
1	a	13	22
2	b	...	...
3	c	19	2f
4	d	1a	30
5	e	1b	
6	f	...	
7	10	1f	
8	11	20	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12	21
1	a	13	22
2	b	...	...
3	c	19	2f
4	d	1a	30
5	e	1b	...
6	f	...	
7	10	1f	100
8	11	20	

Lets Count

Hexadecimal (base 16)

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

0	9	12	21
1	a	13	22
2	b	...	...
3	c	19	2f
4	d	1a	30
5	e	1b	...
6	f	...	ff
7	10	1f	100
8	11	20	...

Equivalent Representations

Equivalent Representations

13

Equivalent Representations

$(13)_{10}$

Equivalent Representations

$(13)_{10} = (\quad)_8$

Equivalent Representations

$(13)_{10} = (15)_8$

Equivalent Representations

$$(13)_{10} = (15)_8 = (\quad)_5$$

Equivalent Representations

$$(13)_{10} = (15)_8 = (23)_5$$

Equivalent Representations

$$(13)_{10} = (15)_8 = (23)_5 = (\qquad)_2$$

Equivalent Representations

$$(13)_{10} = (15)_8 = (23)_5 = (1101)_2$$

Equivalent Representations

$$(13)_{10} = (15)_8 = (23)_5 = (1101)_2 = (\quad)_{16}$$

Equivalent Representations

$$(13)_{10} = (15)_8 = (23)_5 = (1101)_2 = (d)_{16}$$

Equivalent Representations

$$(13)_{10} = (15)_8 = (23)_5 = (1101)_2 = (d)_{16}$$

Representation of number N in base b_1 → Representation of number N in base b_2

Base Conversions

Base Conversions

(i) N in base b ⟶ N in decimal

Base Conversions

(i) N in base b $\longrightarrow$ N in decimal

(ii) N in decimal $\longrightarrow$ N in base b

Base Conversions

(i) N in base b ⟶ N in decimal

(ii) N in decimal ⟶ N in base b

(i) base b → decimal

$(3\ 7\ 5)_{10}$

$(3\ 7\ 5)_{10}$

$(3\ 7\ \underset{1}{5})_{10}$

$(3\ 7\ 5)_{10}$

$(3\,7\,5)_{10}$

$\underbrace{}_{10}\;\underbrace{}_{1}$

$(3\ 7\ 5)_{10}$

10 1

$(3 \ 7 \ 5)_{10}$

100   10   1

$$(3\ 7\ 5)_{10}$$

100 10 1

||

10^2

$$(3 \ 7 \ 5)_{10}$$

100 10 1

|| ||

10^2 10^1

$(3\ 7\ 5)_{10}$

$\begin{array}{ccc} 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array}$

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0$$

100   10   1
|| || ||
10^2 10^1 10^0

$$(3\,7\,5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1$$

100   10   1
|| || ||
10^2 10^1 10^0

(i) base b → decimal

$$(3\,7\,5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2$$

$$\underbrace{100}_{10^2} \quad \underbrace{10}_{10^1} \quad \underbrace{1}_{10^0}$$

$$(3\,7\,5)_{10} = 5\cdot10^0 + 7\cdot10^1 + 3\cdot10^2 = 375$$

100 10 1

|| || ||

10^2 10^1 10^0

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\underbrace{3}_{\substack{100 \\ || \\ 10^2}}\ \underbrace{7}_{\substack{10 \\ || \\ 10^1}}\ \underbrace{5}_{\substack{1 \\ || \\ 10^0}}$$

$$(1\ 2\ 5)_8$$

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1

|| || ||

10^2 10^1 10^0

$$(1\ 2\ 5)_8$$

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100 10 1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8$$

1

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100   10   1
|| || ||
10^2 10^1 10^0

$(1\ 2\ 5)_8$

1

$$(3\,7\,5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1

10^2 10^1 10^0

$$(1\,2\,5)_8$$

8   1

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8$$

8   1

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1

|| || ||

10^2 10^1 10^0

$$(1\ 2\ 5)_8$$

64   8   1

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100   10   1

|| || ||

10^2 10^1 10^0

$(1\ 2\ 5)_8$

64   8   1

||

8^2

$$(3\,7\,5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100 10 1
|| || ||
10^2 10^1 10^0

$$(1\,2\,5)_8$$

64 8 1
|| || ||
8^2 8^1 8^0

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1

10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2$$

64   8   1

8^2 8^1 8^0

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100 10 1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

64 8 1
|| || ||
8^2 8^1 8^0

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

64   8   1
|| || ||
8^2 8^1 8^0

$$(1\ 0\ 1\ 1)_2$$

$(3\,7\,5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100 10 1
|| || ||
10^2 10^1 10^0

$(1\,2\,5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64 8 1
|| || ||
8^2 8^1 8^0

$(1\,0\,1\,1)_2$

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100 10 1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

64 8 1
|| || ||
8^2 8^1 8^0

$$(1\ 0\ 1\ 1)_2$$

1

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100   10   1
|| || ||
10^2 10^1 10^0

$(1\ 2\ 5)_{8} = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64   8   1
|| || ||
8^2 8^1 8^0

$(1\ 0\ 1\ 1)_{2}$

2   1

$(3\,7\,5)_{10} = 5{\cdot}10^0 + 7{\cdot}10^1 + 3{\cdot}10^2 = 375$

100　10　1
||　||　||
10^2　10^1　10^0

$(1\,2\,5)_8 = 5{\cdot}8^0 + 2{\cdot}8^1 + 1{\cdot}8^2 = 85$

64　8　1
||　||　||
8^2　8^1　8^0

$(1\,0\,1\,1)_2$

4　2　1

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100   10   1
|| || ||
10^2 10^1 10^0

$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64   8   1
|| || ||
8^2 8^1 8^0

$(1\ 0\ 1\ 1)_2$

8   4   2   1

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100	10	1
$\|\|$	$\|\|$	$\|\|$
10^2	10^1	10^0

$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64	8	1
$\|\|$	$\|\|$	$\|\|$
8^2	8^1	8^0

$(1\ 0\ 1\ 1)_2$

8	4	2	1
$\|\|$	$\|\|$	$\|\|$	$\|\|$
2^3	2^2	2^1	2^0

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100 10 1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

64 8 1
|| || ||
8^2 8^1 8^0

$$(1\ 0\ 1\ 1)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3$$

8 4 2 1
|| || || ||
2^3 2^2 2^1 2^0

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

64   8   1
|| || ||
8^2 8^1 8^0

$$(1\ 0\ 1\ 1)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

8   4   2   1
|| || || ||
2^3 2^2 2^1 2^0

(i) base b → decimal

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100   10   1

10^2 10^1 10^0

$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64   8   1

8^2 8^1 8^0

$(1\ 0\ 1\ 1)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$

8   4   2   1

2^3 2^2 2^1 2^0

$(3\ b\ 2)_{16}$

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100 10 1
10^2 10^1 10^0

$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64 8 1
8^2 8^1 8^0

$(1\ 0\ 1\ 1)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$

8 4 2 1
2^3 2^2 2^1 2^0

$(3\ b\ 2)_{16}$

$$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

100   10   1
|| || ||
10^2 10^1 10^0

$$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

64   8   1
|| || ||
8^2 8^1 8^0

$$(1\ 0\ 1\ 1)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

8   4   2   1
|| || || ||
2^3 2^2 2^1 2^0

$$(3\ b\ 2)_{16}$$

16^2 16^1 16^0

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100 10 1

10^2 10^1 10^0

$(1\ 2\ 5)_{8} = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64 8 1

8^2 8^1 8^0

$(1\ 0\ 1\ 1)_{2} = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$

8 4 2 1

2^3 2^2 2^1 2^0

$(3\ b\ 2)_{16} = 2 \cdot 16^0 + 11 \cdot 16^1 + 3 \cdot 16^2$

16^2 16^1 16^0

$(3\ 7\ 5)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$

100　10　1
10^2　10^1　10^0

$(1\ 2\ 5)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$

64　8　1
8^2　8^1　8^0

$(1\ 0\ 1\ 1)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$

8　4　2　1
2^3　2^2　2^1　2^0

$(3\ b\ 2)_{16} = 2 \cdot 16^0 + 11 \cdot 16^1 + 3 \cdot 16^2 = 946$

16^2　16^1　16^0

$(3\ 7\ 5)_{10} = 5{\cdot}10^0 + 7{\cdot}10^1 + 3{\cdot}10^2 = 375$

$$\underset{\substack{100 \\ || \\ 10^2}}{3} \quad \underset{\substack{10 \\ || \\ 10^1}}{7} \quad \underset{\substack{1 \\ || \\ 10^0}}{5}$$

$(1\ 2\ 5)_8 = 5{\cdot}8^0 + 2{\cdot}8^1 + 1{\cdot}8^2 = 85$

$$\underset{\substack{64 \\ || \\ 8^2}}{1} \quad \underset{\substack{8 \\ || \\ 8^1}}{2} \quad \underset{\substack{1 \\ || \\ 8^0}}{5}$$

$(1\ 0\ 1\ 1)_2 = 1{\cdot}2^0 + 1{\cdot}2^1 + 0{\cdot}2^2 + 1{\cdot}2^3 = 11$

$$\underset{\substack{8 \\ || \\ 2^3}}{1} \quad \underset{\substack{4 \\ || \\ 2^2}}{0} \quad \underset{\substack{2 \\ || \\ 2^1}}{1} \quad \underset{\substack{1 \\ || \\ 2^0}}{1}$$

$(3\ b\ 2)_{16} = 2{\cdot}16^0 + 11{\cdot}16^1 + 3{\cdot}16^2 = 946$

$$\underset{16^2}{3} \quad \underset{16^1}{b} \quad \underset{16^0}{2}$$

$(a_n \ldots a_2 a_1 a_0)_b = a_0{\cdot}b^0 + a_1{\cdot}b^1 + a_2{\cdot}b^2 + \ldots + a_n{\cdot}b^n$

Base Conversions

(i) N in base b $\longrightarrow$ N in decimal

(ii) N in decimal $\longrightarrow$ N in base b

Base Conversions

(i) N in base b $\longrightarrow$ N in decimal

(ii) N in decimal $\longrightarrow$ N in base b

(ii) decimal $\rightleftharpoons$ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

$$(75)_{10} = (\hspace{3cm})_2$$

… — — — — — — — — — — — —

$$(75)_{10} = (\qquad)_2$$

... — — — — — — — — — — —

2^0

$$(75)_{10} = (\qquad)_2$$

… — — — — — — — — — — — — —

2^1 $\quad$ 2^0

$(75)_{10} = ($ $)_2$

... — — — — — — — — — — — — —

2^2 2^1 2^0

$$(75)_{10} = (\qquad)_2$$

... —— —— —— —— —— —— —— —— —— ——

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

$$(75)_{10} = (\qquad)_2$$

... ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

2^9 $\quad$ 2^8 $\quad$ 2^7 $\quad$ 2^6 $\quad$ 2^5 $\quad$ 2^4 $\quad$ 2^3 $\quad$ 2^2 $\quad$ 2^1 $\quad$ 2^0

$||$

1

$$(75)_{10} = (\qquad)_2$$

... — — — — — — — — — — —

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

$$2^1 = 2 \qquad 2^0 = 1$$

$$(75)_{10} = (\qquad)_2$$

... | — | — | — | — | — | — | — | — | — | —
2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

$2^2 = 4$ $2^1 = 2$ $2^0 = 1$

$$(75)_{10} = (\qquad)_2$$

... ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

|| || || ||

8 4 2 1

$(75)_{10} = ($ $)_2$

... — — — — — — — — — —

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

                                       || || || || ||

                                   16   8   4   2   1

$(75)_{10} = ($ $\qquad)_2$

... ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

2^9 $\quad$ 2^8 $\quad$ 2^7 $\quad$ 2^6 $\quad$ 2^5 $\quad$ 2^4 $\quad$ 2^3 $\quad$ 2^2 $\quad$ 2^1 $\quad$ 2^0

$\qquad\qquad\qquad\qquad\quad ||\qquad ||\qquad ||\qquad ||\qquad ||\qquad ||$

$\qquad\qquad\qquad\qquad\quad 32\qquad 16\qquad 8\qquad 4\qquad 2\qquad 1$

$(75)_{10} = ($ $)_2$

... — — — — — — — — — —

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

|| || || || || || ||

64 32 16 8 4 2 1

$$(75)_{10} = (\qquad)_2$$

... — — — — — — — — — —

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

|| || || || || || || ||

128 64 32 16 8 4 2 1

$(75)_{10} = (\qquad)_2$

... —— —— —— —— —— —— —— —— —— ——

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

|| || || || || || || || ||

256 128 64 32 16 8 4 2 1

$$(75)_{10} = (\qquad)_2$$

... ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

| 2^9 | 2^8 | 2^7 | 2^6 | 2^5 | 2^4 | 2^3 | 2^2 | 2^1 | 2^0 |
| 512 | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

$$(75)_{10} = (\qquad\qquad)_2$$

?

... ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

|| || || || || || || || || ||

512   256   128   64   32   16   8   4   2   1

(ii) decimal ⇆ base b (demonstrated on b=2)

$(75)_{10} = ($ $)_2$

... ___ **1** ___ ___ ___ ___ ___ ___ ___ ___ ___

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
‖	‖	‖	‖	‖	‖	‖	‖	‖	‖
512	256	128	64	32	16	8	4	2	1

$$(75)_{10} = (\qquad)_2$$

?

... ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
||	||	||	||	||	||	||	||	||	||
512	256	128	64	32	16	8	4	2	1

$$(75)_{10} = (\qquad)_2$$

$$\dots \; \underline{\quad} \; \overset{0}{\underline{\quad}} \; \underline{\quad} \; \underline{\quad} \; \underline{\quad} \; \underline{\quad} \; \underline{\quad} \; \underline{\quad} \; \underline{\quad} \; \underline{\quad}$$

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
‖	‖	‖	‖	‖	‖	‖	‖	‖	‖
512	256	128	64	32	16	8	4	2	1

$$(75)_{10} = (\qquad\qquad)_2$$

...	0	0	0	__	__	__	__	__	__	__
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$
	512	256	128	64	32	16	8	4	2	1

$(75)_{10} = ($ $)_2$

	0	0	0							
...	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$
	512	256	128	64	32	16	8	4	2	1

75

$(75)_{10} = ($ \qquad $)_2$

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	0	—	—	—	—	—	—
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

75

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	0	1	1	1	1	1	1
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

75

$(75)_{10} = ($ $)_2$

	0	0	0	0	1	1	1	1	1	1
...	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

75

1 + 2 + 4 + 8 + 16 + 32 = 63

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	0	1	1	1	1	1	1
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

75

$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

$$1 + 2 + 4 + 8 + \ldots + 2^k =$$

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	0	1	1	1	1	1	1
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

75

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

$$(75)_{10} = (\qquad\qquad)_2$$

...	0	0	0	?	_	_	_	_	_	_
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

75

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	1	_	_	_	_	_	_
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

75

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

$$(75)_{10} = (\qquad)_2$$

... $\underline{\ 0\ }$ $\underline{\ 0\ }$ $\underline{\ 0\ }$ $\underline{\ 1\ }$ $\underline{\ \ }$ $\underline{\ \ }$ $\underline{\ \ }$ $\underline{\ \ }$ $\underline{\ \ }$ $\underline{\ \ }$

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
512	256	128	64	32	16	8	4	2	1

75

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

$$\begin{array}{r} 75 \\ -\ 64 \\ \hline 11 \end{array}$$

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	1	—	—	—	—	—	—
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

75
= 64
11

(ii) decimal → base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

0	0	0	1	0	_	_	_	_	_
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
||	||	||	||	||	||	||	||	||	||
512	256	128	64	32	16	8	4	2	1

11

$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

$$1 + 2 + 4 + 8 + \dots + 2^k = 2^{k+1} - 1$$

$$\begin{array}{r} 75 \\ \underline{-\ 64} \\ 11 \end{array}$$

(ii) decimal ⟷ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	1	0	0	__	__	__	__
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

$$\begin{array}{r} 75 \\ -\,64 \\ \hline 11 \end{array}$$

(ii) decimal ⇌ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

...	0	0	0	1	0	0	?	_	_	_
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

$$\begin{array}{r} 75 \\ - 64 \\ \hline 11 \end{array}$$

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad\qquad)_2$$

	...	0	0	0	1	0	0	0	__	__	__
		2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
		||	||	||	||	||	||	||	||	||	||
		512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

$$\begin{array}{r} 75 \\ -\ 64 \\ \hline 11 \end{array}$$

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad)_2$$

0	0	0	1	0	0	0	1	1	1
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
‖	‖	‖	‖	‖	‖	‖	‖	‖	‖
512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

$$\begin{array}{r} 75 \\ - 64 \\ \hline 11 \end{array}$$

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\quad\quad\quad)_2$$

...	0	0	0	1	0	0	?	_	_	_
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

75
- 64
11

$$(75)_{10} = (\qquad\qquad)_2$$

	0	0	0	1	0	0	1	__	__	__
...	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

75
− 64
11

(ii) decimal ⇌ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad\qquad)_2$$

0	0	0	1	0	0	1	_	_	_
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
||	||	||	||	||	||	||	||	||	||
512	256	128	64	32	16	8	4	2	1

11

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \dots + 2^k = 2^{k+1} - 1$

$$
\begin{array}{cc}
75 & 11 \\
\underline{-\ 64} & \underline{-\ 8} \\
11 & 3
\end{array}
$$

$$(75)_{10} = (\qquad\qquad)_2$$

...	0	0	0	1	0	0	1	__	__	__
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

3

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

```
 75        11
-64       - 8
 11         3
```

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad\qquad)_2$$

0	0	0	1	0	0	1	0	_	_
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
||	||	||	||	||	||	||	||	||	||
512	256	128	64	32	16	8	4	2	1

3

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

75	11
- 64	- 8
11	3

(ii) decimal ⇄ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad\qquad)_2$$

0	0	0	1	0	0	1	0	1	__
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
||	||	||	||	||	||	||	||	||	||
512	256	128	64	32	16	8	4	2	1

3

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \dots + 2^k = 2^{k+1} - 1$

$$\begin{array}{cc} 75 & 11 \\ \underline{-\,64} & \underline{-\,8} \\ 11 & 3 \end{array}$$

(ii) decimal ⇆ base b (demonstrated on b=2)

$$(75)_{10} = (\qquad\qquad)_2$$

...	0	0	0	1	0	0	1	0	1	__
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

3

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + ... + 2^k = 2^{k+1} - 1$

75	11	3
-64	-8	-2
11	3	1

$$(75)_{10} = (\qquad\qquad)_2$$

...	0	0	0	1	0	0	1	0	1	__
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	||	||	||	||	||	||	||	||	||	||
	512	256	128	64	32	16	8	4	2	1

1

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

75	11	3
÷ 64	÷ 8	÷ 2
11	3	1

$$(75)_{10} = (\qquad\qquad)_2$$

	0	0	0	1	0	0	1	0	1	1
...	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$	$\parallel$
	512	256	128	64	32	16	8	4	2	1

1

$1 + 2 + 4 + 8 + 16 + 32 = 63$

$1 + 2 + 4 + 8 + \ldots + 2^k = 2^{k+1} - 1$

75	11	3
- 64	- 8	- 2
11	3	1

$$(75)_{10} = (\qquad\qquad)_2$$

...	0	0	0	1	0	0	1	0	1	1
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

(ii) decimal → base b (demonstrated on b=2)

$$(75)_{10} = (1001011)_2$$

...	0	0	0	1	0	0	1	0	1	1
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$	$\|\|$
	512	256	128	64	32	16	8	4	2	1

$$(75)_{10} = (1001011)_2$$

0	0	0	1	0	0	1	0	1	1
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
||	||	||	||	||	||	||	||	||	||
512	256	128	64	32	16	8	4	2	1

Base Conversions

(i) N in base b ⟶ N in decimal

(ii) N in decimal ⟶ N in base b

Base Conversions

(i) N in base b $\longrightarrow$ N in decimal

(ii) N in decimal $\longrightarrow$ N in base b

(iii) N in binary $\longleftrightarrow$ N in hexadecimal

$$(3b9)_{16} = (\qquad\qquad)_2$$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary

$(3b9)_{16} = ($ $)_2$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
a	
b	
c	
d	
e	
f	

$(3b9)_{16} = ($ $)_2$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	
2	
3	
4	
5	
6	
7	
8	
9	
a	
b	
c	
d	
e	
f	

$(3b9)_{16} = ($ $)_2$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	
3	
4	
5	
6	
7	
8	
9	
a	
b	
c	
d	
e	
f	

$(3b9)_{16} = ($ $)_2$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	
4	
5	
6	
7	
8	
9	
a	
b	
c	
d	
e	
f	

$(3b9)_{16} = ($ $)_2$

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	0011
4	
5	
6	
7	
8	
9	
a	
b	
c	
d	
e	
f	

$$(3b9)_{16} = (\qquad\qquad)_2$$

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (\qquad\qquad)_2$$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

$(3b9)_{16} = ($ $)_2$

Hex Digit	4 bit binary
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

$(3b9)_{16} = ($ 1001 $)_2$

9

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (\quad 10111001)_2$$

b   9

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

$$\underbrace{0011}_{3}\;\underbrace{1011}_{b}\;\underbrace{1001}_{9}$$

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

3   b   9

$$(11011010011)_2 = (\quad)_{16}$$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (\underbrace{0011}_{3}\underbrace{1011}_{b}\underbrace{1001}_{9})_2$$

$$(\ 11011010011)_2 = (\qquad)_{16}$$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

3   b   9

$$(\ 11011010011)_2 = (\qquad)_{16}$$

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

$$\quad\quad 3 \quad\quad b \quad\quad 9$$

$$(\ 11011010011)_2 = (\quad\quad)_{16}$$

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (\underbrace{0011}_{3}\underbrace{1011}_{b}\underbrace{1001}_{9})_2$$

$$(\underbrace{0110}\underbrace{1101}\underbrace{0011})_2 = (\qquad)_{16}$$

Hex Digit	4 bit binary
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

$(3b9)_{16} = (001110111001)_2$

      3   b   9

$(011011010011)_2 = (\quad)_{16}$

      3

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

$$\underbrace{0011}_{3}\ \underbrace{1011}_{b}\ \underbrace{1001}_{9}$$

$$(011011010011)_2 = (\quad)_{16}$$

$$\underbrace{0110}_{d}\ \underbrace{1101}_{3}\ 0011$$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

3   b   9

$$(011011010011)_2 = (\qquad)_{16}$$

6   d   3

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

$$(3b9)_{16} = (001110111001)_2$$

3   b   9

$$(011011010011)_2 = (6d3)_{16}$$

6   d   3

(iii) binary ← hexadecimal

$(011011010011)_2$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$=$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 1$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 +$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (\qquad) \cdot 2^4$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 \qquad) \cdot 2^4$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 \qquad\qquad) \cdot 2^4$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 \qquad) \cdot 2^4$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 +$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + () \cdot 2^8$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + \qquad) \cdot 2^8$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
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

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	1101
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	0011 = $1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3$ = 3
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	1101
e	1110
f	1111

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

3

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \quad\quad (3) \cdot 2^0$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	1101
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	1101
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	$1101 = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3$
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	$1101 = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3 = 13$
e	1110
f	1111

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

13

$= \qquad (3) \cdot 2^0$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4$

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1{\cdot}2^0 + 1{\cdot}2^1 + 0{\cdot}2^2 + 0{\cdot}2^3 = 3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	$1101 = 1{\cdot}2^0 + 0{\cdot}2^1 + 1{\cdot}2^2 + 1{\cdot}2^3 = 13$
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	$1101 = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3 = 13$
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	$0110 = 0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3$
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	$1101 = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3 = 13$
e	1110
f	1111

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
2	0010
3	$0011 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 = 3$
4	0100
5	0101
6	$0110 = 0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3 = 6$
7	0111
8	1000
9	1001
a	1010
b	1011
c	1100
d	$1101 = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3 = 13$
e	1110
f	1111

$(011011010011)_2 =$

$= 1\cdot2^0+1\cdot2^1+0\cdot2^2+0\cdot2^3+1\cdot2^4+0\cdot2^5+1\cdot2^6+1\cdot2^7+0\cdot2^8+1\cdot2^9+1\cdot2^{10}+0\cdot2^{11}$

$= (1\cdot2^0+1\cdot2^1+0\cdot2^2+0\cdot2^3)\cdot2^0+(1\cdot2^0+0\cdot2^1+1\cdot2^2+1\cdot2^3)\cdot2^4+(0\cdot2^0+1\cdot2^1+1\cdot2^2+0\cdot2^3)\cdot2^8$

$= \qquad (3)\cdot2^0 \qquad + \qquad (13)\cdot2^4$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4$

6

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1{\cdot}2^0+1{\cdot}2^1+0{\cdot}2^2+0{\cdot}2^3+1{\cdot}2^4+0{\cdot}2^5+1{\cdot}2^6+1{\cdot}2^7+0{\cdot}2^8+1{\cdot}2^9+1{\cdot}2^{10}+0{\cdot}2^{11}$

$= (1{\cdot}2^0+1{\cdot}2^1+0{\cdot}2^2+0{\cdot}2^3){\cdot}2^0+(1{\cdot}2^0+0{\cdot}2^1+1{\cdot}2^2+1{\cdot}2^3){\cdot}2^4+(0{\cdot}2^0+1{\cdot}2^1+1{\cdot}2^2+0{\cdot}2^3){\cdot}2^8$

$= \qquad (3){\cdot}2^0 \qquad + \qquad (13){\cdot}2^4 \qquad + \qquad (6){\cdot}2^8$

$(011011010011)_2 =$

$= 1{\cdot}2^0 + 1{\cdot}2^1 + 0{\cdot}2^2 + 0{\cdot}2^3 + 1{\cdot}2^4 + 0{\cdot}2^5 + 1{\cdot}2^6 + 1{\cdot}2^7 + 0{\cdot}2^8 + 1{\cdot}2^9 + 1{\cdot}2^{10} + 0{\cdot}2^{11}$

$= (1{\cdot}2^0 + 1{\cdot}2^1 + 0{\cdot}2^2 + 0{\cdot}2^3){\cdot}2^0 + (1{\cdot}2^0 + 0{\cdot}2^1 + 1{\cdot}2^2 + 1{\cdot}2^3){\cdot}2^4 + (0{\cdot}2^0 + 1{\cdot}2^1 + 1{\cdot}2^2 + 0{\cdot}2^3){\cdot}2^8$

$= \quad (3){\cdot}2^0 \quad + \quad (13){\cdot}2^4 \quad + \quad (6){\cdot}2^8$

2^0

$=$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

$2^0 = 1$

$=$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

$2^0 = 1 = 16^0$

$=$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

$= \qquad (3) \cdot 16^0$

$(011011010011)_2 =$

$= 1\cdot2^0+1\cdot2^1+0\cdot2^2+0\cdot2^3+1\cdot2^4+0\cdot2^5+1\cdot2^6+1\cdot2^7+0\cdot2^8+1\cdot2^9+1\cdot2^{10}+0\cdot2^{11}$

$= (1\cdot2^0+1\cdot2^1+0\cdot2^2+0\cdot2^3)\cdot2^0+(1\cdot2^0+0\cdot2^1+1\cdot2^2+1\cdot2^3)\cdot2^4+(0\cdot2^0+1\cdot2^1+1\cdot2^2+0\cdot2^3)\cdot2^8$

$= \qquad (3)\cdot2^0 \qquad + \qquad (13)\cdot2^4 \qquad + \qquad (6)\cdot2^8$

2^4

$= \qquad (3)\cdot16^0$

$(011011010011)_2 =$

$= 1{\cdot}2^0+1{\cdot}2^1+0{\cdot}2^2+0{\cdot}2^3+1{\cdot}2^4+0{\cdot}2^5+1{\cdot}2^6+1{\cdot}2^7+0{\cdot}2^8+1{\cdot}2^9+1{\cdot}2^{10}+0{\cdot}2^{11}$

$= (1{\cdot}2^0+1{\cdot}2^1+0{\cdot}2^2+0{\cdot}2^3){\cdot}2^0+(1{\cdot}2^0+0{\cdot}2^1+1{\cdot}2^2+1{\cdot}2^3){\cdot}2^4+(0{\cdot}2^0+1{\cdot}2^1+1{\cdot}2^2+0{\cdot}2^3){\cdot}2^8$

$= \quad (3){\cdot}2^0 \quad + \quad (13){\cdot}2^4 \quad + \quad (6){\cdot}2^8$

$2^4 = 16$

$= \quad (3){\cdot}16^0$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

$2^4 = 16 = 16^1$

$= \qquad (3) \cdot 16^0$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \quad (3) \cdot 2^0 \quad + \quad (13) \cdot 2^4 \quad + \quad (6) \cdot 2^8$

$= \quad (3) \cdot 16^0 \quad + \quad (13) \cdot 16^1$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

2^8

$= \qquad (3) \cdot 16^0 \qquad + \qquad (13) \cdot 16^1$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \quad (3) \cdot 2^0 \quad + \quad (13) \cdot 2^4 \quad + \quad (6) \cdot 2^8$

$2^8 = (2^4)^2$

$= \quad (3) \cdot 16^0 \quad + \quad (13) \cdot 16^1$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

$2^8 = (2^4)^2 = (16)^2$

$= \qquad (3) \cdot 16^0 \qquad + \qquad (13) \cdot 16^1$

$(011011010011)_2 =$

$= 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7 + 0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}$

$= (1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0 + (1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4 + (0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8$

$= \qquad (3) \cdot 2^0 \qquad + \qquad (13) \cdot 2^4 \qquad + \qquad (6) \cdot 2^8$

$= \qquad (3) \cdot 16^0 \qquad + \qquad (13) \cdot 16^1 \qquad + \qquad (6) \cdot 16^2$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

$= 1{\cdot}2^0+1{\cdot}2^1+0{\cdot}2^2+0{\cdot}2^3+1{\cdot}2^4+0{\cdot}2^5+1{\cdot}2^6+1{\cdot}2^7+0{\cdot}2^8+1{\cdot}2^9+1{\cdot}2^{10}+0{\cdot}2^{11}$

$= (1{\cdot}2^0+1{\cdot}2^1+0{\cdot}2^2+0{\cdot}2^3){\cdot}2^0+(1{\cdot}2^0+0{\cdot}2^1+1{\cdot}2^2+1{\cdot}2^3){\cdot}2^4+(0{\cdot}2^0+1{\cdot}2^1+1{\cdot}2^2+0{\cdot}2^3){\cdot}2^8$

$= \qquad (3){\cdot}2^0 \qquad + \qquad (13){\cdot}2^4 \qquad + \qquad (6){\cdot}2^8$

$= \qquad (3){\cdot}16^0 \qquad + \qquad (13){\cdot}16^1 \qquad + \qquad (6){\cdot}16^2$

$= (6d3)_{16}$

Addition

Addition

$$325_{10}$$
$$+ \, 692_{10}$$

Addition

$$
\begin{array}{r}
325_{10} \\
+\ \underline{692_{10}} \\
{}_{10}
\end{array}
$$

Addition

$$325_{10}$$
$$+\ 692_{10}$$
$$7_{10}$$

Addition

$$1$$
$$325_{10}$$
$$+ \; 692_{10}$$
$$17_{10}$$

Addition

$$\begin{array}{r} {\scriptstyle 1\ 1} \\ 325_{10} \\ +\ \underline{692_{10}} \\ 017_{10} \end{array}$$

Addition

$$1 \ 1$$
$$325_{10}$$
$$+ \ 692_{10}$$
$$\overline{1017_{10}}$$

Addition

$$\begin{array}{r} {}^{1\ 1}\ \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} 365_{8} \\ +\ 243_{8} \\ \hline \end{array}$$

Addition

$$
\begin{array}{r}
\overset{1\ 1}{325}_{10} \\
+\ 692_{10} \\
\hline
1017_{10}
\end{array}
$$

$$
\begin{array}{r}
365_8 \\
+\ 243_8 \\
\hline
_8
\end{array}
$$

Addition

$\overset{1\ 1}{}$

325_{10}
$+\ 692_{10}$
$\overline{}$
1017_{10}

$\overset{1}{}$

365_8
$+\ 243_8$
$\overline{}$
0_8

Addition

1 1
$$325_{10}$$
$$+ \; 692_{10}$$
$$1017_{10}$$

1 1
$$365_8$$
$$+ \; 243_8$$
$$30_8$$

Addition

$$\begin{array}{r} {}^{1}{}^{1} \\ 325_{10} \\ +692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} {}^{1}{}^{1} \\ 365_{8} \\ +243_{8} \\ \hline 630_{8} \end{array}$$

Addition

$$\begin{array}{r} {}^{1}\ {}^{1} \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} {}^{1}\ {}^{1} \\ 365_{8} \\ +\ 243_{8} \\ \hline 630_{8} \end{array}$$

$$\begin{array}{r} 10011100_{2} \\ +\ 11011001_{2} \\ \hline \end{array}$$

Addition

$$1\ 1$$
$$+\ 325_{10}$$
$$\underline{692_{10}}$$
$$1017_{10}$$

$$1\ 1$$
$$+\ 365_8$$
$$\underline{243_8}$$
$$630_8$$

$$+\ 10011100_2$$
$$\underline{11011001_2}$$
$$_2$$

Addition

$$1\ 1$$
$$325_{10}$$
$$+\ \underline{\ 692_{10}}$$
$$1017_{10}$$

$$1\ 1$$
$$365_8$$
$$+\ \underline{\ 243_8}$$
$$630_8$$

$$10011100_2$$
$$+\ \underline{\ 11011001_2}$$
$$1_2$$

Addition

$$\begin{array}{r} {}^{1\ 1} \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} {}^{1\ 1} \\ 365_{8} \\ +\ 243_{8} \\ \hline 630_{8} \end{array}$$

$$\begin{array}{r} 10011100_{2} \\ +\ 11011001_{2} \\ \hline 01_{2} \end{array}$$

Addition

$$\begin{array}{r} {}^{1}\ {}^{1} \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} {}^{1}\ {}^{1} \\ 365_{8} \\ +\ 243_{8} \\ \hline 630_{8} \end{array}$$

$$\begin{array}{r} 10011100_{2} \\ +\ 11011001_{2} \\ \hline 101_{2} \end{array}$$

Addition

$$1\ 1$$
$$+ \quad 325_{10}$$
$$\underline{\quad 692_{10}}$$
$$1017_{10}$$

$$1\ 1$$
$$+ \quad 365_{8}$$
$$\underline{\quad 243_{8}}$$
$$630_{8}$$

$$1$$
$$+ \quad 10011100_{2}$$
$$\underline{\quad 11011001_{2}}$$
$$0101_{2}$$

Addition

$$1\ 1$$
$$325_{10}$$
$$+\ \underline{692_{10}}$$
$$1017_{10}$$

$$1\ 1$$
$$365_8$$
$$+\ \underline{243_8}$$
$$630_8$$

$$1\ 1$$
$$10011100_2$$
$$+\ \underline{11011001_2}$$
$$10101_2$$

Addition

$1\ 1$
325_{10}
$+\ 692_{10}$
1017_{10}

$1\ 1$
365_{8}
$+\ 243_{8}$
630_{8}

$1\ 1$
10011100_{2}
$+\ 11011001_{2}$
110101_{2}

Addition

$$1 \; 1$$
$$\begin{array}{r} 325_{10} \\ + \; 692_{10} \\ \hline 1017_{10} \end{array}$$

$$1 \; 1$$
$$\begin{array}{r} 365_{8} \\ + \; 243_{8} \\ \hline 630_{8} \end{array}$$

$$1 \; 1$$
$$\begin{array}{r} 10011100_{2} \\ + \; 11011001_{2} \\ \hline 1110101_{2} \end{array}$$

Addition

$$1\ 1$$
$$325_{10}$$
$$+\ 692_{10}$$
$$\overline{1017_{10}}$$

$$1\ 1$$
$$365_{8}$$
$$+\ 243_{8}$$
$$\overline{630_{8}}$$

$$1\qquad 1\ 1$$
$$10011100_{2}$$
$$+\ 11011001_{2}$$
$$\overline{01110101_{2}}$$

Addition

$$1\ 1$$
$$325_{10}$$
$$+\ 692_{10}$$
$$\overline{1017_{10}}$$

$$1\ 1$$
$$365_8$$
$$+\ 243_8$$
$$\overline{630_8}$$

$$1\qquad 1\ 1$$
$$10011100_2$$
$$+\ 11011001_2$$
$$\overline{101110101_2}$$

Subtraction

Subtraction

$$427_{10}$$
$$- \ 192_{10}$$

Subtraction

$$427_{10}$$
$$- \; 192_{10}$$
$$_{10}$$

Subtraction

$$427_{10}$$
$$- \ 192_{10}$$
$$5_{10}$$

Subtraction

$$\overset{12}{\cancel{4}2}7_{10}$$
$$-\ \underline{192_{10}}$$
$$5_{10}$$

Subtraction

$$\begin{array}{r} \overset{3\ \ 12}{4\cancel{2}7}_{10} \\ -\ 192_{10} \\ \hline 5_{10} \end{array}$$

Subtraction

$$3 \quad 12$$
$$\cancel{4}\cancel{2}7_{10}$$
$$-\ \underline{192_{10}}$$
$$35_{10}$$

Subtraction

$$3 \quad 12$$
$$\cancel{4}\cancel{2}7_{10}$$
$$- \underline{192_{10}}$$
$$235_{10}$$

Subtraction

$$\begin{array}{r} \overset{3 \ \ 12}{\cancel{4}\cancel{2}7}_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array}$$

$$\begin{array}{r} 536_{8} \\ -\ 351_{8} \\ \hline \end{array}$$

Subtraction

$$\begin{array}{r} \overset{3\ \ 12}{4\cancel{2}7}_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array}$$

$$\begin{array}{r} 536_{8} \\ -\ 351_{8} \\ \hline _{8} \end{array}$$

Subtraction

$$\begin{array}{r} \overset{3\;12}{\cancel{4}\cancel{2}7}_{10} \\ -\;192_{10} \\ \hline 235_{10} \end{array}$$

$$\begin{array}{r} 536_8 \\ -\;351_8 \\ \hline 5_8 \end{array}$$

Subtraction

$$3 \quad 12$$
$$\cancel{4}\cancel{2}7_{10}$$
$$- \underline{192_{10}}$$
$$235_{10}$$

$$13_8$$
$$5\cancel{3}\cancel{6}_8$$
$$- \underline{351_8}$$
$$5_8$$

Subtraction

$$
\begin{array}{r}
{}^{3}\;{}^{12} \\
\cancel{4}\cancel{2}7_{10} \\
-\;192_{10} \\
\hline
235_{10}
\end{array}
$$

$$
\begin{array}{r}
{}^{4}\;{}^{13_8} \\
\cancel{5}\cancel{3}6_8 \\
-\;351_8 \\
\hline
5_8
\end{array}
$$

Subtraction

$$\begin{array}{r} \overset{3\ \ 12}{\cancel{4}\cancel{2}7}_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array}$$

$$\begin{array}{r} \overset{4\ \ 13_8}{\cancel{5}\cancel{3}6}_8 \\ -\ 351_8 \\ \hline 65_8 \end{array}$$

Subtraction

$$3 \quad 12$$
$$\cancel{4}\cancel{2}7_{10}$$
$$- \quad 192_{10}$$
$$235_{10}$$

$$4 \quad 13_8$$
$$\cancel{5}\cancel{3}6_8$$
$$- \quad 351_8$$
$$165_8$$

Signed Numbers

Signed Numbers

$(26)_{10} = (11010)_2$

Signed Numbers

$$(26)_{10} = (11010)_2$$

16 8 4 2 1

Signed Numbers

$(26)_{10} = (11010)_2$

16 8 4 2 1

$(-26)_{10}$

Signed Numbers

$(26)_{10} = (11010)_2$

16 8 4 2 1

$(-26)_{10} = (-11010)_2$

Signed Numbers

$(26)_{10} = (11010)_2$

16 8 4 2 1

$(-26)_{10} = (-11010)_2$

Approaches to represent signed numbers using only 0s and 1s:

Signed Numbers

$$(26)_{10} = (11010)_2$$

16 8 4 2 1

$$(-26)_{10} = (-11010)_2$$

Approaches to represent signed numbers using only 0s and 1s:

- Sign and Magnitude

Signed Numbers

$$(26)_{10} = (11010)_2$$

16 8 4 2 1

$$(-26)_{10} = (-11010)_2$$

Approaches to represent signed numbers using only 0s and 1s:

- Sign and Magnitude

sign   magnitude

Signed Numbers

$$(26)_{10} = (11010)_2$$

16 8 4 2 1

$$(-26)_{10} = (-11010)_2$$

Approaches to represent signed numbers using only 0s and 1s:

- Sign and Magnitude

sign   magnitude

1

Signed Numbers

$(26)_{10} = (11010)_2$

16 8 4 2 1

$(-26)_{10} = (-11010)_2$

Approaches to represent signed numbers using only 0s and 1s:

- Sign and Magnitude

1000...011010

sign   magnitude

Signed Numbers

$(26)_{10} = (11010)_2$

16 8 4 2 1

$(-26)_{10} = (-11010)_2$

Approaches to represent signed numbers using only 0s and 1s:

- Sign and Magnitude

  1000...011010

  sign   magnitude

- Two's Complement

Two's Complement

Two's Complement

In a k-bit two's complement representation of a number:

Two's Complement

In a k-bit two's complement representation of a number:

- A positive integer is represented in its (k-1)-bit unsigned binary representation, padded with a 0 to its left

Two's Complement

In a k-bit two's complement representation of a number:

- A positive integer is represented in its (k-1)-bit unsigned binary representation, padded with a 0 to its left

- The sum of a number and its additive inverse is 2^k

Two's Complement

$(26)_{10}$

Two's Complement

$(26)_{10} = ($ $)_{\text{8 bit 2's complement}}$

Two's Complement

$(26)_{10} = ($ _____ $)_{\text{8 bit 2's complement}}$

7 bits

Two's Complement

$(26)_{10} = ($ 0011010 $)$ 8 bit 2's complement

7 bits

Two's Complement

$$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$$

7 bits

Two's Complement

$(26)_{10} = (00011010)$ 8 bit 2's complement

7 bits

$(-26)_{10}$

Two's Complement

$(26)_{10} = (00011010)_{8 \text{ bit 2's complement}}$

7 bits

$(-26)_{10} = (\qquad)_{8 \text{ bit 2's complement}}$

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = ()_{\text{8 bit 2's complement}}$

$$
\begin{array}{r}
0\ 0\ 0\ 1\ 1\ 0\ 1\ 0 \quad \leftarrow 26\\
+ \quad \leftarrow -26\\
\hline
 \quad \leftarrow 2^8
\end{array}
$$

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = (\qquad\qquad)_{\text{8 bit 2's complement}}$

$$0\ 0\ 0\ 1\ 1\ 0\ 1\ 0 \quad \leftarrow 26$$
$$+\qquad\qquad\qquad\qquad \leftarrow -26$$
$$\overline{1\ 0\ 0\ 0\ 0\ 0\ 0\ 0} \quad \leftarrow 2^8$$

Two's Complement

$$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$$

7 bits

$$(-26)_{10} = ()_{\text{8 bit 2's complement}}$$

$$
\begin{array}{r}
0\,0\,0\,1\,1\,0\,1\,0 \quad \leftarrow 26\\
+0 \quad \leftarrow -26\\
\hline
1\,0\,0\,0\,0\,0\,0\,0\,0 \quad \leftarrow 2^8
\end{array}
$$

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = (\qquad)_{\text{8 bit 2's complement}}$

$$
\begin{array}{r}
\overset{1}{} \\
0\ 0\ 0\ 1\ 1\ 0\ 1\ 0 \qquad 26 \\
+\qquad\qquad 1\ 0 \qquad -26 \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \qquad 2^8
\end{array}
$$

Two's Complement

$(26)_{10} = (0\underbrace{0011010}_{\text{7 bits}})_{\text{8 bit 2's complement}}$

$(-26)_{10} = ($ $)_{\text{8 bit 2's complement}}$

$$
\begin{array}{c}
\overset{1}{}\;\overset{}{0}\;0\;0\;1\;1\;0\;1\;0 \qquad \text{26} \\
+1\;1\;0 \qquad \text{-26} \\
\hline
1\;0\;0\;0\;0\;0\;0\;0\;0 \qquad 2^8
\end{array}
$$

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = (\qquad)_{\text{8 bit 2's complement}}$

```
      1 1 1
  0 0 0 1 1 0 1 0        ← 26
+       0 1 1 0          ← -26
_____
  1 0 0 0 0 0 0 0 0      ← 2^8
```

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = ($ $)_{\text{8 bit 2's complement}}$

$$
\begin{array}{r}
\overset{1}{}\overset{1}{}\overset{1}{}\overset{1}{} \\
0\ 0\ 0\ 1\ 1\ 0\ 1\ 0 \quad 26 \\
+\qquad 0\ 0\ 1\ 1\ 0 \quad {-26} \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \quad 2^8
\end{array}
$$

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = ()_{\text{8 bit 2's complement}}$

$$
\begin{array}{r}
\overset{1\ \ 1\ \ 1\ \ 1\ \ 1}{0\ 0\ 0\ 1\ 1\ 0\ 1\ 0} \\
+\quad\quad 1\ 0\ 0\ 1\ 1\ 0 \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0
\end{array}
$$

26

-26

2^8

Two's Complement

$(26)_{10} = (00011010)_{\text{8 bit 2's complement}}$

7 bits

$(-26)_{10} = (\qquad\qquad)_{\text{8 bit 2's complement}}$

$$
\begin{array}{r}
1\ \ 1\ \ 1\ \ 1\ \ 1\ \ 1 \\
0\ 0\ 0\ 1\ 1\ 0\ 1\ 0 \qquad \text{26} \\
+\ \ 1\ 1\ 0\ 0\ 1\ 1\ 0 \qquad \text{-26} \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \qquad 2^8
\end{array}
$$

Two's Complement

$(26)_{10} = (00011010)$ 8 bit 2's complement

7 bits

$(-26)_{10} = ($ $)$ 8 bit 2's complement


```
  1  1  1  1  1  1  1
  0  0  0  1  1  0  1  0        26
+
  1  1  1  0  0  1  1  0        -26
_____
1 0  0  0  0  0  0  0  0        2^8
```

Two's Complement

$(26)_{10} = (00011010)$ 8 bit 2's complement

7 bits

$(-26)_{10} = ($ $)$ 8 bit 2's complement

Two's Complement

$(26)_{10} = (00011010)$ 8 bit 2's complement

7 bits

$(-26)_{10} = (11100110)$ 8 bit 2's complement

```
  1   1   1   1   1   1   1
    0   0   0   1   1   0   1   0        26
+
    1   1   1   0   0   1   1   0        -26

  1   0   0   0   0   0   0   0   0      2^8
```

Two's Complement

Two's Complement

$(00101101)_{\text{8 bit 2's complement}}$

Two's Complement

$$(00101101)_{\text{8 bit 2's complement}} = (\quad)_{10}$$

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = ($ $)_{10}$

64 32 16 8 4 2 1

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}}$

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

-x

+

+x

$\overline{}$

1 0 0 0 0 0 0 0

2^8

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

$$\begin{array}{r} 1\ 1\ 1\ 0\ 1\ 0\ 1\ 0 \\ + \\ \hline 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \end{array}$$

-x

+x

2^8

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

$$
\begin{array}{r}
1\ 1\ 1\ 0\ 1\ 0\ 1\ 0 \qquad \leftarrow \text{-x} \\
+ \qquad\qquad\qquad\qquad 0 \qquad \leftarrow \text{+x} \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \qquad \leftarrow 2^8
\end{array}
$$

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

$$64 \quad 32 \quad 16 \quad 8 \quad 4 \quad 2 \quad 1$$

$(11101010)_{\text{8 bit 2's complement}} = (\quad\quad)_{10}$

$$
\begin{array}{r}
1 \\
1\ 1\ 1\ 0\ 1\ 0\ 1\ 0 \\
+ \quad\quad\quad\quad\quad\ 1\ 0 \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0
\end{array}
$$

-x

+x

2^8

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

```
        1   1
    1 1 1 0 1 0 1 0        -x
  +
            1 1 0          +x
  _____
    1 0 0 0 0 0 0 0 0      2^8
```

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

$\underbrace{0}_{}\ \underbrace{0}_{64}\ \underbrace{1}_{32}\ \underbrace{0}_{16}\ \underbrace{1}_{8}\ \underbrace{1}_{4}\ \underbrace{0}_{2}\ \underbrace{1}_{1}$

$(11101010)_{\text{8 bit 2's complement}} = (\qquad)_{10}$

$$
\begin{array}{r}
\overset{1\ \ 1\ \ \ \ \ 1}{1\ 1\ 1\ 0\ 1\ 0\ 1\ 0} \quad \text{-x} \\
+ \qquad 0\ 1\ 1\ 0 \quad \text{+x} \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \quad 2^8
\end{array}
$$

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = ()_{10}$

$$
\begin{array}{r}
1\ 1\ 1\ 1 \\
1\ 1\ 1\ 0\ 1\ 0\ 1\ 0 \\
+\quad\quad 1\ 0\ 1\ 1\ 0 \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0
\end{array}
$$

-x

+x

2^8

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

$$
\begin{array}{r}
\overset{1}{1}\,\overset{1}{1}\,\overset{1}{1}\,0\,\overset{1}{1}\,0\,\overset{1}{1}\,0 \\
+0\,1\,0\,1\,1\,0 \\
\hline
1\,0\,0\,0\,0\,0\,0\,0\,0
\end{array}
$$

-x

+x

2^8

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

<small>64 32 16 8 4 2 1</small>

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

	1	1	1	1	1	1		
	1	1	1	0	1	0	1	0

-x

+ 0 0 1 0 1 1 0   +x

1 0 0 0 0 0 0 0 0 2^8

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = ()_{10}$

$$
\begin{array}{c}
1\ 1\ 1\ 1\ 1\ 1\ 1 \\
1\ 1\ 1\ 0\ 1\ 0\ 1\ 0 \quad \text{-x} \\
+\ 0\ 0\ 0\ 1\ 0\ 1\ 1\ 0 \quad \text{+x} \\
\hline
1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \quad 2^8
\end{array}
$$

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

```
  1 1 1 1 1 1 1
  1 1 1 0 1 0 1 0        -x
+ 0 0 0 1 0 1 1 0        22
─────────────────
1 0 0 0 0 0 0 0 0        2^8
```

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (\quad)_{10}$

```
  1  1  1  1  1  1  1
  1 1 1 0 1 0 1 0          ← -22
+ 0 0 0 1 0 1 1 0          ← 22
─────────────────────
1 0 0 0 0 0 0 0 0          ← 2^8
```

Two's Complement

$(00101101)_{\text{8 bit 2's complement}} = (45)_{10}$

64 32 16 8 4 2 1

$(11101010)_{\text{8 bit 2's complement}} = (-22)_{10}$

```
  1 1 1 1 1 1 1
    1 1 1 0 1 0 1 0        → -22
  + 0 0 0 1 0 1 1 0        → 22
  ─────────────────
  1 0 0 0 0 0 0 0 0        → 2^8
```