

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

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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
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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
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
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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

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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]

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Digital Data

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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

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33	!	49	1	65	A	81	Q	97	a	113	q
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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

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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

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- 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

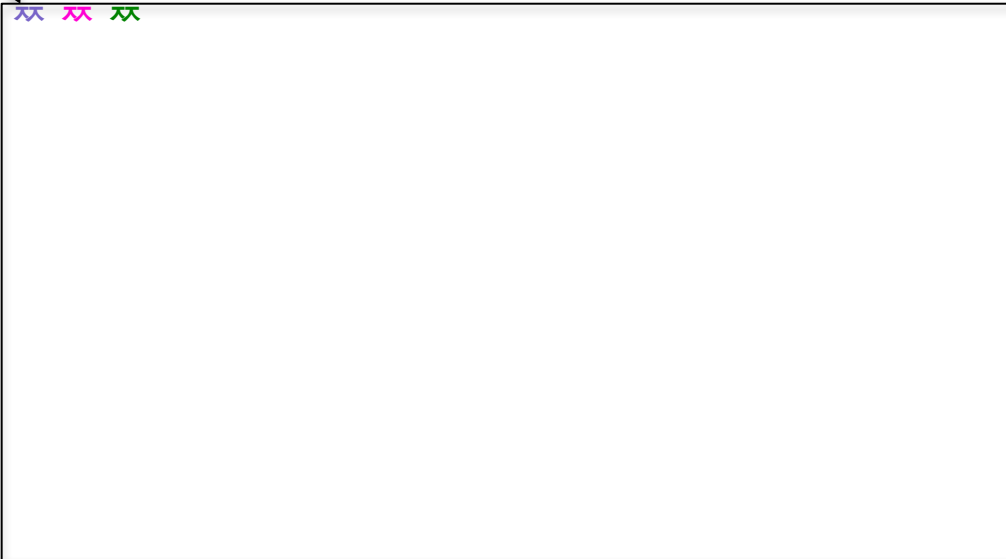


✂ ✂ ✂

Digital Data



(120, 100, 200)

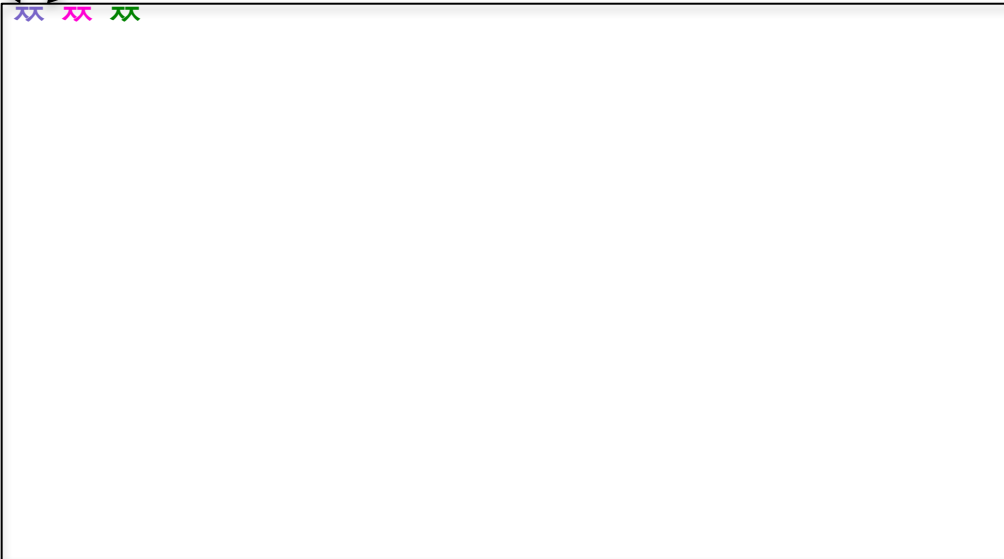


Digital Data



(120, 100, 200)

(255, 0, 210)



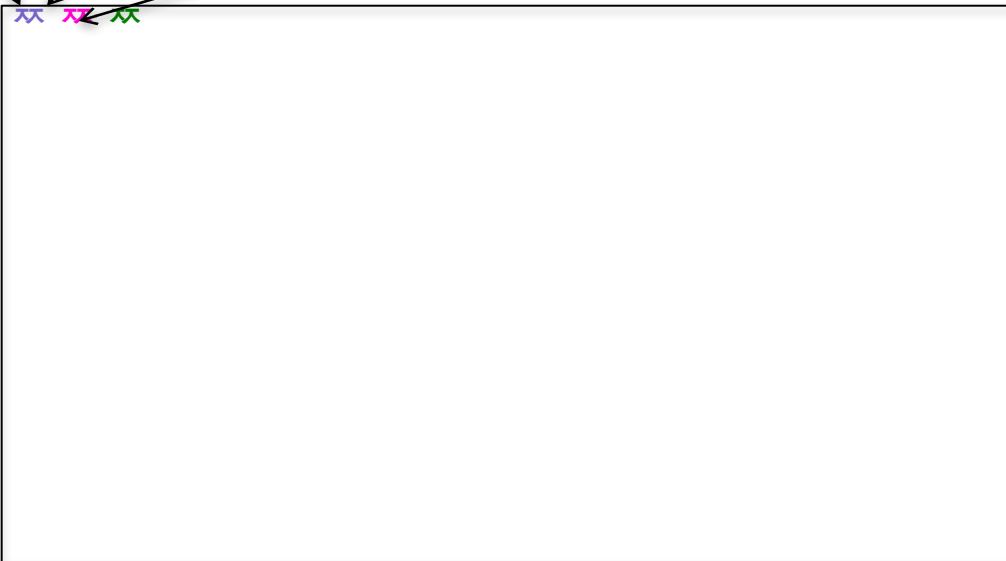
Digital Data



(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

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

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 **b₁**



Representation of
number **N** in base **b₂**

Base Conversions

Base Conversions

(i) N in base b  N in decimal

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  N in decimal

(ii) N in decimal  N in base b

(i) base b \Rightarrow decimal

(i) base b \Rightarrow decimal

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

(i) base b \rightarrow decimal

$(37\underline{5})_{10}$

(i) base b \rightarrow decimal

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

(i) base b \rightarrow decimal

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

(i) base b \rightarrow decimal

$(3 \underbrace{7}_{10} \underbrace{5}_1)_{10}$

(i) base b \rightarrow decimal

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

(i) base b \rightarrow decimal

$(\underbrace{3}_{100} \underbrace{7}_{10} \underbrace{5}_1)_{10}$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ \text{100} & \text{10} & \text{1} \\ || & & \\ 10^2 & & \end{array} (375)_{10}$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ \text{100} & \text{10} & \text{1} \\ || & || & \\ 10^2 & 10^1 & \end{array} 10$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ \text{100} & \text{10} & \text{1} \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} 10$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$(125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$(12\boxed{5})_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ & & 1 \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ & & 1 \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{cc} \boxed{1} & \boxed{2} & \boxed{5} \\ & 8 & 1 \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ & 8 & 1 \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & & \\ 8^2 & & \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$(1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{cccc} \boxed{1} & \boxed{0} & \boxed{1} & \boxed{1} \\ & & & \end{array} (1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{cccc} \boxed{1} & \boxed{0} & \boxed{1} & \boxed{1} \\ & & & 1 \\ & & & 2 \end{array} (1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ \quad \quad 2 \quad 1 \\ \end{array} (1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{ccc} \boxed{1} & \boxed{0} & \boxed{1} & \boxed{1} \\ 4 & 2 & 1 & \\ || & || & || & \\ 2^2 & 2^1 & 2^0 & \end{array} (1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{ccc} \boxed{3} & \boxed{7} & \boxed{5} \\ 100 & 10 & 1 \\ || & || & || \\ 10^2 & 10^1 & 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{ccc} \boxed{1} & \boxed{2} & \boxed{5} \\ 64 & 8 & 1 \\ || & || & || \\ 8^2 & 8^1 & 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{cccc} \boxed{1} & \boxed{0} & \boxed{1} & \boxed{1} \\ 8 & 4 & 2 & 1 \end{array} (1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

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

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

$$\begin{array}{c} \boxed{3} \boxed{b} \boxed{2} \\ 16 \end{array} (3b2)_{16}$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

$$\begin{array}{c} \boxed{3} \boxed{b} \boxed{2} \\ 16^2 \quad 16^1 \quad 16^0 \end{array} (3b2)_{16}$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

$$\begin{array}{c} \boxed{3} \boxed{b} \boxed{2} \\ 16^2 \quad 16^1 \quad 16^0 \end{array} (3b2)_{16} = 2 \cdot 16^0 + 11 \cdot 16^1 + 3 \cdot 16^2$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

$$\begin{array}{c} \boxed{3} \boxed{b} \boxed{2} \\ 16^2 \quad 16^1 \quad 16^0 \end{array} (3b2)_{16} = 2 \cdot 16^0 + 11 \cdot 16^1 + 3 \cdot 16^2 = 946$$

(i) base b \rightarrow decimal

$$\begin{array}{c} \boxed{3} \boxed{7} \boxed{5} \\ 100 \quad 10 \quad 1 \\ || \quad || \quad || \\ 10^2 \quad 10^1 \quad 10^0 \end{array} (375)_{10} = 5 \cdot 10^0 + 7 \cdot 10^1 + 3 \cdot 10^2 = 375$$

$$\begin{array}{c} \boxed{1} \boxed{2} \boxed{5} \\ 64 \quad 8 \quad 1 \\ || \quad || \quad || \\ 8^2 \quad 8^1 \quad 8^0 \end{array} (125)_8 = 5 \cdot 8^0 + 2 \cdot 8^1 + 1 \cdot 8^2 = 85$$

$$\begin{array}{c} \boxed{1} \boxed{0} \boxed{1} \boxed{1} \\ 8 \quad 4 \quad 2 \quad 1 \\ || \quad || \quad || \quad || \\ 2^3 \quad 2^2 \quad 2^1 \quad 2^0 \end{array} (1011)_2 = 1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 1 \cdot 2^3 = 11$$

$$\begin{array}{c} \boxed{3} \boxed{b} \boxed{2} \\ 16^2 \quad 16^1 \quad 16^0 \end{array} (3b2)_{16} = 2 \cdot 16^0 + 11 \cdot 16^1 + 3 \cdot 16^2 = 946$$

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

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  N in decimal

(ii) N in decimal  N in base b

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

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

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

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

...

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

$$(75)_{10} = (\quad)_{2}$$

• • •

 2^0

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

$$(75)_{10} = (\quad)_{2}$$

A diagram illustrating the powers of two. It consists of a series of horizontal black bars arranged horizontally. From left to right, there are three dots (\dots), followed by ten bars, and finally two more bars labeled 2^1 and 2^0 in orange text below them.

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

$$(75)_{10} = (\quad)_{2}$$

A diagram illustrating the binary representation of the number 10. It shows a sequence of horizontal bars representing bits. From left to right, there are three dots, followed by four bars, then two more bars, and finally three bars at the end. Below the last three bars are the labels 2^2 , 2^1 , and 2^0 respectively, indicating their positional values.

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

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

...	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

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

$$(75)_{10} = (\quad)_{2}$$

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

$$(75)_{10} = (\quad)_{2}$$

Diagram illustrating the bit positions of a 10-bit shift register, labeled from 2^9 down to 2^0 . The bits are arranged in a row, with the least significant bit (2^0) on the right and the most significant bit (2^9) on the left. The bit positions are labeled as follows:

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

The bit positions are further labeled with their corresponding values (2 and 1) below the 2^1 and 2^0 positions.

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

$$(75)_{10} = (\quad)_{2}$$

[illegible]

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

$$(75)_{10} = (\quad)_{2}$$

[illegible]

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

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

...										
	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

(ii) decimal \rightarrow base b (demonstrated on b=2)

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

...	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
					32	16	8	4	2	1

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

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

...	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	
	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

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

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

...	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	
	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

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

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

...	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	
	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

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

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

...	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
	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 to base b (demonstrated on b=2)

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

...	<div><div></div></div>	<div><div>?</div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
	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 to base b (demonstrated on b=2)

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

...	<div><div></div><div></div></div>	<div><div>1</div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<div><div></div><div></div></div>
	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 to base b (demonstrated on b=2)

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

...	<div><div></div></div>	<div><div>?</div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
	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

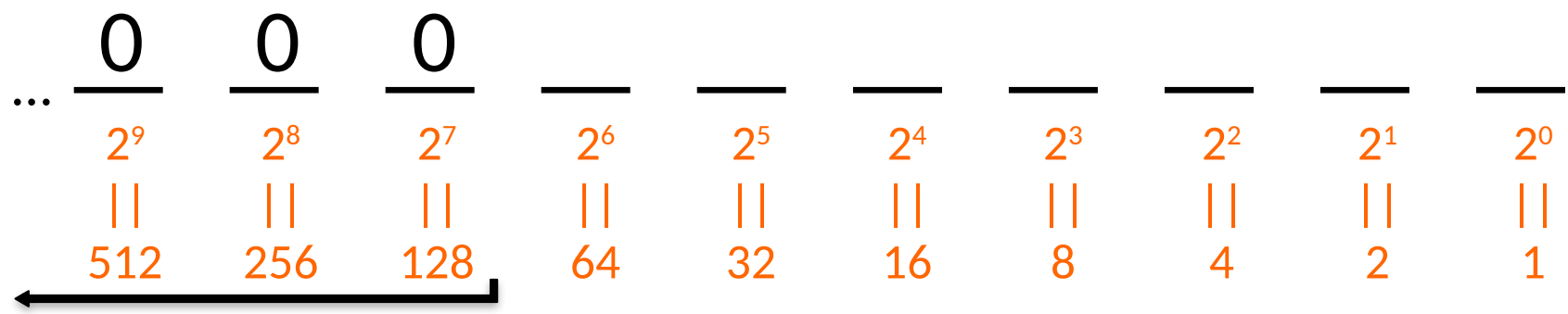
(ii) decimal to base b (demonstrated on b=2)

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

...	<div><div></div></div>	<div><div>0</div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
	<div><div>2⁹</div></div>	<div><div>2⁸</div></div>	<div><div>2⁷</div></div>	<div><div>2⁶</div></div>	<div><div>2⁵</div></div>	<div><div>2⁴</div></div>	<div><div>2³</div></div>	<div><div>2²</div></div>	<div><div>2¹</div></div>	<div><div>2⁰</div></div>
	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>	<div><div> </div></div>
	<div><div>512</div></div>	<div><div>256</div></div>	<div><div>128</div></div>	<div><div>64</div></div>	<div><div>32</div></div>	<div><div>16</div></div>	<div><div>8</div></div>	<div><div>4</div></div>	<div><div>2</div></div>	<div><div>1</div></div>

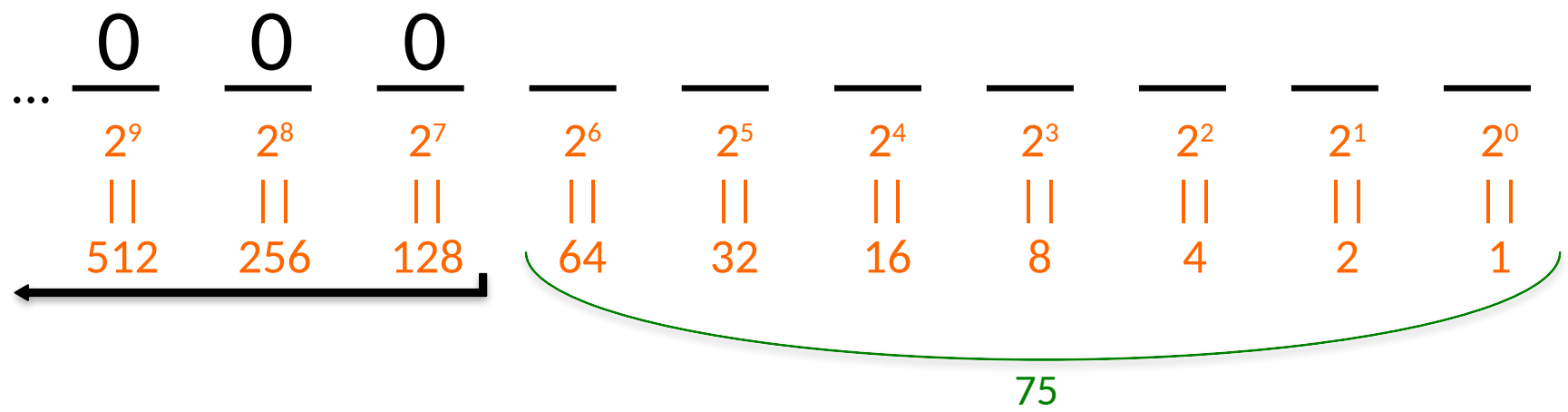
(ii) decimal to base b (demonstrated on b=2)

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



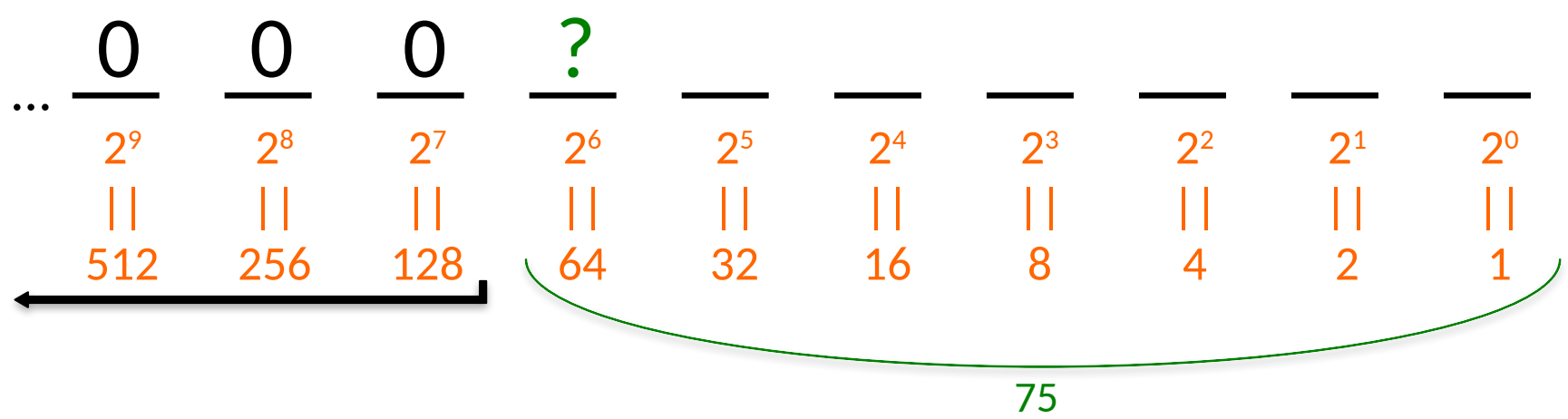
(ii) decimal to base b (demonstrated on b=2)

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



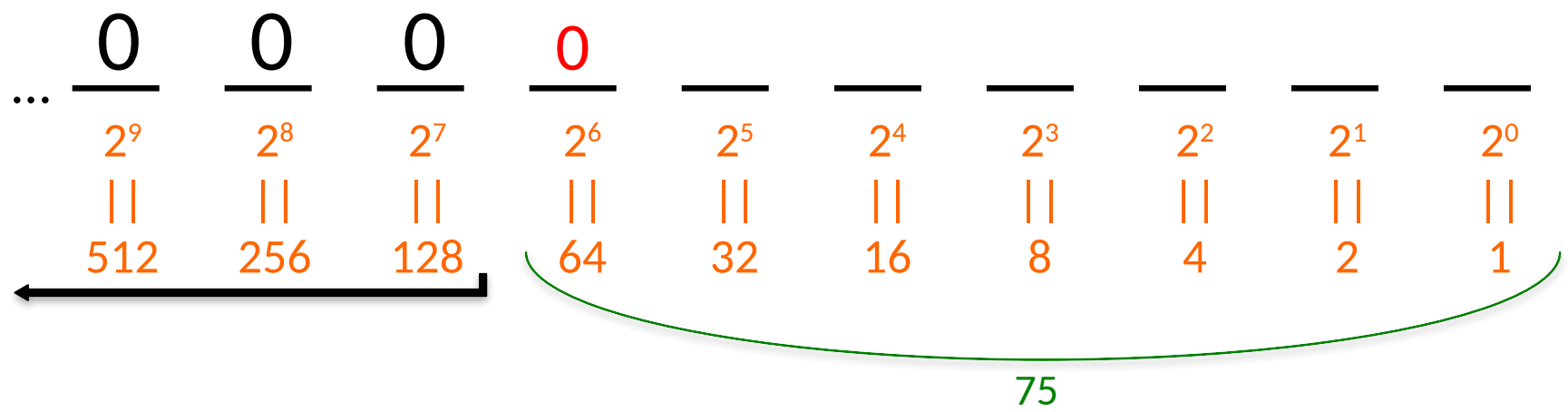
(ii) decimal to base b (demonstrated on b=2)

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



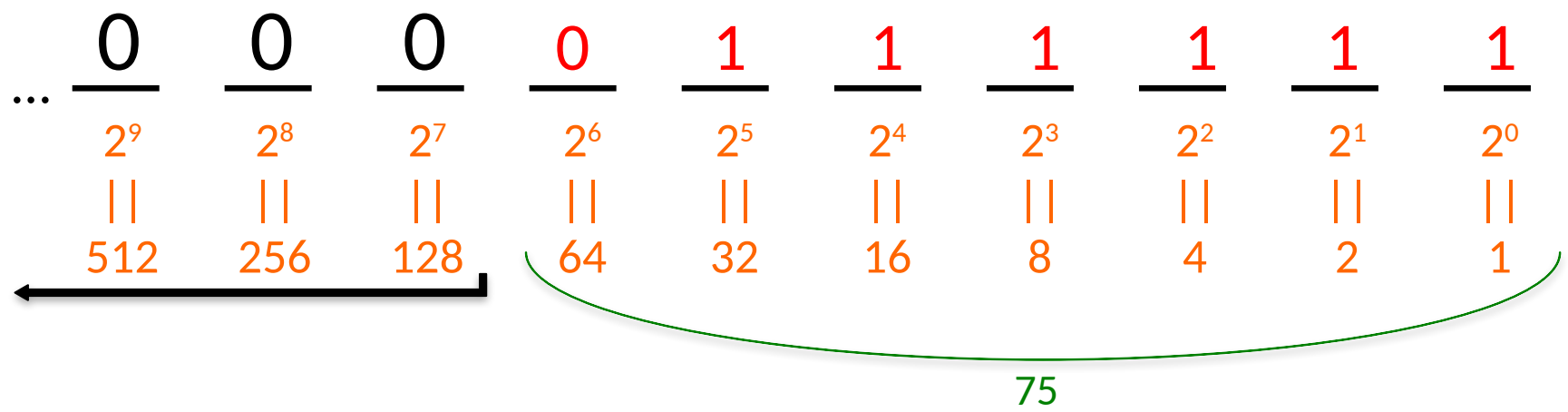
(ii) decimal to base b (demonstrated on b=2)

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



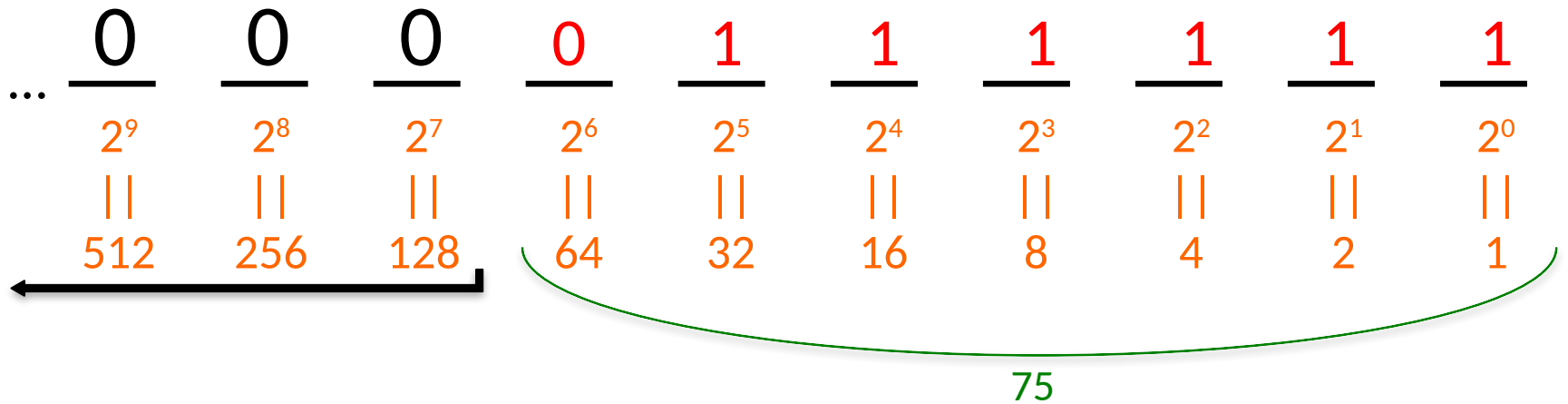
(ii) decimal to base b (demonstrated on b=2)

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



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

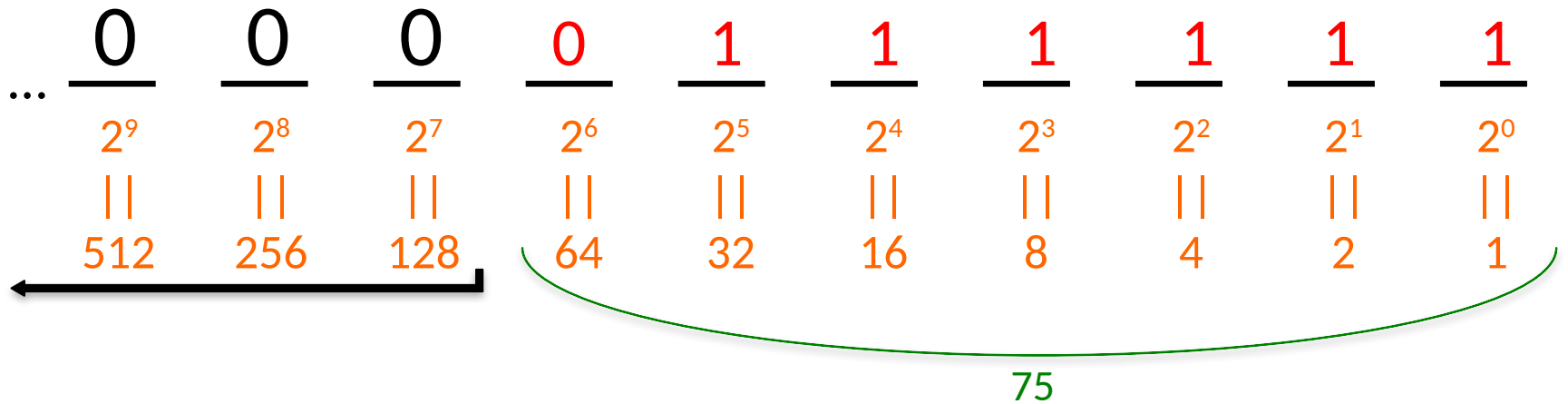
$$(75)_{10} = (\quad)_2$$



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

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

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

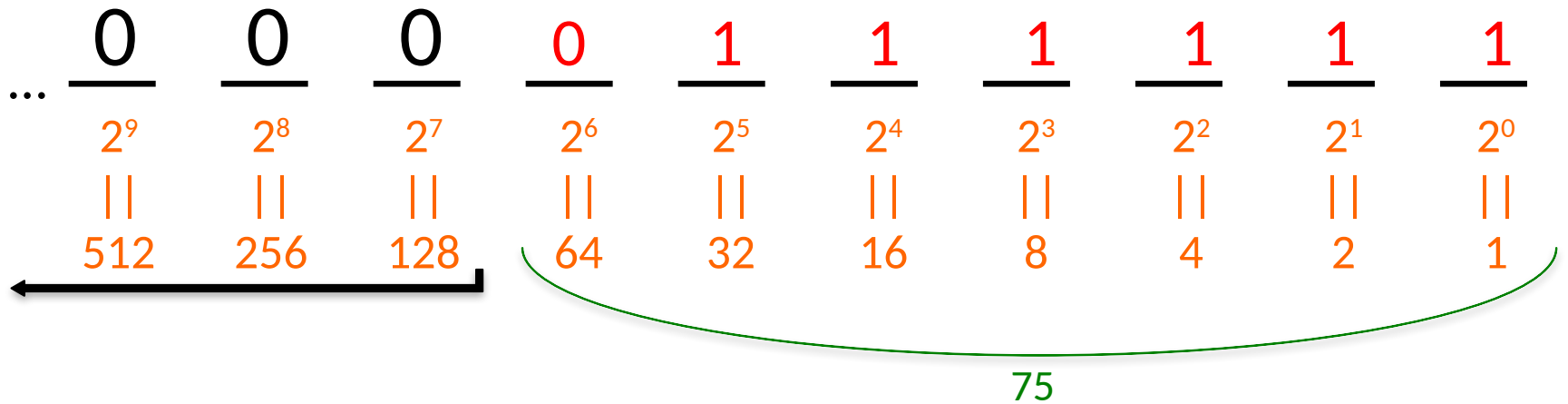


$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

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

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

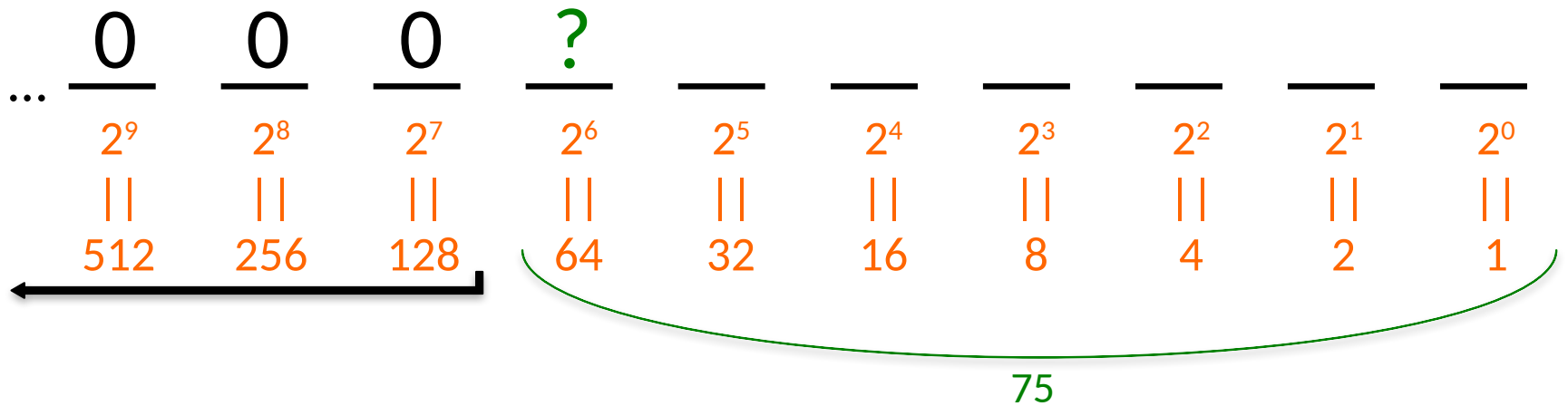


$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

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

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

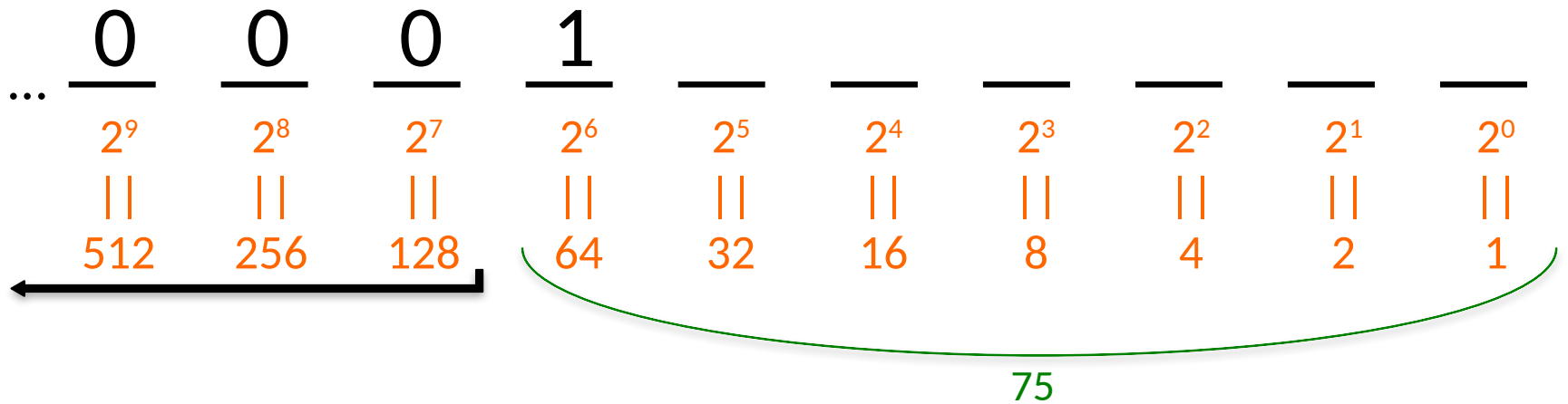


$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

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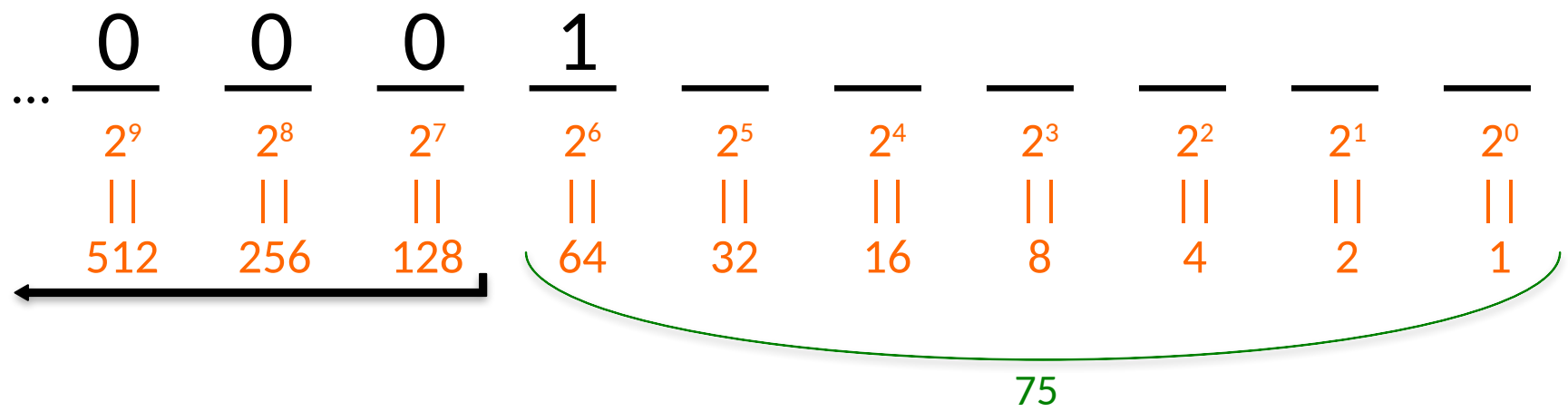


$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

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

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



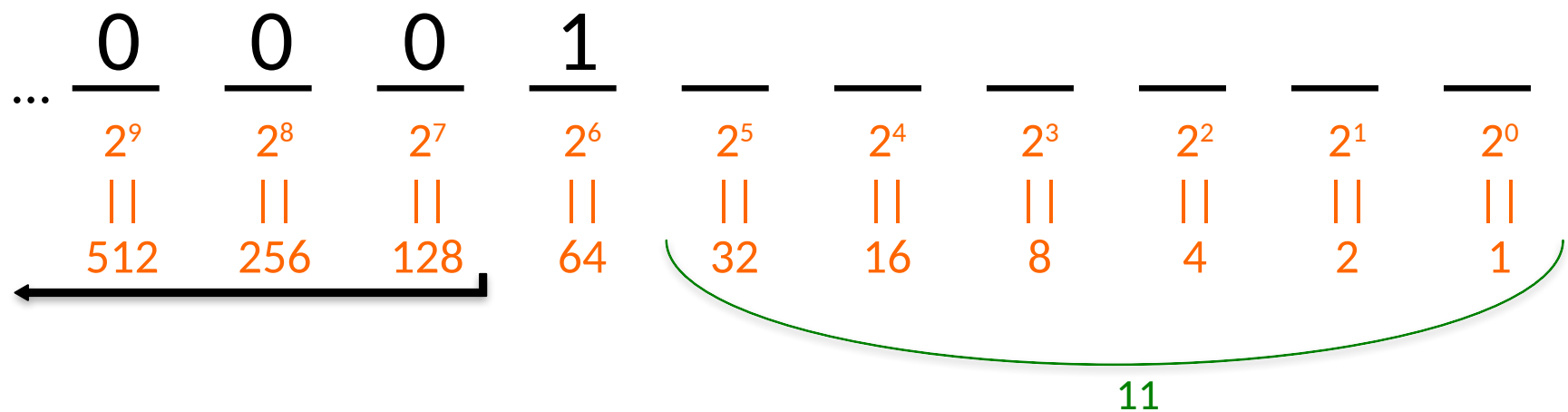
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

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

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



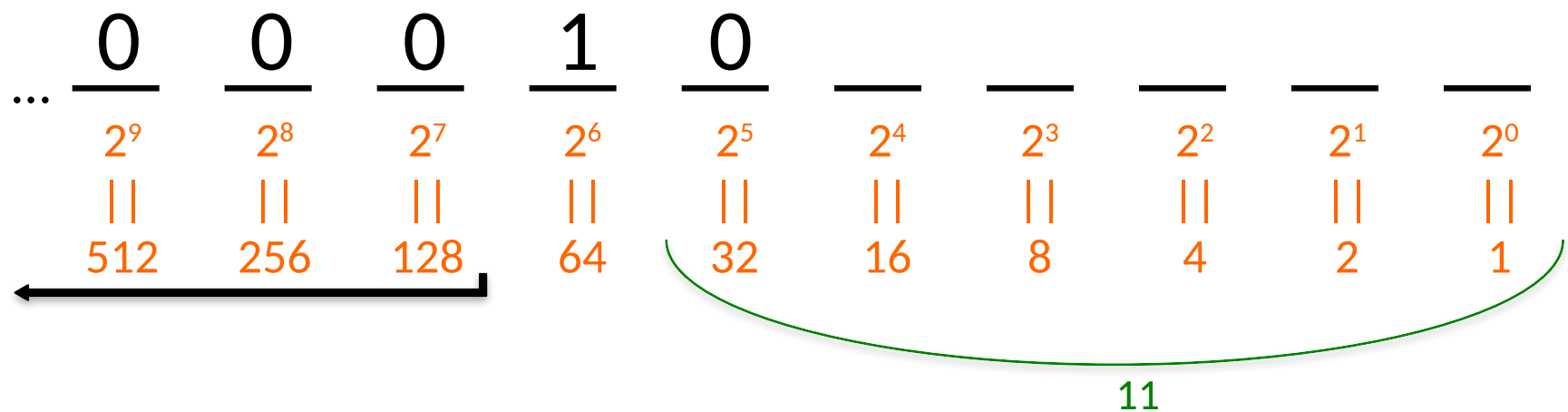
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

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

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



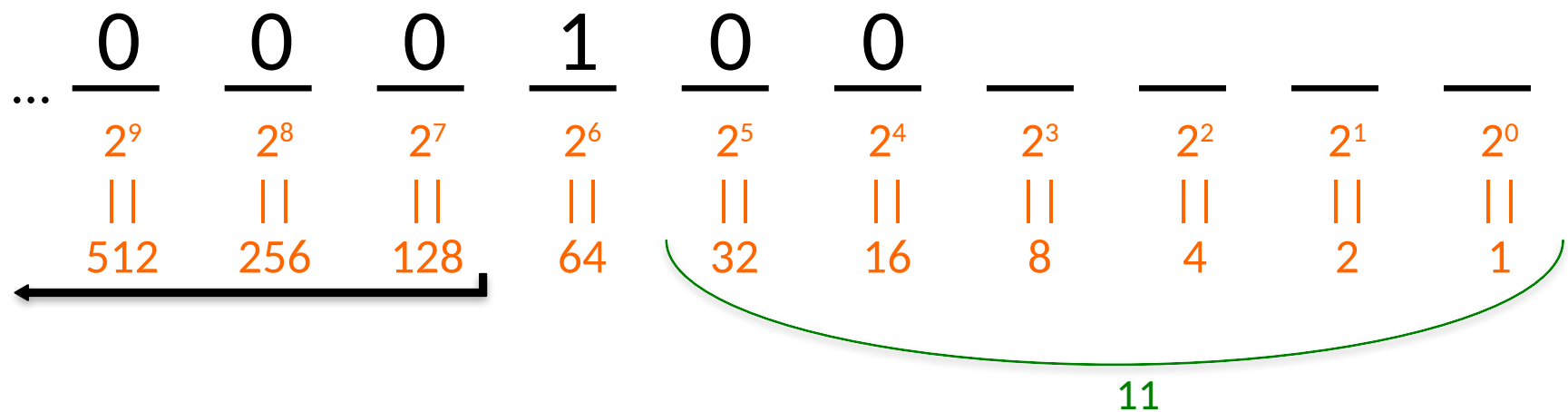
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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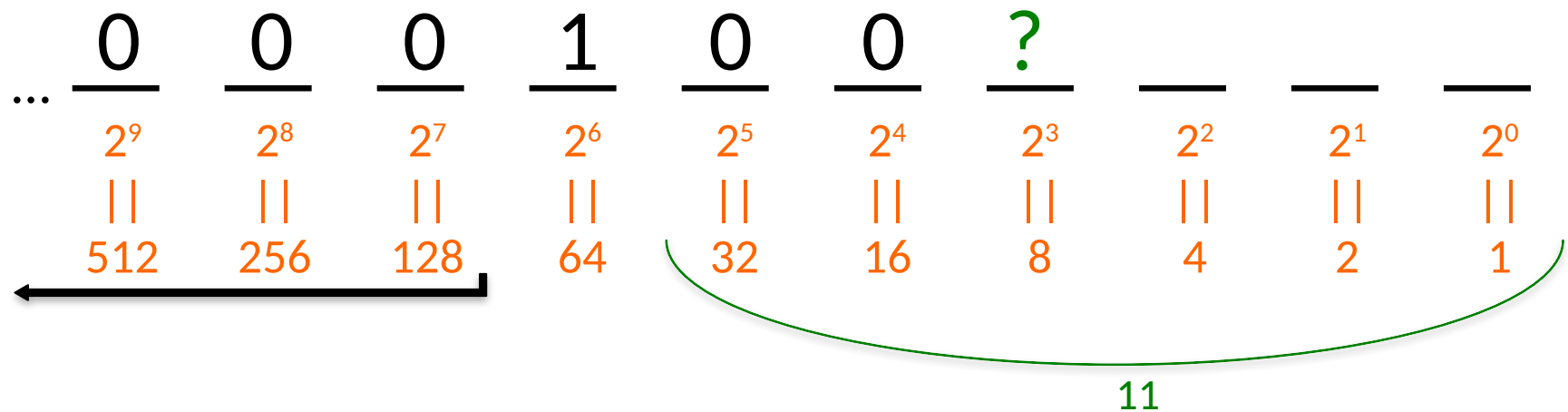
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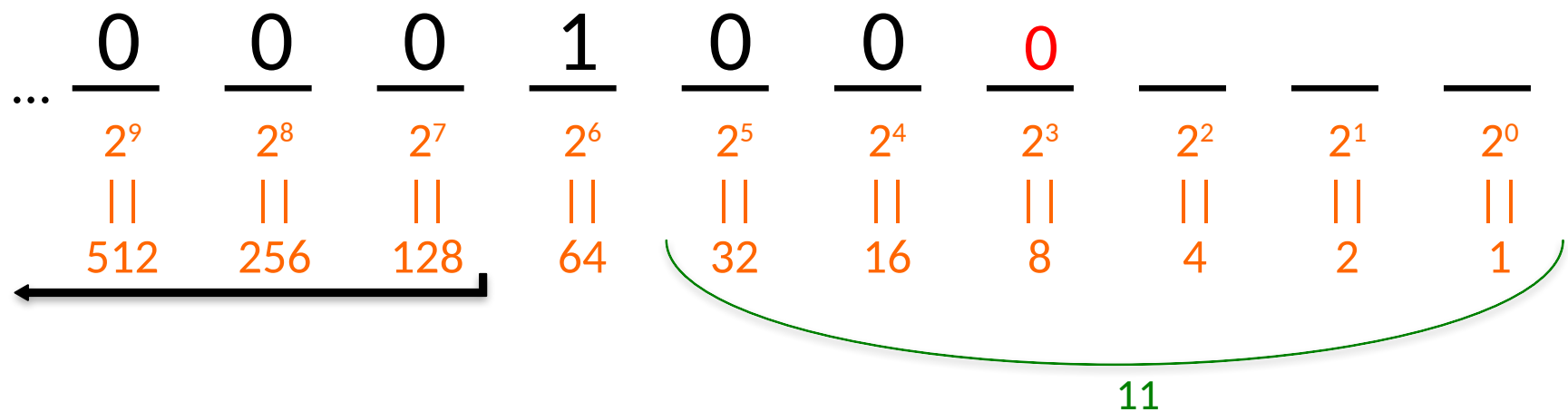
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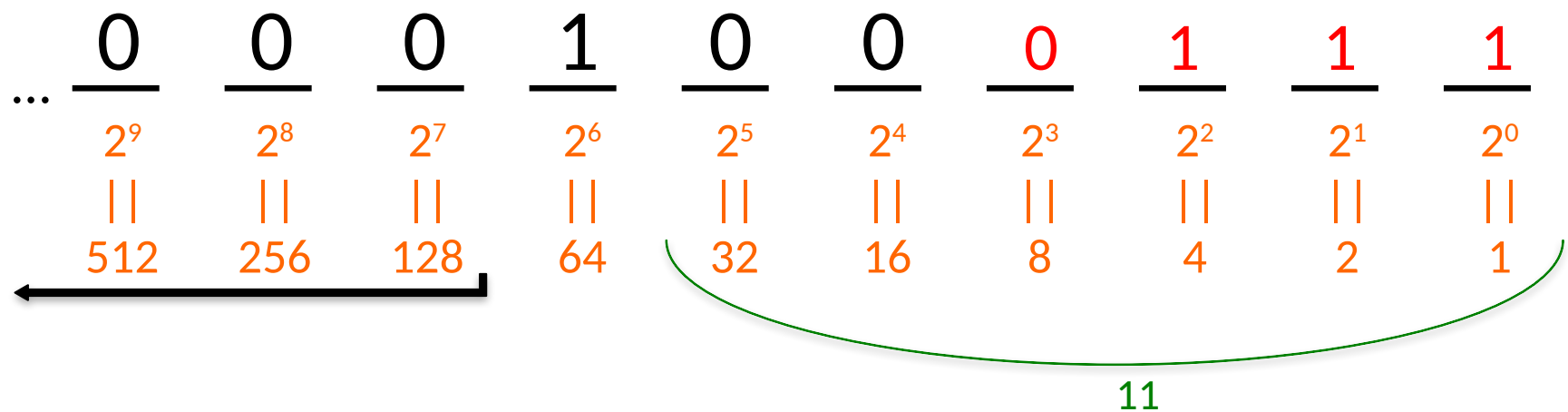
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(ii) decimal to base b (demonstrated on b=2)

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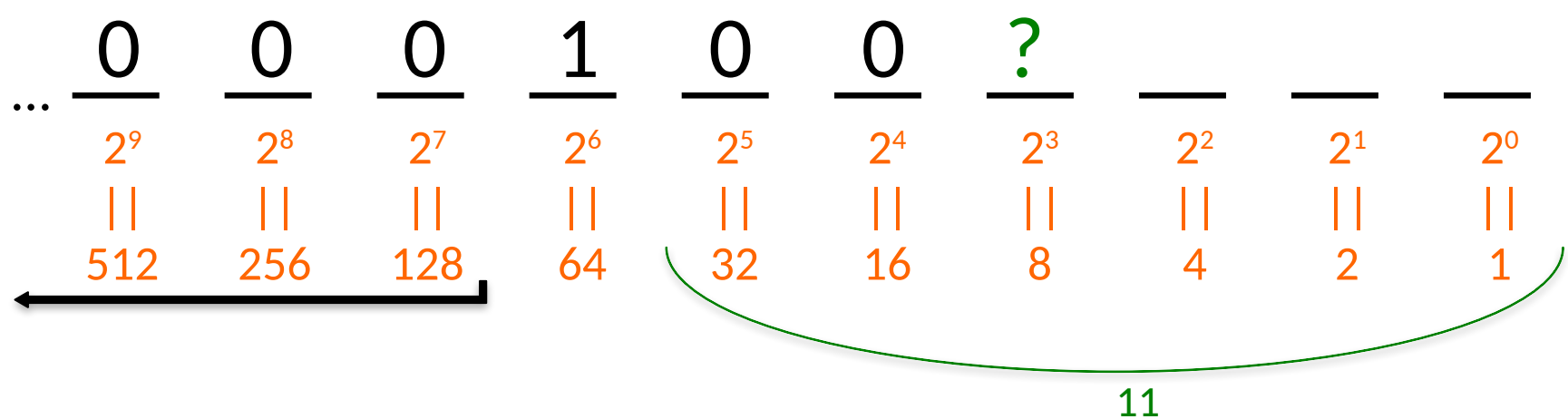
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

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

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



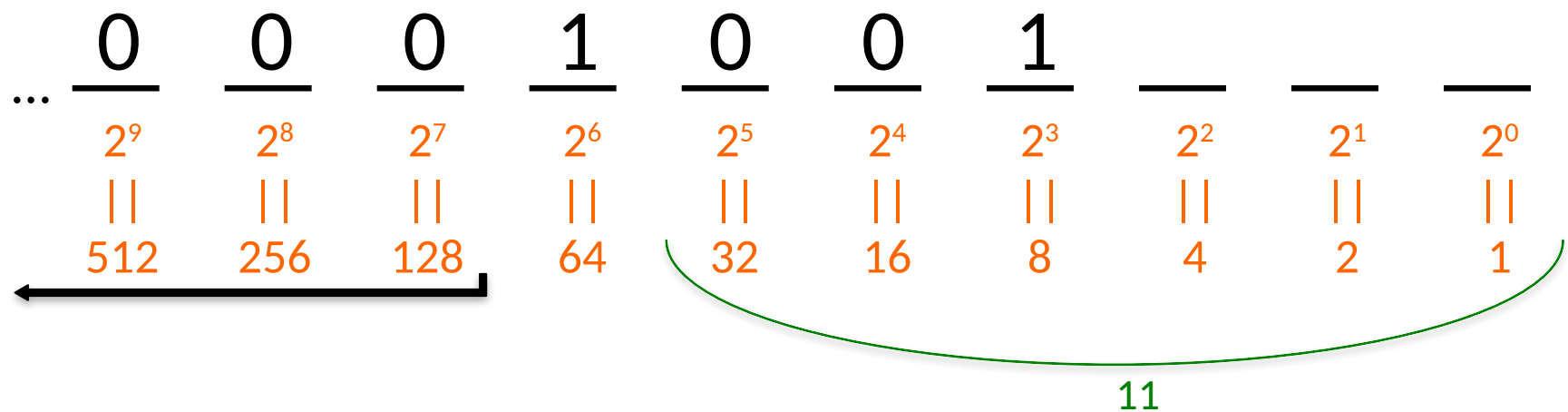
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

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

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



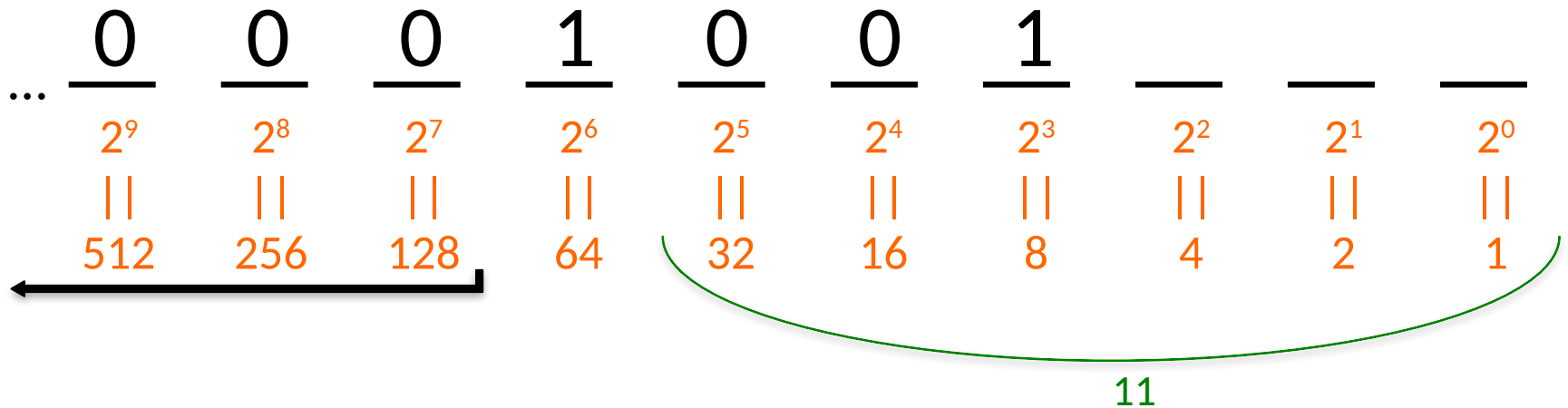
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

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

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



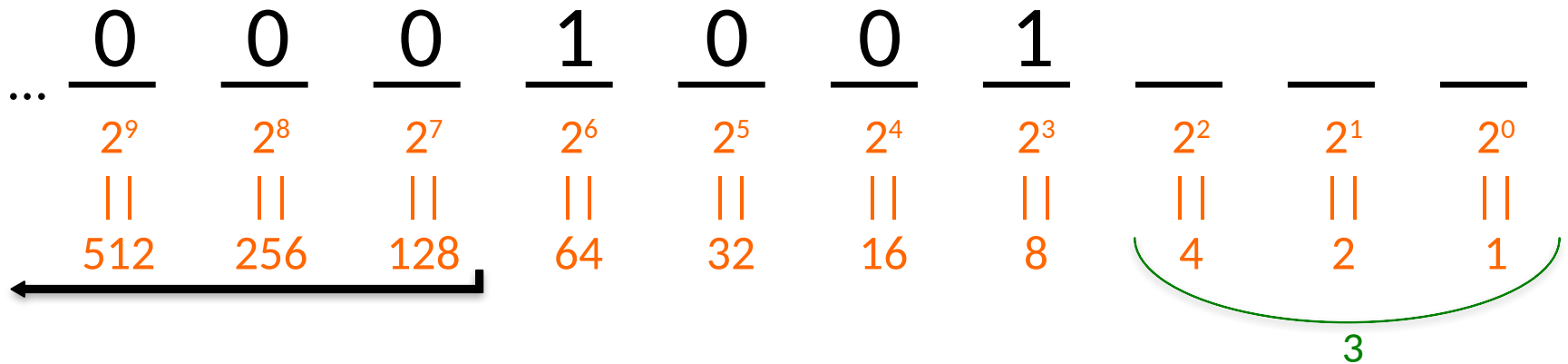
$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

$$\begin{array}{r} 75 \\ \div 64 \\ \hline 11 \end{array} \quad \begin{array}{r} 11 \\ \div 8 \\ \hline 3 \end{array}$$

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

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



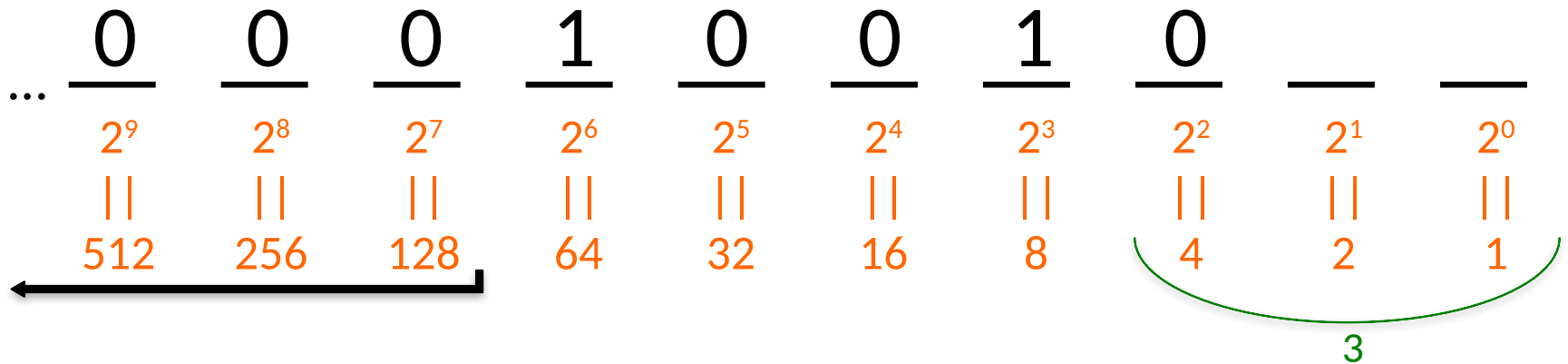
$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

$$\begin{array}{r} 75 \\ \div 64 \\ \hline 11 \end{array} \qquad \begin{array}{r} 11 \\ \div 8 \\ \hline 3 \end{array}$$

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

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



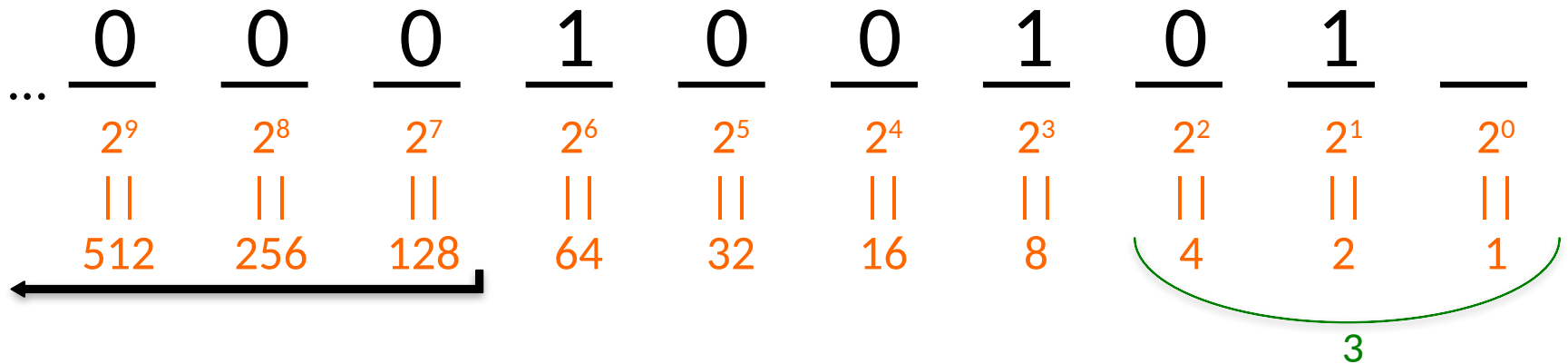
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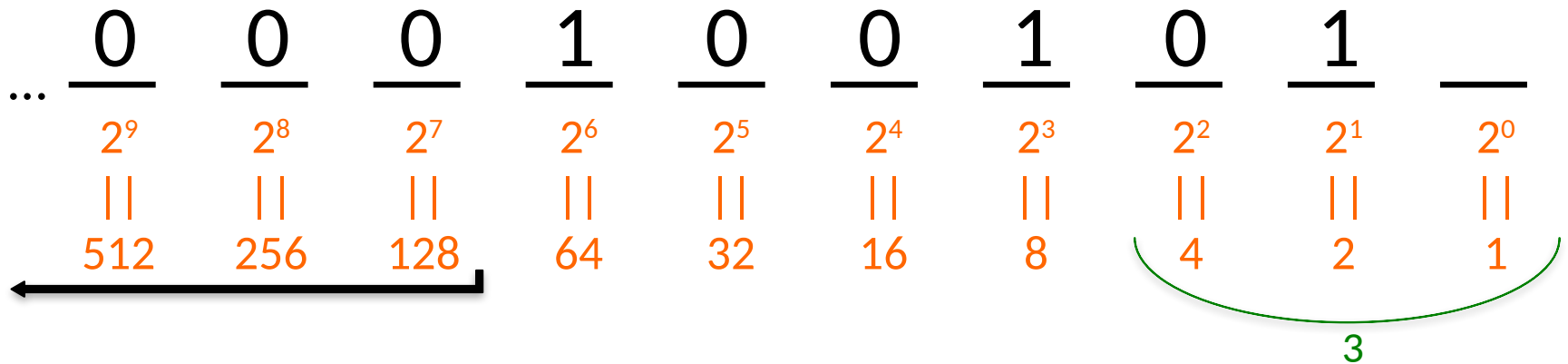
$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

$$\begin{array}{r} 75 \\ \div 64 \\ \hline 11 \end{array} \qquad \begin{array}{r} 11 \\ \div 8 \\ \hline 3 \end{array}$$

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

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



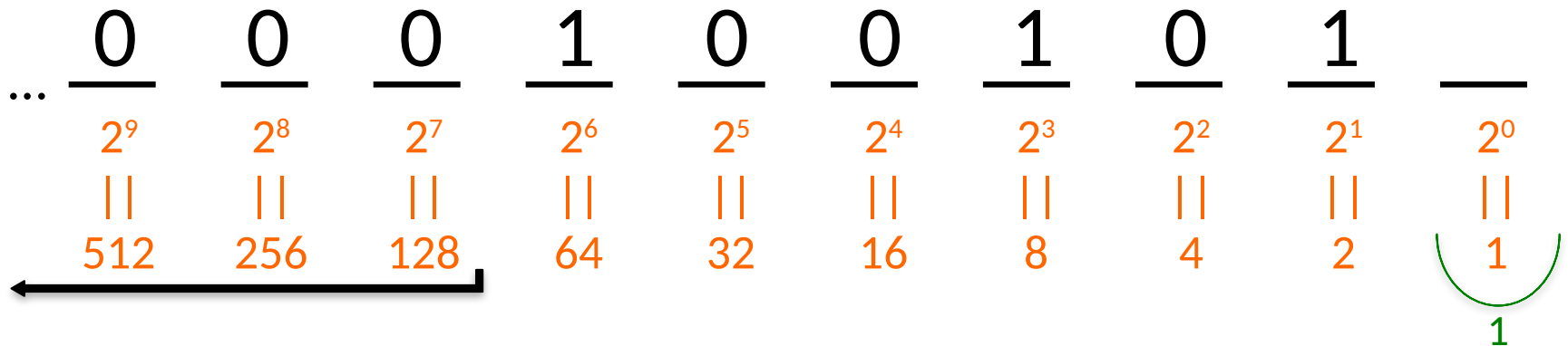
$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

$\begin{array}{r} 75 \\ \div 64 \\ \hline 11 \end{array}$	$\begin{array}{r} 11 \\ \div 8 \\ \hline 3 \end{array}$	$\begin{array}{r} 3 \\ \div 2 \\ \hline 1 \end{array}$
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(ii) decimal \rightarrow base b (demonstrated on $b=2$)

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



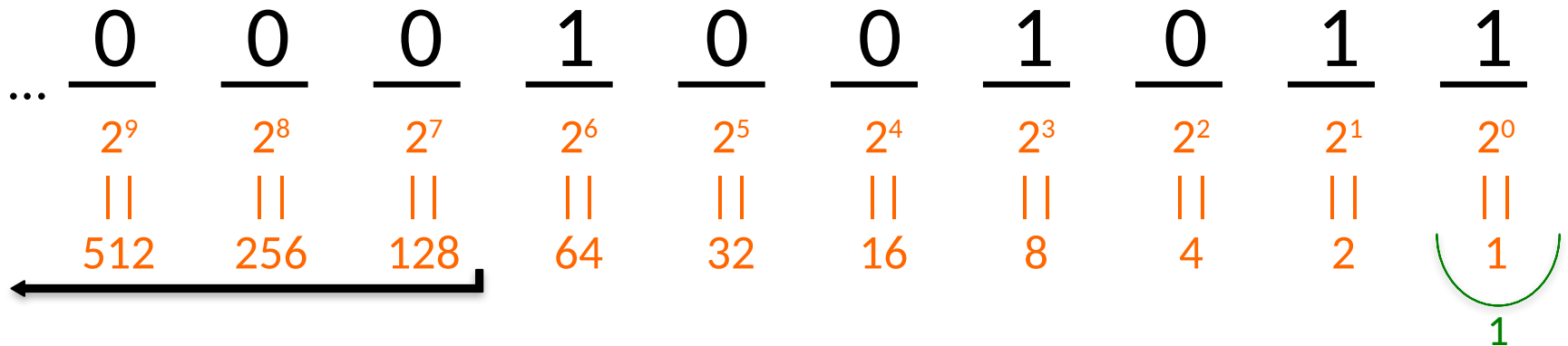
$$1 + 2 + 4 + 8 + 16 + 32 = 63$$

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

$$\begin{array}{r} 75 \\ \div 64 \\ \hline 11 \end{array} \quad \begin{array}{r} 11 \\ \div 8 \\ \hline 3 \end{array} \quad \begin{array}{r} 3 \\ \div 2 \\ \hline 1 \end{array}$$

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

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




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

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

$$\begin{array}{r} 75 \\ \div 64 \\ \hline 11 \end{array} \quad \begin{array}{r} 11 \\ \div 8 \\ \hline 3 \end{array} \quad \begin{array}{r} 3 \\ \div 2 \\ \hline 1 \end{array}$$


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

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

...	<u>0</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>1</u>	<u>1</u>
	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
										

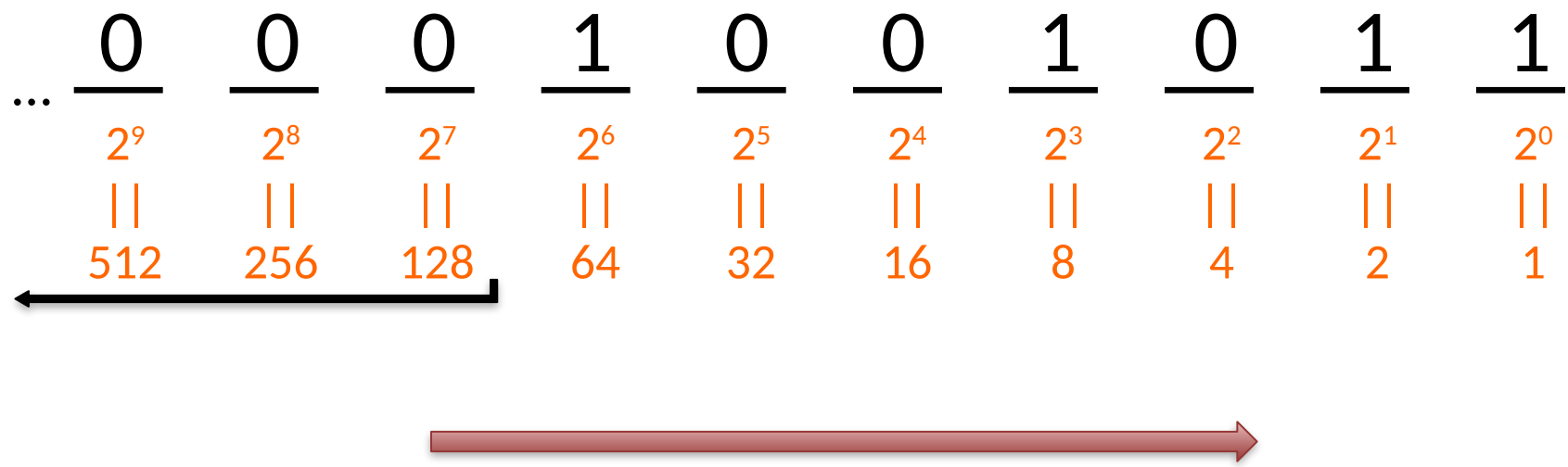
(ii) decimal \rightarrow base b (demonstrated on $b=2$)

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

...	<u>0</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>1</u>	<u>1</u>
	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 to base b (demonstrated on b=2)

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



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  N in decimal

(ii) N in decimal  N in base b

(iii) N in binary  N in hexadecimal

(iii) binary ← hexadecimal

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

[illegible]

$$(3b9)_{16} = (\quad)_{10}$$

(iii) binary ← hexadecimal

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

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

(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	

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

(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	

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

(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	

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

(iii) binary ← hexadecimal

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	

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

(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

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

(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

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

(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

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

$$\underline{1001}_2$$

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

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

$$\underbrace{1011}_b \underbrace{1001}_9)_{2}$$

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

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

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

$$(1101101\underbrace{0011})_2 = (\quad)_{16}$$

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

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

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

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

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

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

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

$$(\underbrace{011011010011}_3)_2 = (\quad)_{16}$$

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

$$(\underbrace{0110}_d \underbrace{1101}_3 \underbrace{0011}_{})_2 = ()_{16}$$

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

$$(\underbrace{0110}_6 \underbrace{1101}_d \underbrace{1001}_3)_2 = (\quad)_{16}$$

(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

$$(3b9)_{16} = (\underbrace{0011}_3 \underbrace{1011}_b \underbrace{1001}_9)_2$$

$$(\underbrace{0110}_6 \underbrace{1101}_d \underbrace{1001}_3)_2 = (6d3)_{16}$$

(iii) binary ← hexadecimal

$(011011010011)_2$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= 1 \cdot 2^0$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

$$= \underline{\hspace{10cm}}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

$$= \underline{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

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

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3)}_{\text{green}} \cdot 2^0 + \underbrace{\hspace{10em}}_{\text{orange}}$$

← hexadecimal

$$(011011010011)_2 =$$

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

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1) \cdot 2^4}_{\text{orange}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

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

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2) \cdot 2^4}_{\text{orange}}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

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

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{\hspace{10em}}_{\text{purple}}$$

← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{= 3} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{= 24} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{= 1024}$$

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

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + \dots) \cdot 2^8}_{\text{purple}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

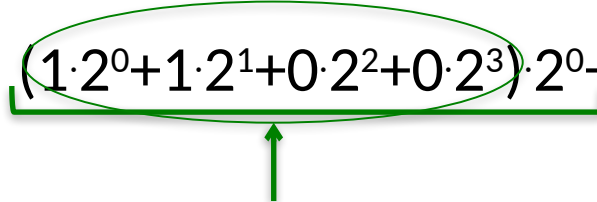
$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$


(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

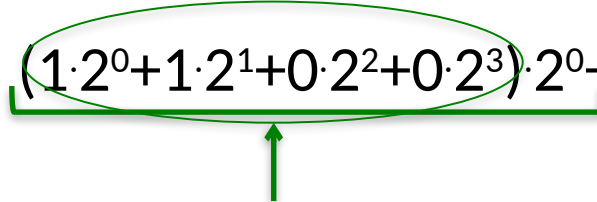
(iii) binary ← hexadecimal

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$


(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3)}_{\substack{\text{green oval} \\ \uparrow \\ 3}} \cdot 2^0 + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3)}_{\text{orange}} \cdot 2^4 + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3)}_{\text{purple}} \cdot 2^8$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}}$$

(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
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a	1010
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(iii) binary ← hexadecimal

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4	0100
5	0101
6	0110
7	0111
8	1000
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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
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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

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} \quad \quad \quad \begin{array}{c} \uparrow \\ 13 \end{array}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

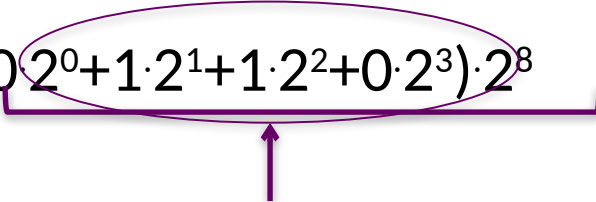
$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$


$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}}$$

(iii) binary ← hexadecimal

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0	0000
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8	1000
9	1001
a	1010
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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
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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

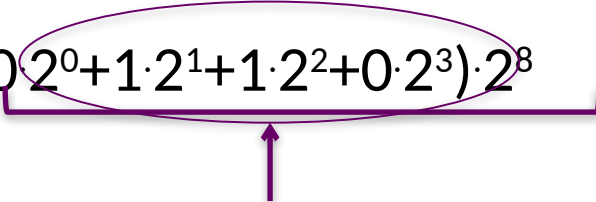
(iii) binary ← hexadecimal

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

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$


$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}}$$

(iii) binary ← hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple, circled}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{6}_{\text{purple, circled}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$=$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$=$$

$2^0 = 1$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$=$$

$2^0 = 1 = 16^0$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}}$$

2^4

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} \quad \begin{array}{c} \text{orange circle around } 2^4 \\ \text{orange arrow pointing to } 2^4 = 16 \end{array}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} \qquad \qquad \qquad \begin{array}{c} \text{orange circle around } 2^4 \\ \text{orange arrow pointing to } 2^4 = 16 = 16^1 \end{array}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} + \underbrace{(13) \cdot 16^1}_{\text{orange}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}} \quad \text{with a circle around } 2^8 \text{ and an arrow pointing to } 2^8 \text{ below}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} + \underbrace{(13) \cdot 16^1}_{\text{orange}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple, circled}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} + \underbrace{(13) \cdot 16^1}_{\text{orange}} \quad \begin{array}{l} \nearrow \\ 2^8 = (2^4)^2 \end{array}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple, circled}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} + \underbrace{(13) \cdot 16^1}_{\text{orange}}$$

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

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} + \underbrace{(13) \cdot 16^1}_{\text{orange}} + \underbrace{(6) \cdot 16^2}_{\text{purple}}$$

(iii) binary \leftarrow hexadecimal

$$(011011010011)_2 =$$

$$= \underbrace{1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3}_{\text{green}} + \underbrace{1 \cdot 2^4 + 0 \cdot 2^5 + 1 \cdot 2^6 + 1 \cdot 2^7}_{\text{orange}} + \underbrace{0 \cdot 2^8 + 1 \cdot 2^9 + 1 \cdot 2^{10} + 0 \cdot 2^{11}}_{\text{purple}}$$

$$= \underbrace{(1 \cdot 2^0 + 1 \cdot 2^1 + 0 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^0}_{\text{green}} + \underbrace{(1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3) \cdot 2^4}_{\text{orange}} + \underbrace{(0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 2^0}_{\text{green}} + \underbrace{(13) \cdot 2^4}_{\text{orange}} + \underbrace{(6) \cdot 2^8}_{\text{purple}}$$

$$= \underbrace{(3) \cdot 16^0}_{\text{green}} + \underbrace{(13) \cdot 16^1}_{\text{orange}} + \underbrace{(6) \cdot 16^2}_{\text{purple}}$$

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

Addition

Addition

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

Addition

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

10

Addition

$$\begin{array}{r} 325_{10} \\ + 692_{10} \\ \hline 7_{10} \end{array}$$

Addition

$$\begin{array}{r} 1 \\ 325_{10} \\ + \\ 692_{10} \\ \hline 17_{10} \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3} \overset{1}{2} 5_{10} \\ + 692_{10} \\ \hline 017_{10} \end{array}$$

Addition

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

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

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

$$\begin{array}{r} 365_8 \\ + 243_8 \\ \hline 8 \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3} \overset{1}{2} 5_{10} \\ + 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} \overset{1}{3} 65_8 \\ + 243_8 \\ \hline 0_8 \end{array}$$

Addition

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

$$\begin{array}{r} ^1 ^1 \\ 365_8 \\ + 243_8 \\ \hline 30_8 \end{array}$$

Addition

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

$$\begin{array}{r} ^1 ^1 \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3}\overset{1}{2}5_{10} \\ + 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} \overset{1}{3}\overset{1}{6}5_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} 10011100_2 \\ + 11011001_2 \\ \hline \end{array}$$

Addition

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

$$\begin{array}{r} \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} 10011100_2 \\ + 11011001_2 \\ \hline 2 \end{array}$$

Addition

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

$$\begin{array}{r} \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} 10011100_2 \\ + 11011001_2 \\ \hline 1_2 \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3}\overset{1}{2}5_{10} \\ + 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} \overset{1}{3}\overset{1}{6}5_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} 10011100_2 \\ + 11011001_2 \\ \hline 01_2 \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3} \overset{1}{2} 5_{10} \\ + 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} \overset{1}{3} \overset{1}{6} 5_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} 10011100_2 \\ + 11011001_2 \\ \hline 101_2 \end{array}$$

Addition

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

$$\begin{array}{r} ^1 ^1 \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} ^1 \\ 10011100_2 \\ + 11011001_2 \\ \hline 0101_2 \end{array}$$

Addition

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

$$\begin{array}{r} ^1 ^1 \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} ^1 ^1 \\ 10011100_2 \\ + 11011001_2 \\ \hline 10101_2 \end{array}$$

Addition

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

$$\begin{array}{r} ^1 ^1 \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} ^1 ^1 \\ 10011100_2 \\ + 11011001_2 \\ \hline 110101_2 \end{array}$$

Addition

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

$$\begin{array}{r} ^1 ^1 \\ 365_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} ^1 ^1 \\ 10011100_2 \\ + 11011001_2 \\ \hline 1110101_2 \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3}\overset{1}{2}5_{10} \\ + 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} \overset{1}{3}\overset{1}{6}5_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} \overset{1}{1}\overset{1}{0}\overset{1}{1}100_2 \\ + 11011001_2 \\ \hline 01110101_2 \end{array}$$

Addition

$$\begin{array}{r} \overset{1}{3}\overset{1}{2}5_{10} \\ + 692_{10} \\ \hline 1017_{10} \end{array}$$

$$\begin{array}{r} \overset{1}{3}\overset{1}{6}5_8 \\ + 243_8 \\ \hline 630_8 \end{array}$$

$$\begin{array}{r} \overset{1}{1}\overset{1}{0}\overset{1}{1}100_2 \\ + 11011001_2 \\ \hline 101110101_2 \end{array}$$

Subtraction

Subtraction

$$\begin{array}{r} 427_{10} \\ - 192_{10} \\ \hline \end{array}$$

Subtraction

$$\begin{array}{r} 427_{10} \\ - 192_{10} \\ \hline \end{array}$$

10

Subtraction

$$\begin{array}{r} 427_{10} \\ - 192_{10} \\ \hline 5_{10} \end{array}$$

Subtraction

$$\begin{array}{r} 12 \\ \cancel{427}_{10} \\ - \\ \underline{192}_{10} \\ 5_{10} \end{array}$$

Subtraction

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

Subtraction

$$\begin{array}{r} \overset{3}{\cancel{4}}\overset{12}{\cancel{2}}\overset{10}{7} \\ - \underset{10}{192} \\ \hline \underset{10}{35} \end{array}$$

Subtraction

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

Subtraction

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

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

Subtraction

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

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

8

Subtraction

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

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

Subtraction

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

$$\begin{array}{r} \overset{13_8}{\cancel{5}3\cancel{6}}_8 \\ - \quad \quad \quad \\ \underline{351}_8 \\ 5_8 \end{array}$$

Subtraction

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

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

Subtraction

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

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

Subtraction

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


$$\begin{array}{r} \overset{4}{\cancel{5}}\overset{13_8}{\cancel{3}}6_8 \\ - \\ \underline{351}_8 \\ 165_8 \end{array}$$

Signed Numbers

Signed Numbers


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

Signed Numbers

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


16	8	4	2	1
1	1	0	1	0


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

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


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

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

Signed Numbers


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


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

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

- Sign and Magnitude

Signed Numbers

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



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

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

- Sign and Magnitude



Signed Numbers

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


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


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

- Sign and Magnitude

1



Signed Numbers

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


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

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


- Sign and Magnitude

1000...011010



sign magnitude

Signed Numbers

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


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

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

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

Two's Complement

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

Two's Complement

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

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

$$(-26)_{10}$$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

$$\begin{array}{r} 00011010 \quad \swarrow 26 \\ + \quad \leftarrow -26 \\ \hline \quad \swarrow 2^8 \end{array}$$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

$$\begin{array}{r} 00011010 \quad \leftarrow 26 \\ + \\ \hline 10000000 \quad \leftarrow -26 \\ \hline 10000000 \quad \leftarrow 2^8 \end{array}$$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

$$\begin{array}{r} 00011010 \quad \leftarrow 26 \\ + \\ \hline 10000000 \quad \leftarrow 2^8 \end{array}$$

$0 \quad \leftarrow -26$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

$$\begin{array}{r} 00011010 \xleftarrow{26} \\ + \\ \hline 10000000 \xleftarrow{2^8} \end{array}$$

$10 \xleftarrow{-26}$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

$$\begin{array}{r} 0001\overset{1}{1}010 \quad \leftarrow 26 \\ + 110 \quad \leftarrow -26 \\ \hline 100000000 \quad \leftarrow 2^8 \end{array}$$

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

$$\begin{array}{r} \overset{1}{1} \overset{1}{1} \overset{1}{0} 10 \\ + 0110 \\ \hline 1000000000 \end{array}$$

Diagram illustrating the addition of 26 and -26 in 8-bit two's complement representation. The first row is 00011010 (26), the second row is 00000110 (-26), and the result is 10000000 (2⁸).

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

Diagram illustrating the addition of 26 and -26 in binary:

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

The result is 2^8 .

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

Diagram illustrating the addition of 26 and -26 in binary:

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

The result is 100000000, which is 2^8 .

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

Diagram illustrating the addition of 26 and -26 in binary:

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

The result is 2^8 .

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

1	1	1	1	1	1	1		
	0	0	0	1	1	0	1	0
+								
	1	1	1	0	0	1	1	0
<hr/>								
1	0	0	0	0	0	0	0	0

← 26

← -26

← 2⁸

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

The diagram illustrates the addition of 26 and -26 in 8-bit two's complement. The first row shows the binary representation of 26 as 00011010, with a green bracket under the last 7 bits and an orange arrow pointing to it from the label 26. The second row shows the binary representation of -26 as 11100110, with an orange oval around the entire 8-bit sequence and an orange arrow pointing to it from the label -26. A plus sign is placed between the two rows. A horizontal line is drawn below the second row. The third row shows the result of the addition as 10000000, with an orange arrow pointing to it from the label 2^8.

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

Two's Complement

$$(26)_{10} = (\underbrace{00011010}_{7 \text{ bits}})_{8 \text{ bit 2's complement}}$$

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

Diagram illustrating the addition of 26 and -26 in binary:

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

The result is 2^8 .

Two's Complement

Two's Complement

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

Two's Complement

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

Two's Complement

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

Diagram illustrating the bit weights for the 8-bit 2's complement representation (00101101):

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

Two's Complement

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

Diagram illustrating the 8-bit 2's complement representation of the decimal number 45. The binary sequence is 00101101, with bit positions 64, 32, 16, 8, 4, 2, and 1 indicated below the bits. The first two bits (00) are the sign bits, and the remaining six bits (101101) represent the magnitude.

Two's Complement

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

Diagram illustrating the bit weights for the 8-bit 2's complement representation (00101101):

Bit Position	Weight	Bit Value
7	128	0
6	64	0
5	32	1
4	16	0
3	8	1
2	4	1
1	2	0
0	1	1

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

Two's Complement

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

Diagram showing bit weights for the 8-bit number 00101101:

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


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

$$\begin{array}{r} + \\ \hline 10000000 \end{array}$$

-X
+X
 2^8

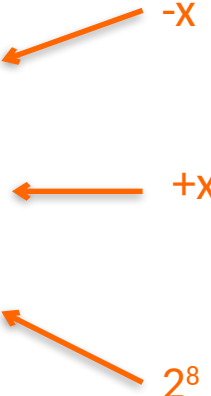
Two's Complement

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




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

$$\begin{array}{r} 11101010 \\ + \\ \hline 10000000 \end{array}$$



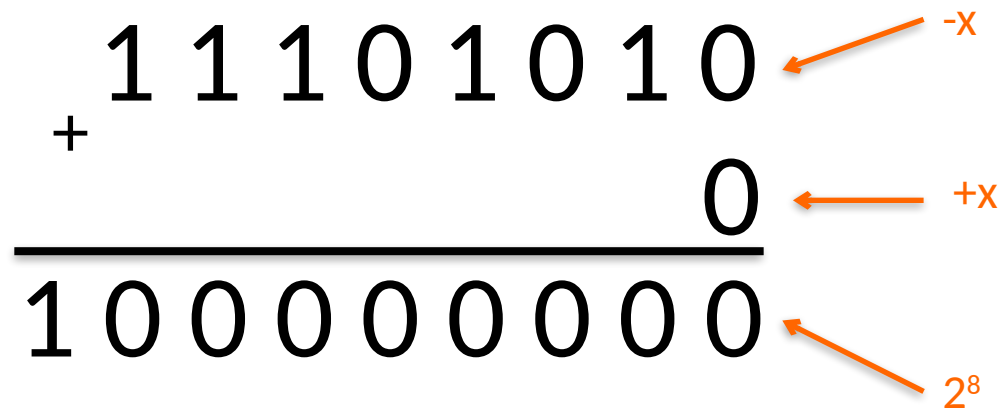
Two's Complement

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




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

$$\begin{array}{r} 11101010 \\ + \quad \quad \quad 0 \\ \hline 100000000 \end{array}$$



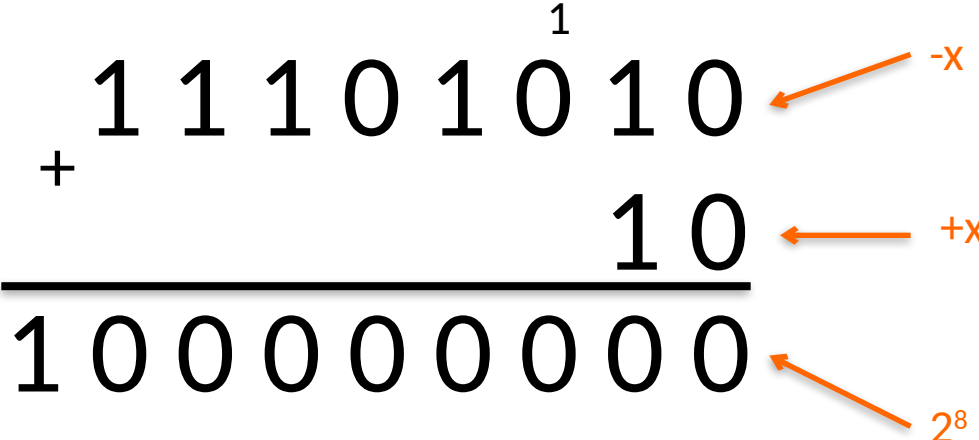
Two's Complement

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



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

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



Two's Complement

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

Note: In the original image, the bits of 00101101 are grouped by green brackets with weights 64, 32, 16, 8, 4, 2, 1 written below them.

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


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

Annotations in the original image:

- An arrow points to the rightmost '0' of the first number with the label $-X$.
- An arrow points to the '110' of the second number with the label $+X$.
- An arrow points to the leading '1' of the result with the label 2^8 .

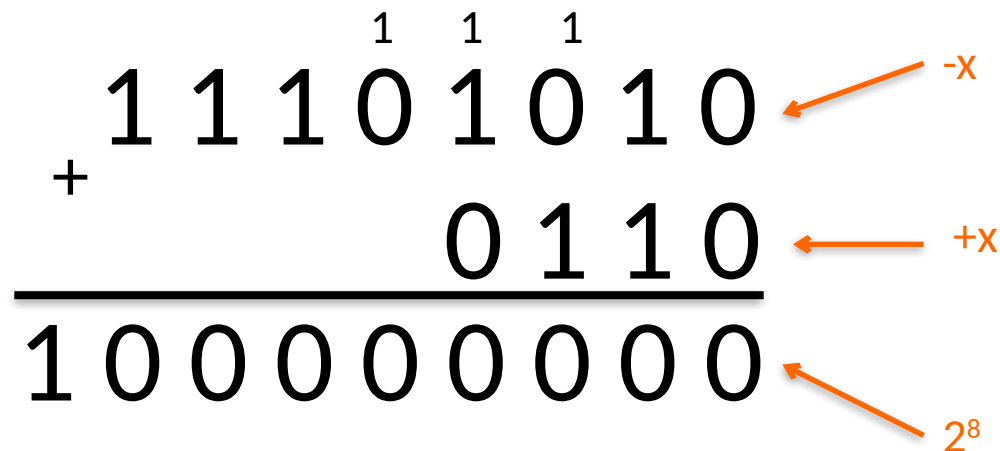
Two's Complement

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



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

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



Two's Complement

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

(Note: In the original image, the bits of 00101101 are grouped with green brackets and labeled with powers of 2: 64, 32, 16, 8, 4, 2, 1 from left to right.)


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

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

(Note: In the original image, there are orange arrows pointing to the right side of the addition: an arrow from the top row points to '-X', an arrow from the bottom row points to '+X', and an arrow from the result row points to '2^8'.)

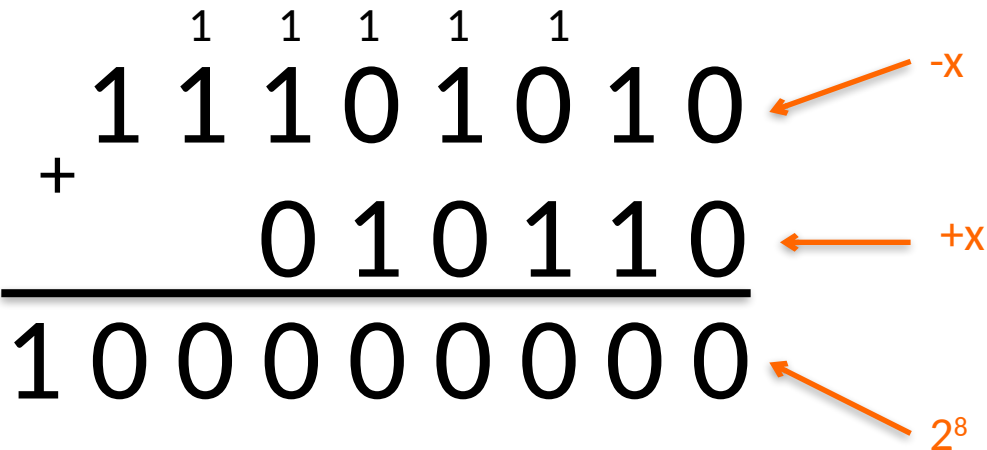
Two's Complement

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



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

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



Two's Complement

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

(Note: In the original image, the bits of 00101101 are grouped with green brackets and labeled with powers of 2: 64, 32, 16, 8, 4, 2, 1 from left to right.)

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

$$\begin{array}{r} \begin{array}{cccccc} 1 & 1 & 1 & 1 & 1 & 1 \end{array} \\ 11101010 \quad \leftarrow -X \\ + \quad 0010110 \quad \leftarrow +X \\ \hline 10000000 \quad \leftarrow 2^8 \end{array}$$

Two's Complement

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

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

Diagram illustrating the addition of two 8-bit numbers, resulting in a carry out of the 8th bit:

$$\begin{array}{r}
 \overset{1}{1} \quad \overset{1}{1} \quad \overset{1}{1} \quad \overset{1}{1} \quad \overset{1}{1} \quad \overset{1}{1} \quad \overset{1}{1} \quad \overset{1}{1} \\
 11101010 \quad \leftarrow -X \\
 + 00010110 \quad \leftarrow +X \\
 \hline
 10000000 \quad \leftarrow 2^8
 \end{array}$$

Two's Complement

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

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

Diagram illustrating the addition of two 8-bit numbers in binary:

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

The result is 2^8 .

Two's Complement

$(00101101)_2$ 8 bit 2's complement = $(45)_{10}$

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

Diagram illustrating the addition of two 8-bit numbers in two's complement:

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

The result is 2^8 , indicating an overflow.

Two's Complement

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

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

Diagram illustrating the addition of two 8-bit numbers, resulting in a value outside the 8-bit range:

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

The result, 2^8 , is outside the 8-bit range.