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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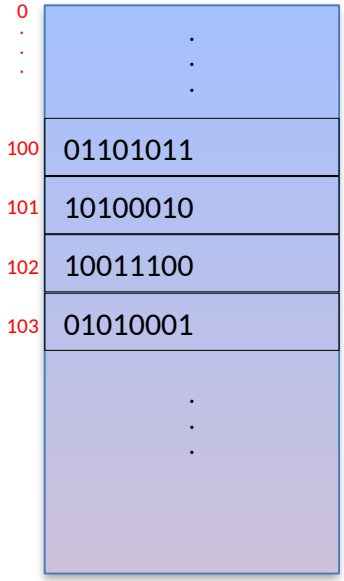
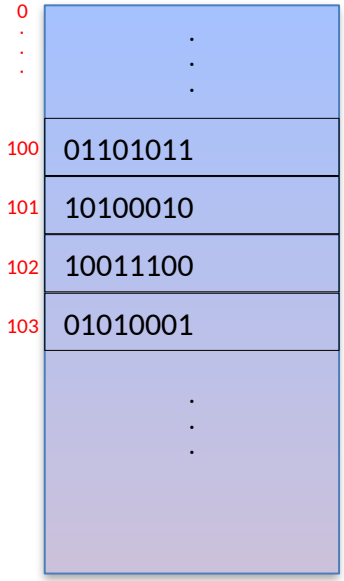


Digital Data

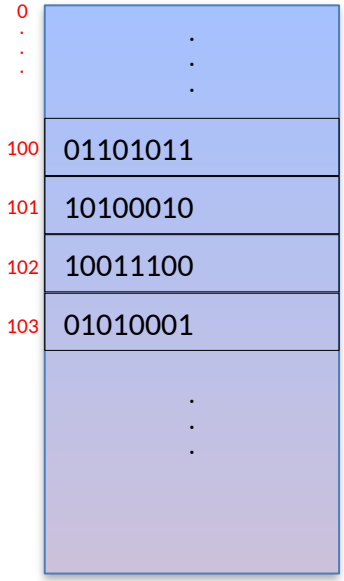
- Data in the computer's memory is represented using units that can each be in one of 2-states (0 or 1).

- Data is represented digitally, using binary numbers



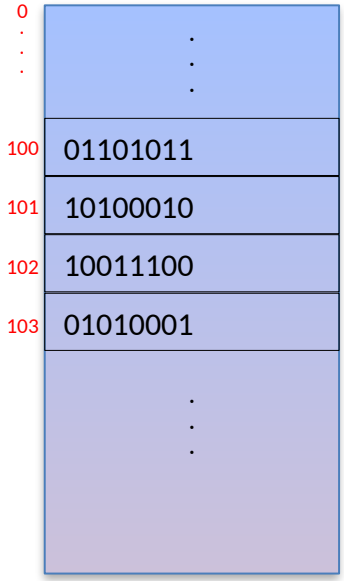
Digital Data

- 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



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



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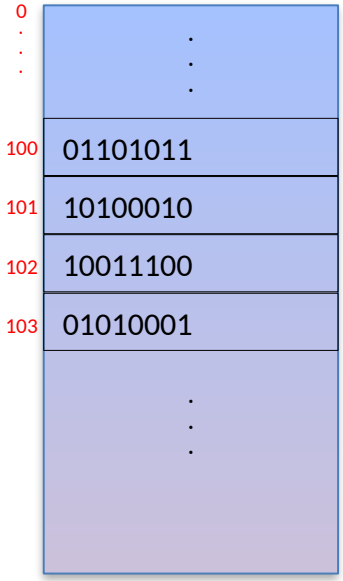
- Kinds of data:
  - Numbers: Represented in binary
  - Text



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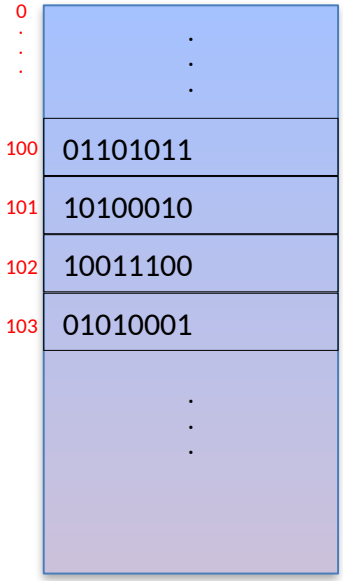
  - Text
  - Images



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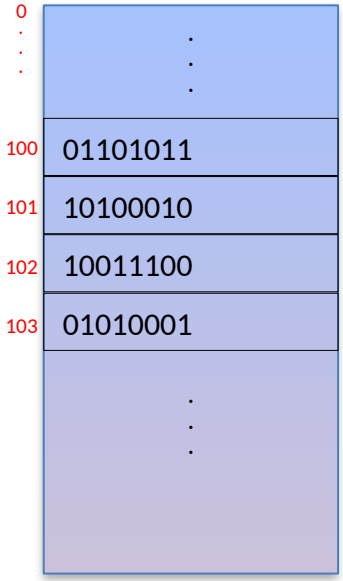
  - Video



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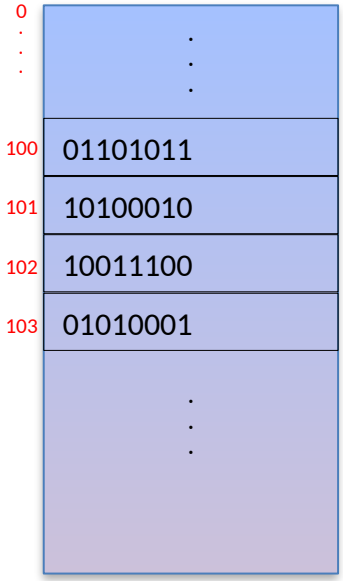
  - Numbers: Represented in binary
  - Text
  - Images
  - Video
  - Audio



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

Hello World!

Digital Data

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

Hello World!

Digital Data

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

Hello World!

Digital Data

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

Hello World!

72

Digital Data

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

Hello World!

Digital Data

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

Hello World!

72 101

Digital Data

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

Hello World!

72 101

Digital Data

Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char
32	[space]	48	0	64	@	80	P	96	`	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
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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

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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
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38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
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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 is represented digitally, using binary numbers

- Kinds of data:
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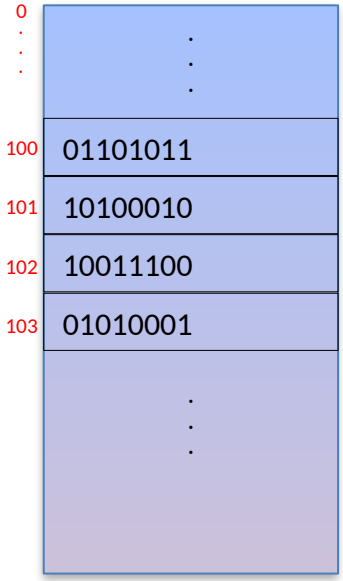
  - Text
  - Images
  - Video
  - Audio



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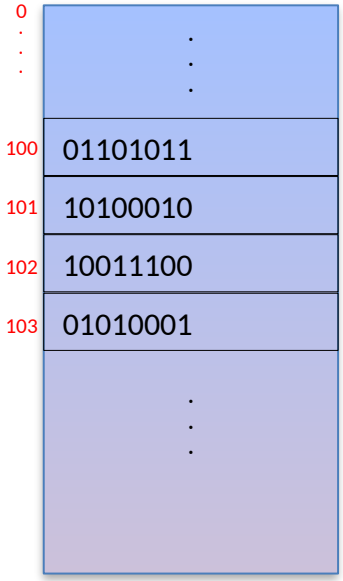
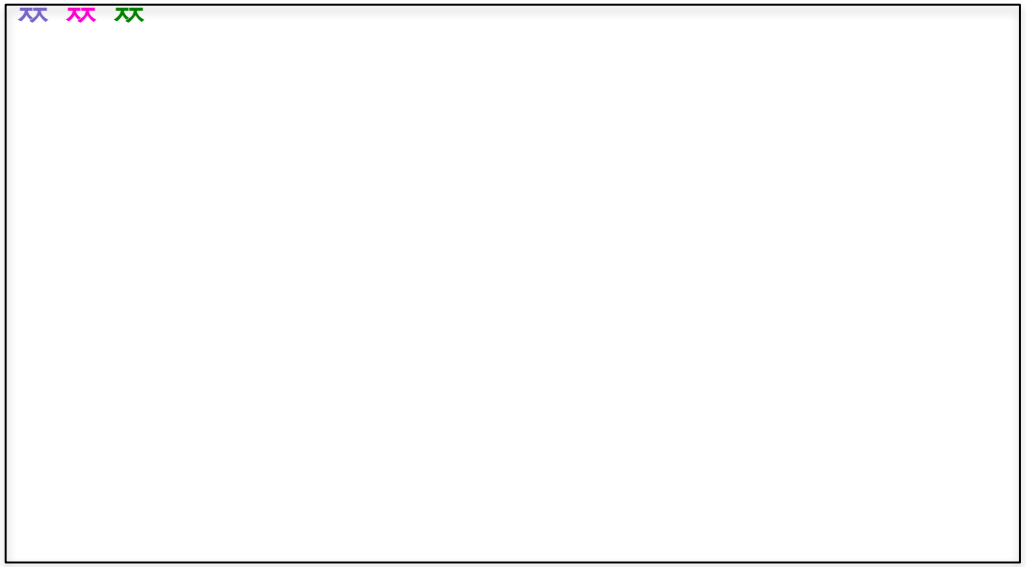


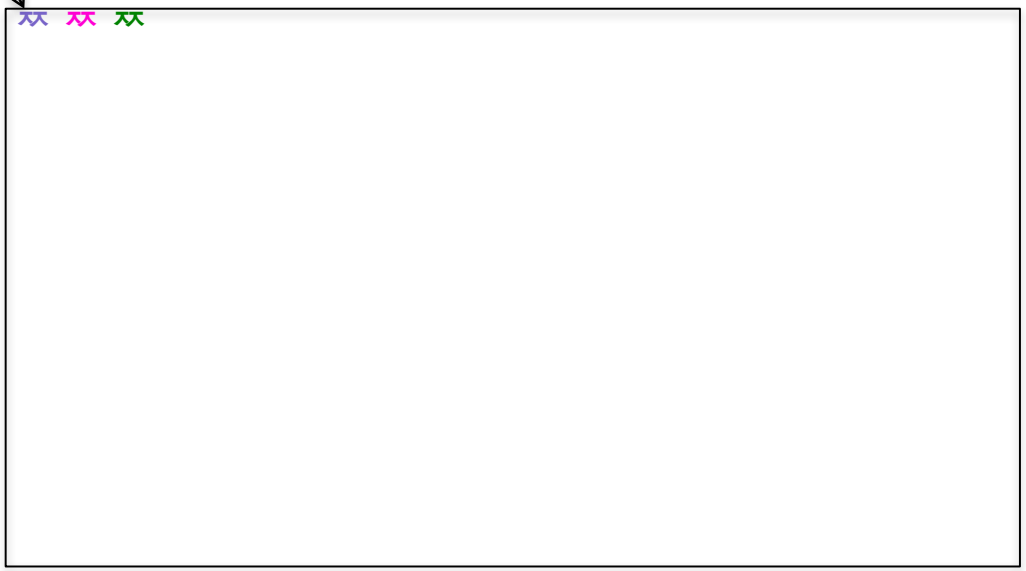
Digital Data

Digital Data



Digital Data

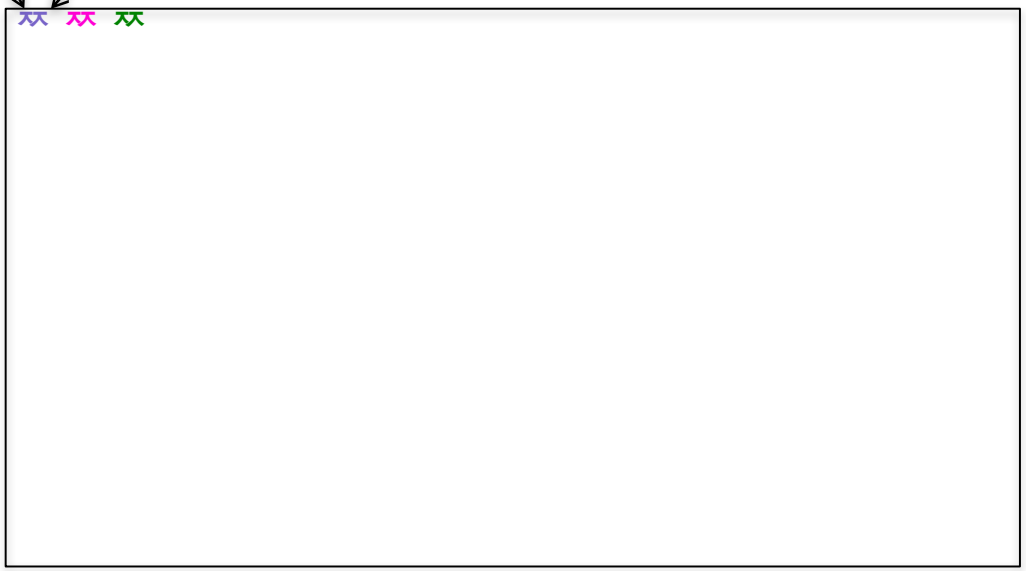
(120, 100, 200)



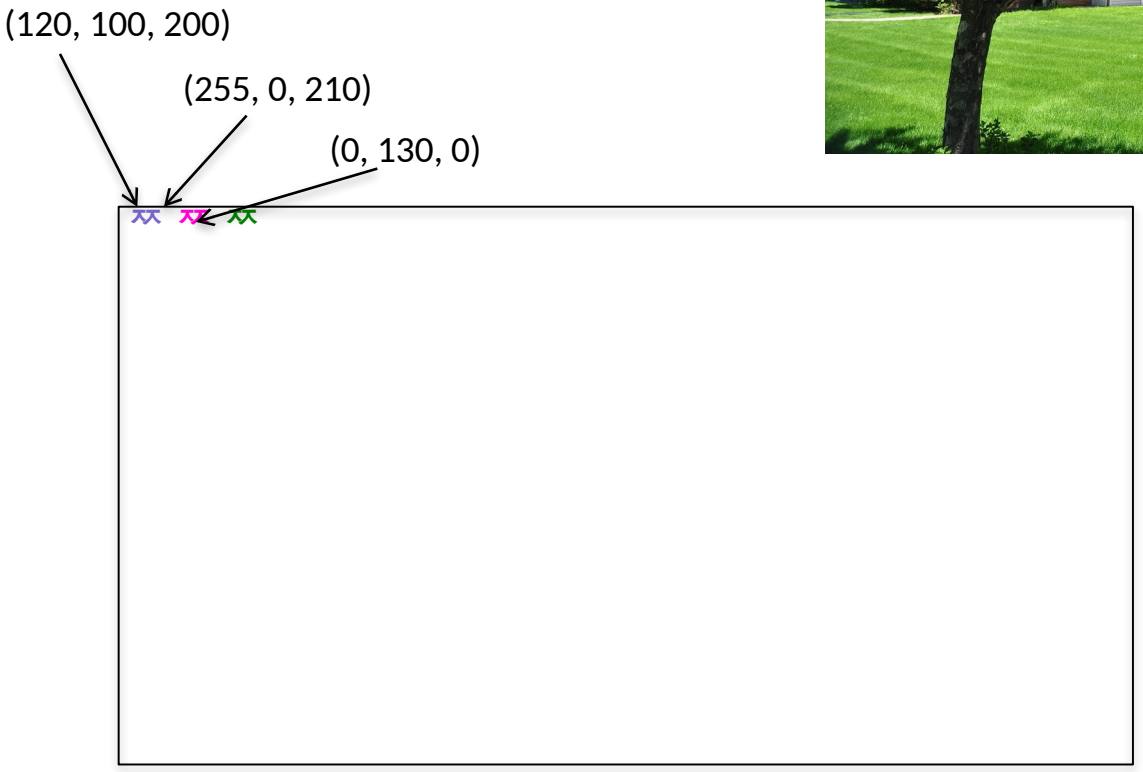
Digital Data

(120, 100, 200)

(255, 0, 210)



Digital Data



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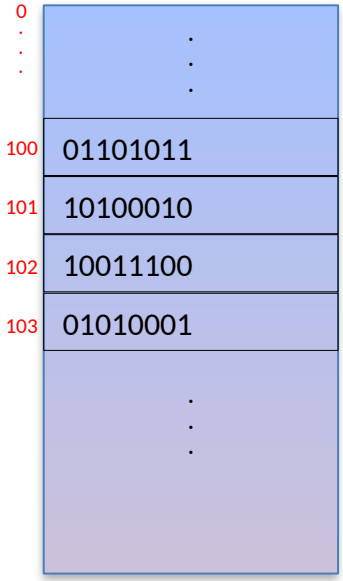

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- Kinds of data:
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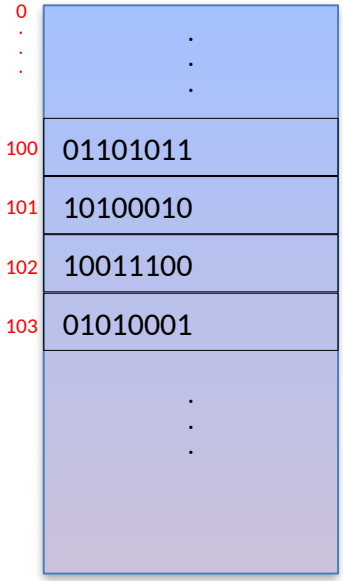
  - Text: Each character is mapped to a number
  - Images: Matrix of pixels' colors. Each color is represented as (R,G,B) levels
  - Video
  - Audio



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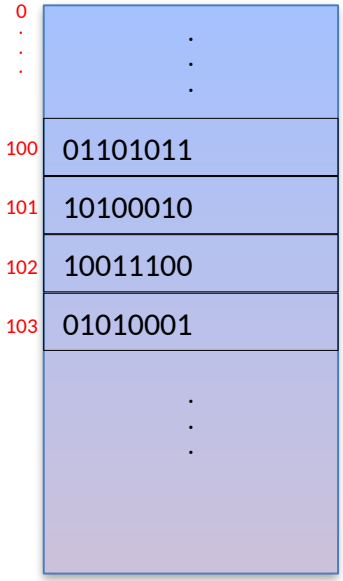
  - Video: Sequence of images
  - Audio



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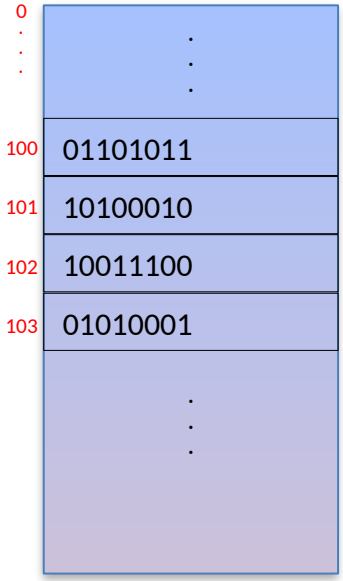
  - Text: Each character is mapped to a number
  - Images: Matrix of pixels' colors. Each color is represented as (R,G,B) levels
  - Video: Sequence of images
  - Audio: Sampled voltage levels



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
1
2
3
4
5
6
7
8
9
10

11
12
…
19

Lets Count

Decimal (base 10)

0
1
2
3
4
5
6
7
8
9
10

11
12
…
19
20

Lets Count

Decimal (base 10)

0
1
2
3
4
5
6
7
8
9
10

11
12
…
19
20
21
…

Lets Count

Decimal (base 10)

0
1
2
3
4
5
6
7
8
9
10

11
12
…
19
20
21
…
99

Lets Count

Decimal (base 10)

0
1
2
3
4
5
6
7
8
9
10

11
12
…
19
20
21
…
99
100

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
1
2
3
4
10
11
12
13
14
20

21
22
…

Lets Count

base 5

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

Lets Count

base 5

0
1
2
3
4
10
11
12
13
14
20

21
22
…
44
100

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

Lets Count

Octal (base 8)

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

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

Lets Count

Octal (base 8)

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

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

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

1

2

3

4

5

6

7

8

9

Lets Count

Hexadecimal (base 16)

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

0

1

2

3

4

5

6

7

8

9

a

Lets Count

Hexadecimal (base 16)

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

0

1

2

3

4

5

6

7

8

9

a

b

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

$(13)_{10} = (15)_{8} = (23)_{5} = (\quad\quad)_{2}$

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 b_1 → Representation of number N in base b_2

Base Conversions

Base Conversions

(i) N in base b N in decimal

Base Conversions

(i) N in base b 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 ␣ decimal

(i) base b ␣ decimal

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

(i) base b ␣ decimal

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

(i) base b ␣ decimal

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

(i) base b ␣ decimal

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

1

(i) base b ␣ decimal

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

(i) base b ␣ decimal

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

10 1

(i) base b ␣ decimal

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

100 10 1

(i) base b ␣ decimal

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

100 10 1

| |

10^2

(i) base b ␣ decimal

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

100 10 1

| | |

10^2 10^1

(i) base b ␣ decimal

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

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

(i) base b ␣ decimal

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

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

(i) base b ␣ decimal

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

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

(i) base b ␣ decimal

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

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

(i) base b ␣ decimal

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

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

(i) base b ⊔ decimal

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

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

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

(i) base b ⌴ decimal

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

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

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

(i) base b ⌴ decimal

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

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

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

1

(i) base b ⌴ decimal

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

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

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

1

(i) base b ⌴ decimal

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

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

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

8 1

(i) base b ⌴ decimal

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

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

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

8 1

(i) base b ⌴ decimal

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

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

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

64 8 1

(i) base b ⌴ decimal

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

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

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

64 8 1
||
8^2

(i) base b ⟶ decimal

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

(i) base b ⌴ decimal

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

1

(i) base b ⟶ decimal

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

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

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

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

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

2 1

(i) base b ⟶ decimal

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

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

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

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

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

4 2 1

(i) base b ⟶ decimal

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

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

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

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

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

8 4 2 1

(i) base b ⌴ decimal

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

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

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

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

(i) base b ⟶ decimal

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

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

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

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

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

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

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

16^2 16^1 16^0

(i) base b ⌴ decimal

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

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

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

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

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

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

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

16^2 16^1 16^0

(i) base b ⊔ decimal

$$(\underbrace{3}_{\substack{100\\ \|\\ 10^2}}\ \underbrace{7}_{\substack{10\\ \|\\ 10^1}}\ \underbrace{5}_{\substack{1\\ \|\\ 10^0}})_{10} = 5\cdot 10^0 + 7\cdot 10^1 + 3\cdot 10^2 = 375$$

$$(\underbrace{1}_{\substack{64\\ \|\\ 8^2}}\ \underbrace{2}_{\substack{8\\ \|\\ 8^1}}\ \underbrace{5}_{\substack{1\\ \|\\ 8^0}})_{8} = 5\cdot 8^0 + 2\cdot 8^1 + 1\cdot 8^2 = 85$$

$$(\underbrace{1}_{\substack{8\\ \|\\ 2^3}}\ \underbrace{0}_{\substack{4\\ \|\\ 2^2}}\ \underbrace{1}_{\substack{2\\ \|\\ 2^1}}\ \underbrace{1}_{\substack{1\\ \|\\ 2^0}})_{2} = 1\cdot 2^0 + 1\cdot 2^1 + 0\cdot 2^2 + 1\cdot 2^3 = 11$$

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

(i) base b ⌴ decimal

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

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

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

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

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

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

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

16^2 16^1 16^0

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

Base Conversions

(i) N in base b 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 ␣ base b (demonstrated on b=2)

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

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

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

… — — — — — — — — — —

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

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

… — — — — — — — — — —

2^0

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

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

… — — — — — — — — — —

2^1 2^0

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

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

… — — — — — — — — — —

2^2 2^1 2^0

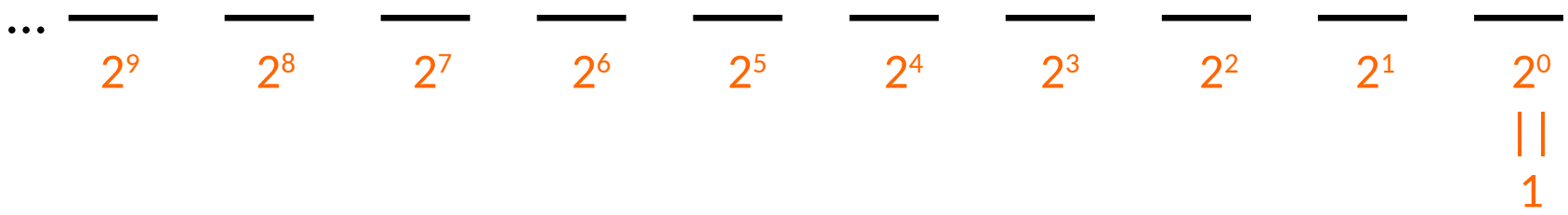
(ii) decimal ⊔ base b (demonstrated on b=2)

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

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

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

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



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

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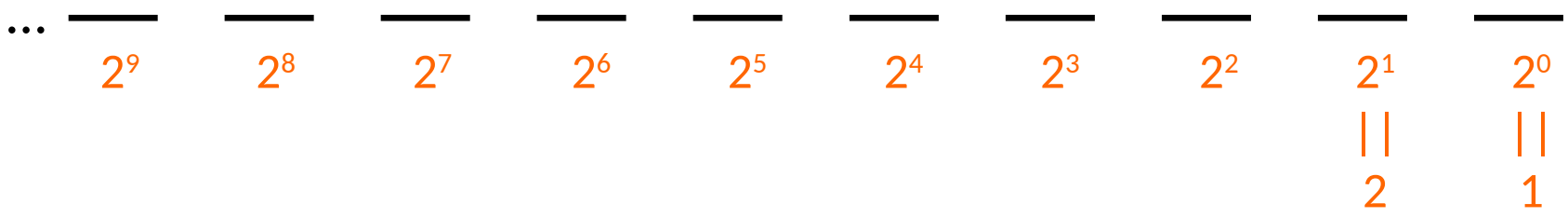

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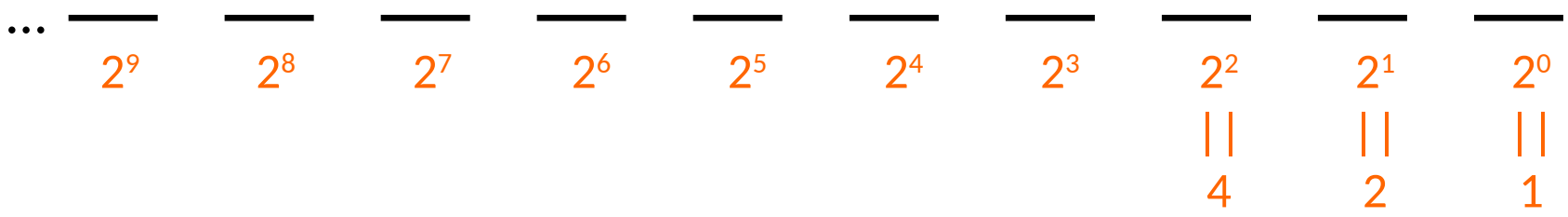

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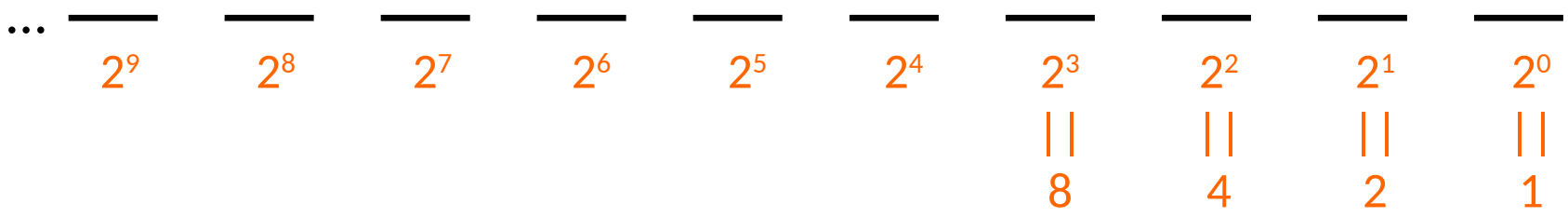

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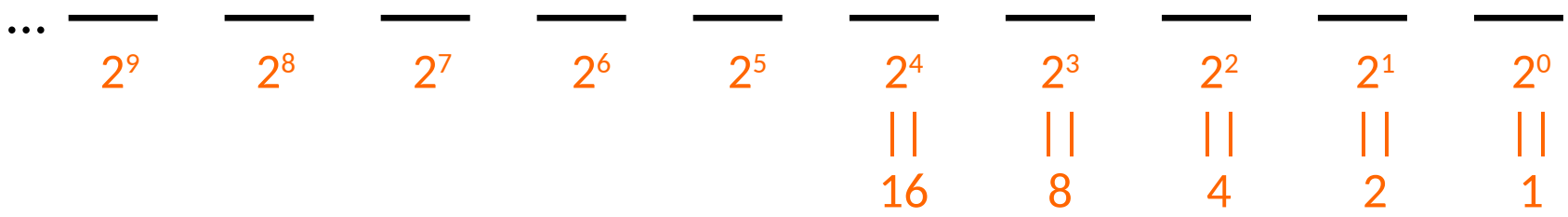

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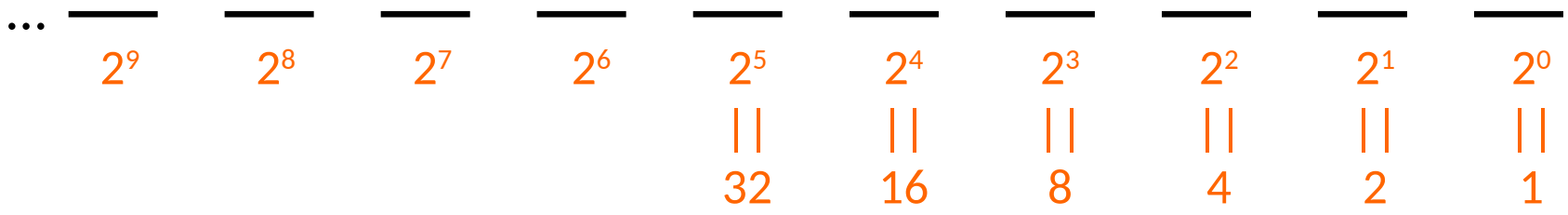

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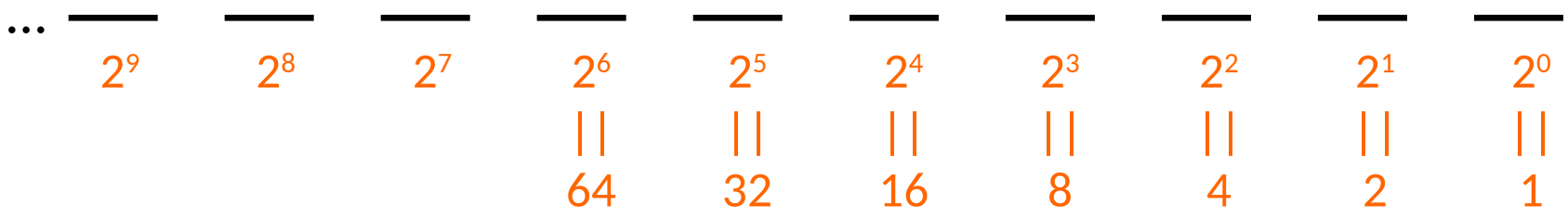


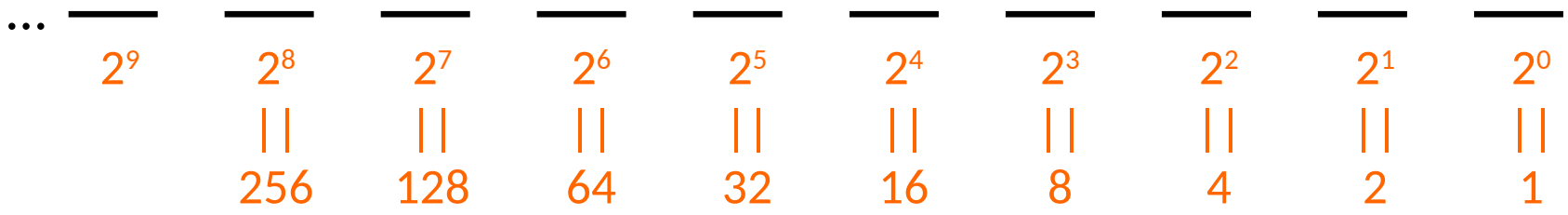
(ii) decimal ␣ base b (demonstrated on b=2)

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

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

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

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



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

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

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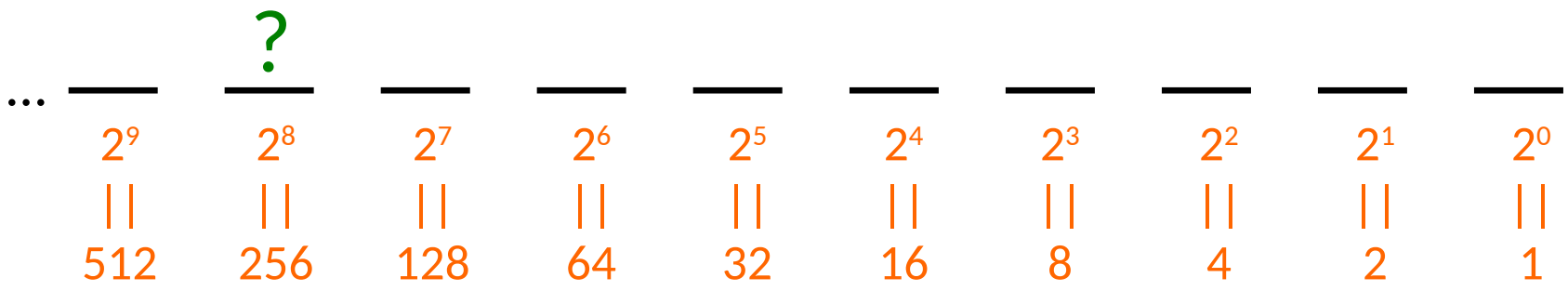
$$(75)_{10} = (\qquad\qquad)_2$$



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

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

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

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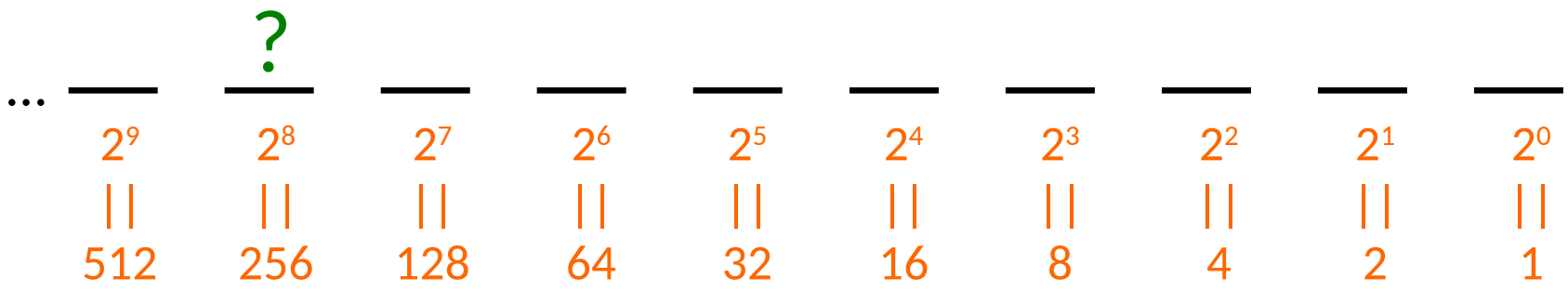

(ii) decimal ␣ base b (demonstrated on b=2)

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

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

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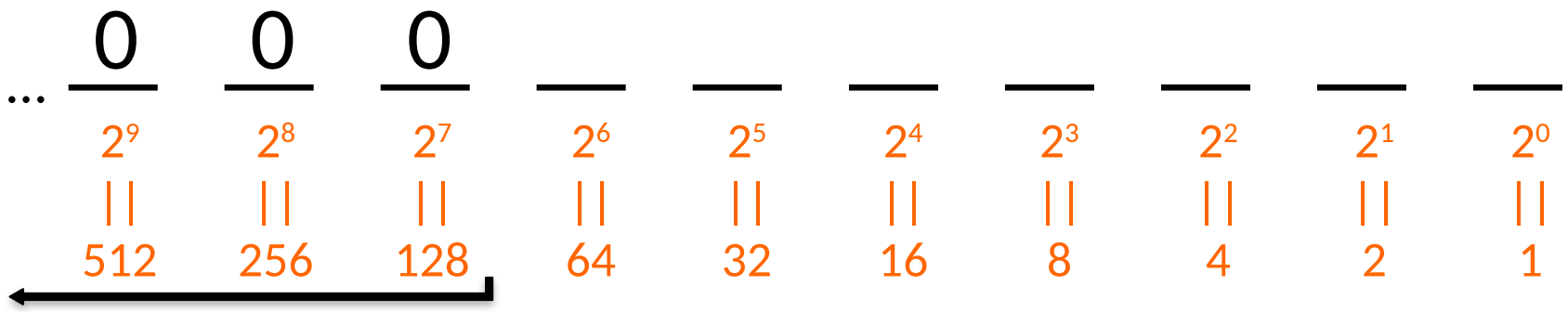
$$(75)_{10} = (\qquad\qquad)_2$$



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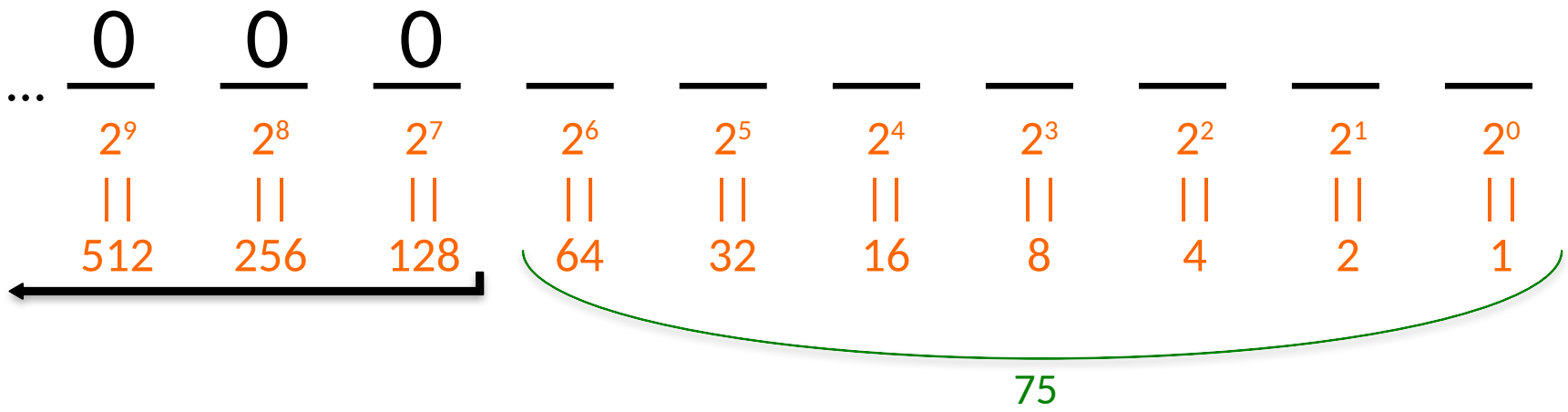

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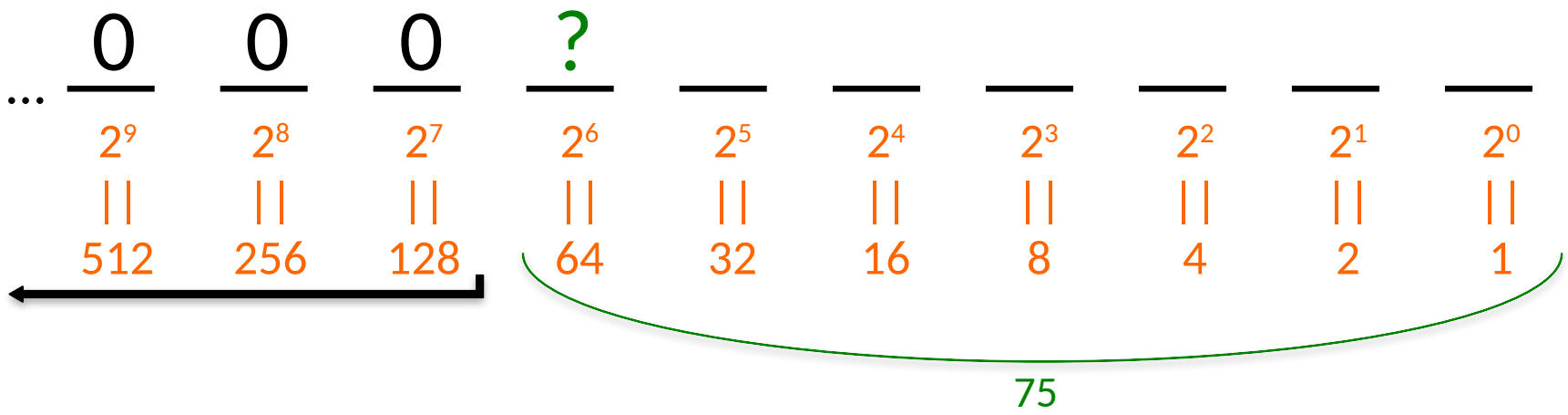

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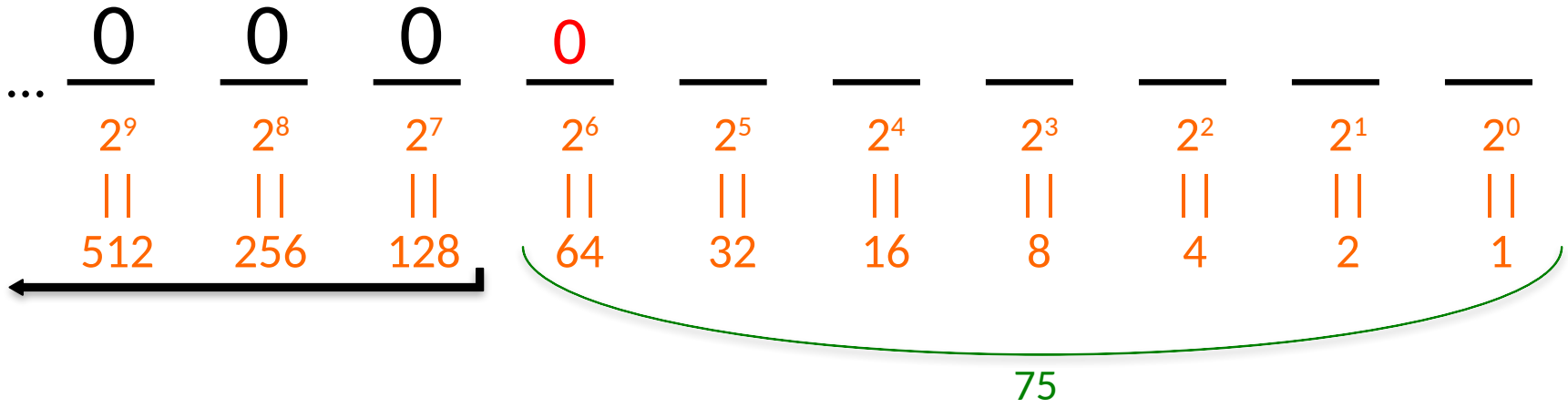

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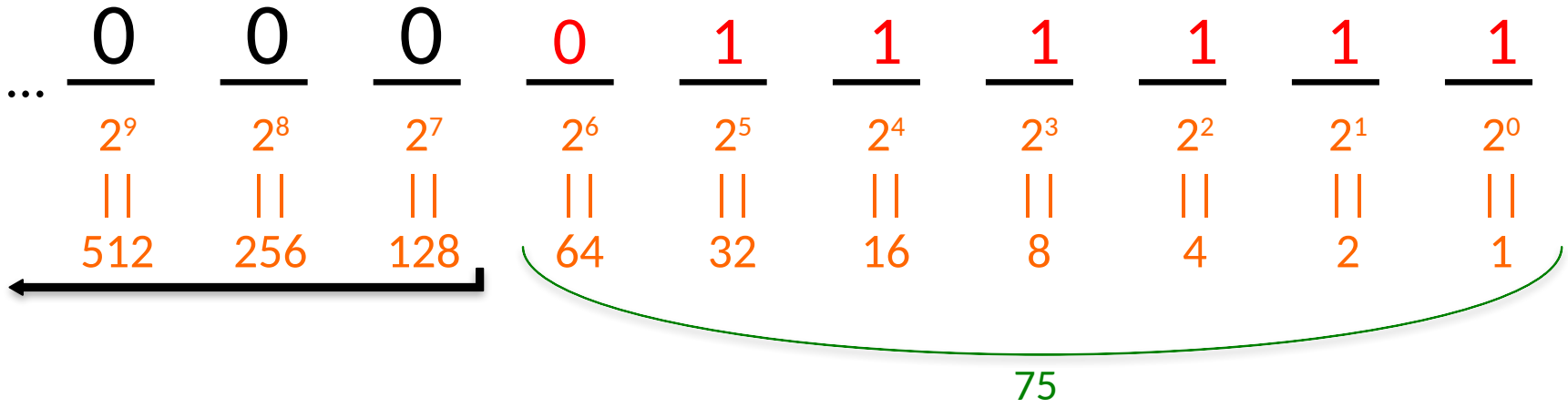

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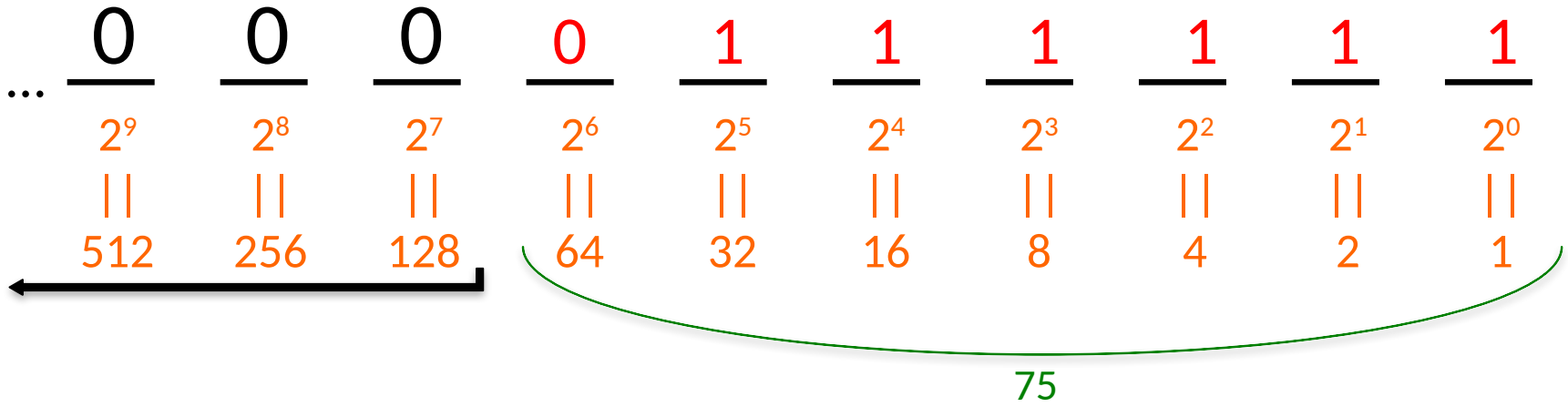
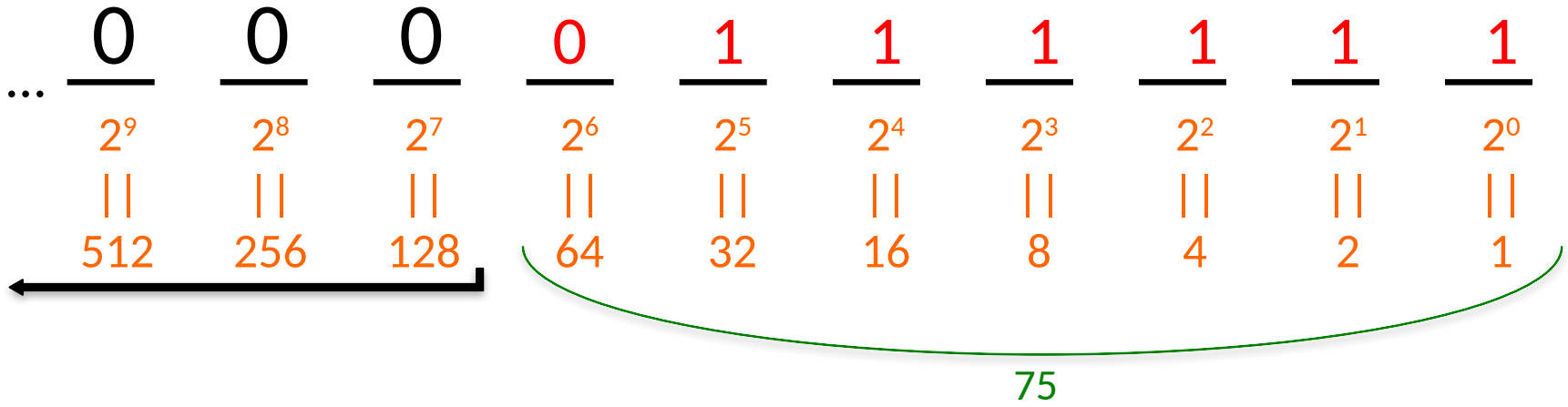


1 + 2 + 4 + 8 + 16 + 32 = 63

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

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



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

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

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

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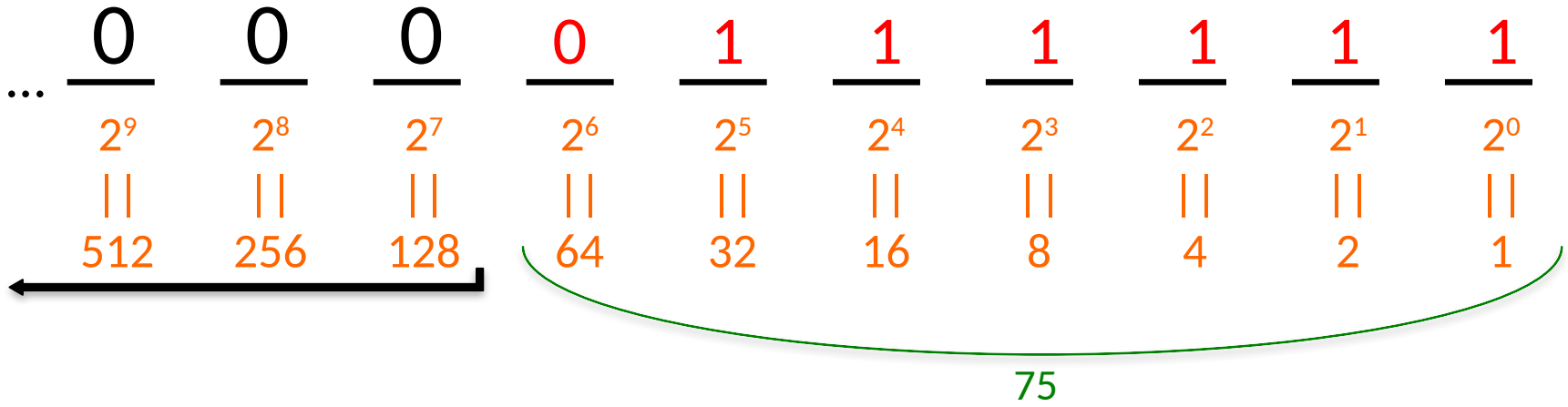

$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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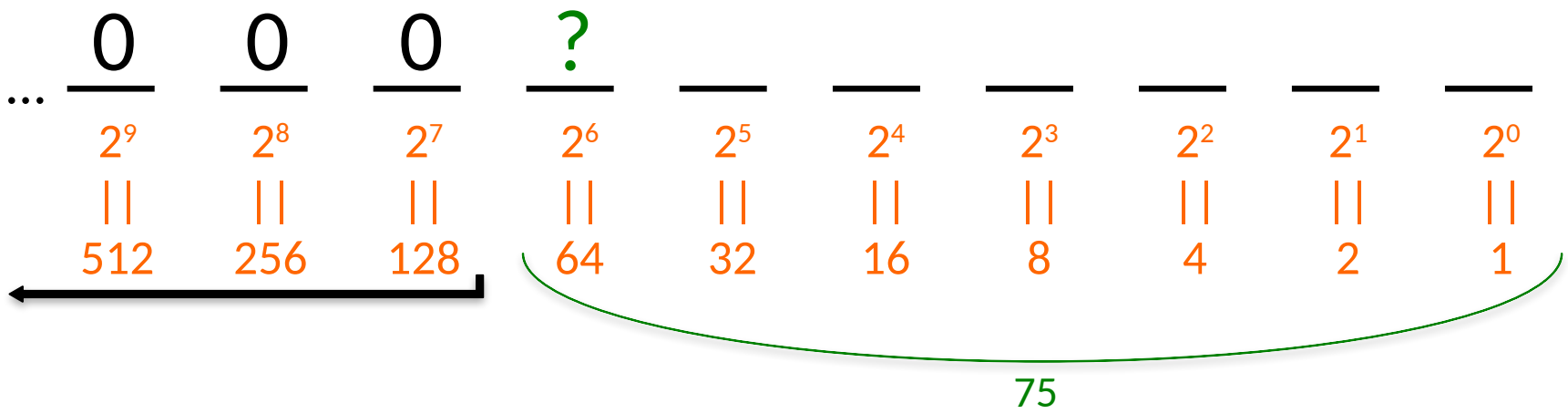
$$(75)_{10} = (\qquad\qquad)_2$$



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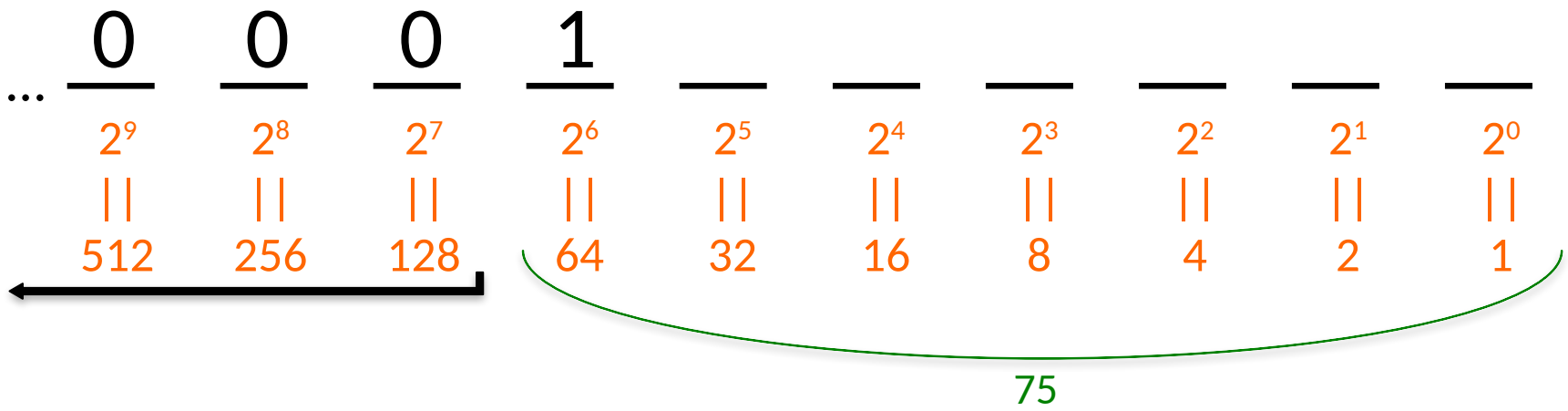

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(ii) decimal ␣ base b (demonstrated on b=2)

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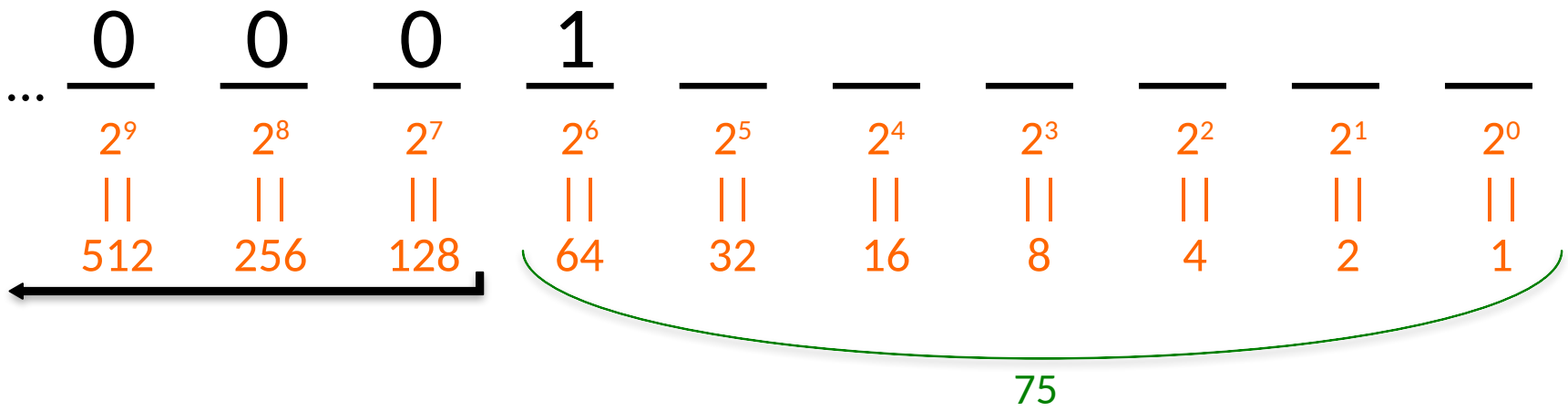


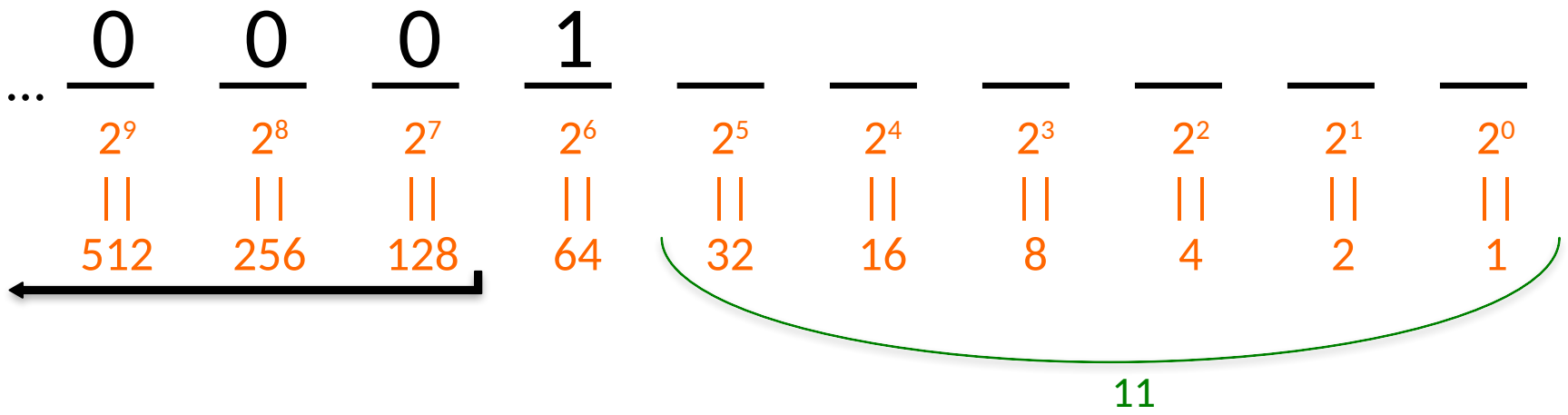
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

75
- 64
11

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

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



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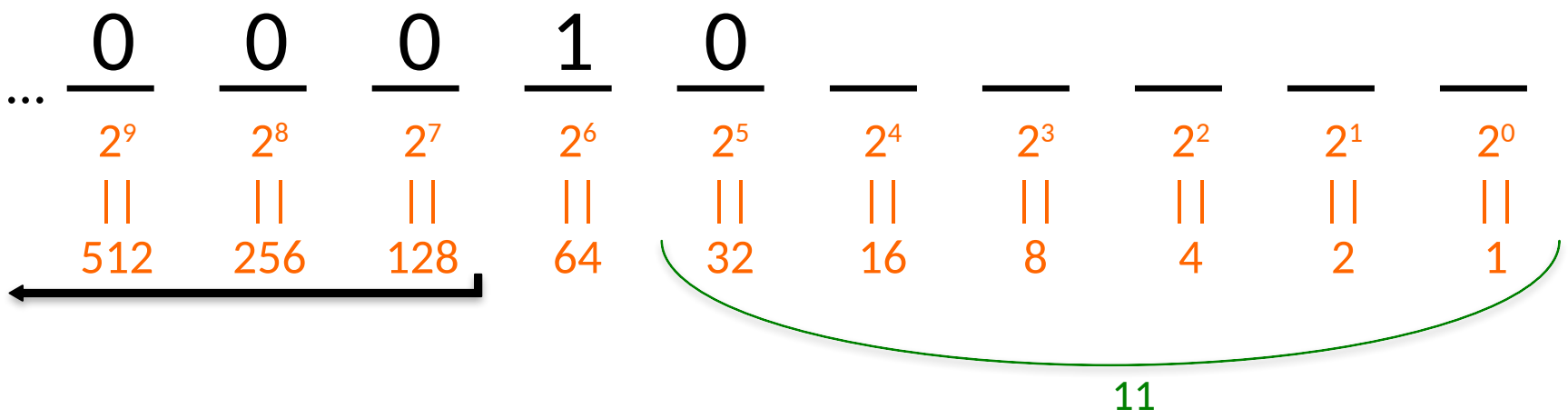

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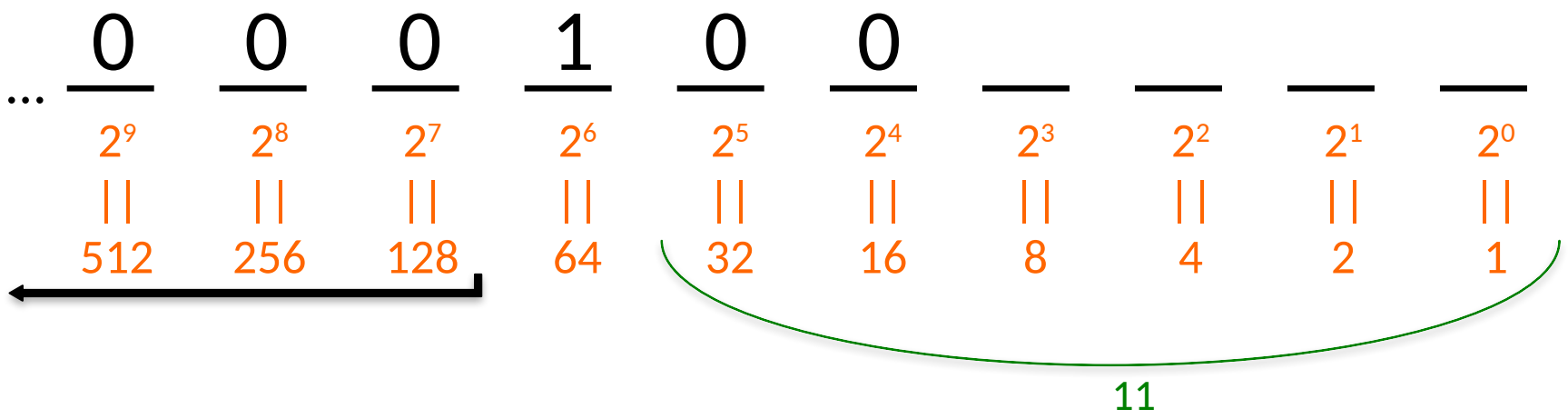

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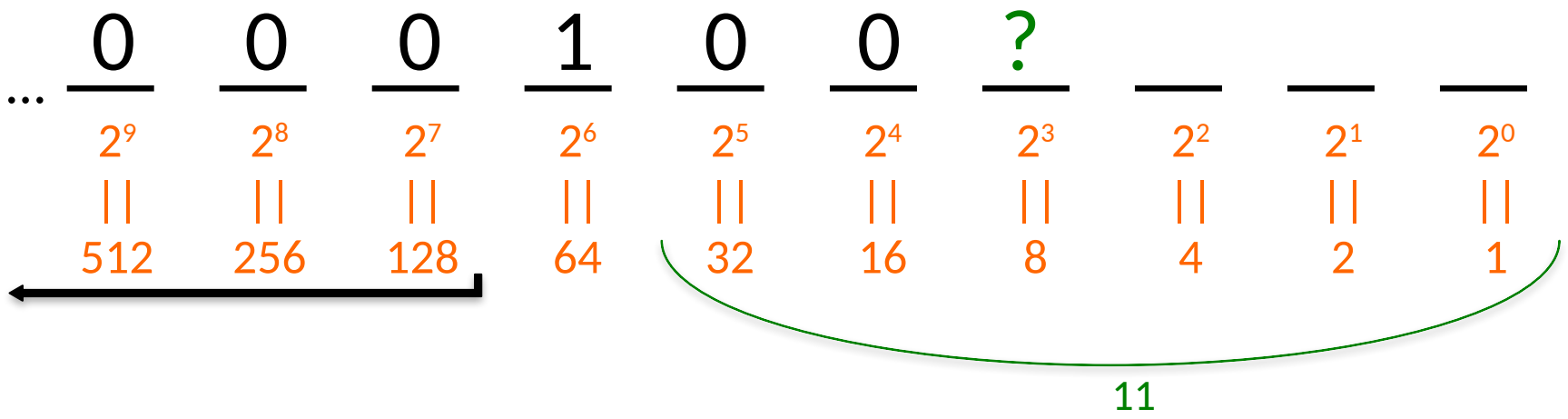

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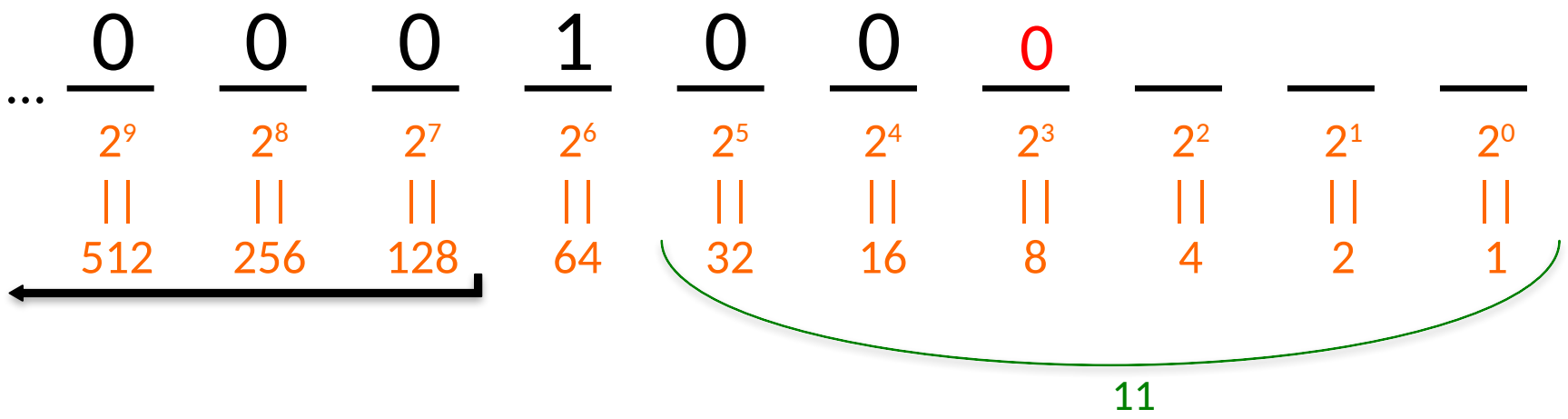

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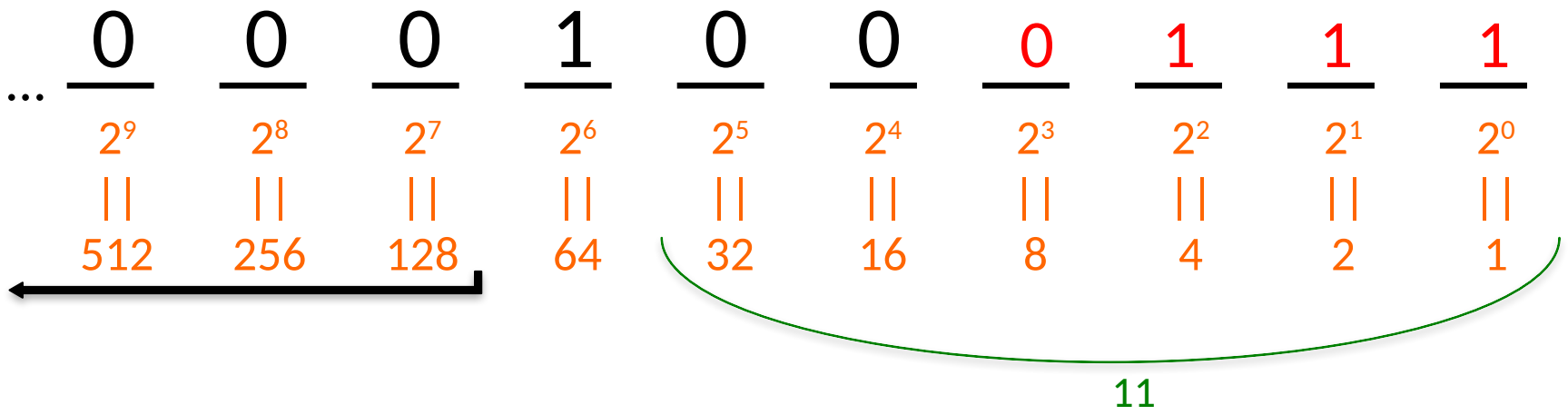

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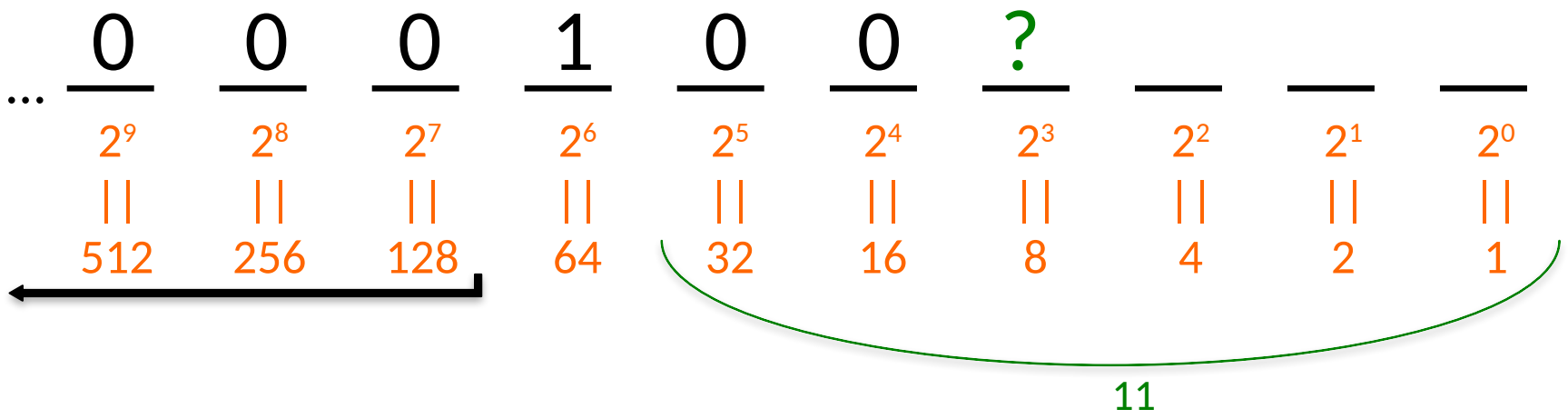

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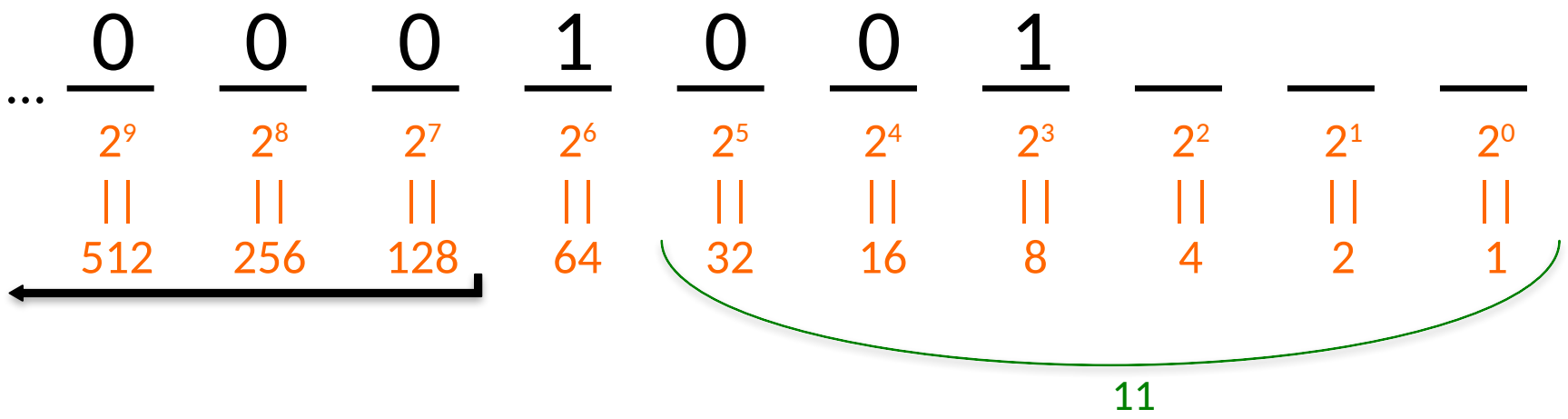

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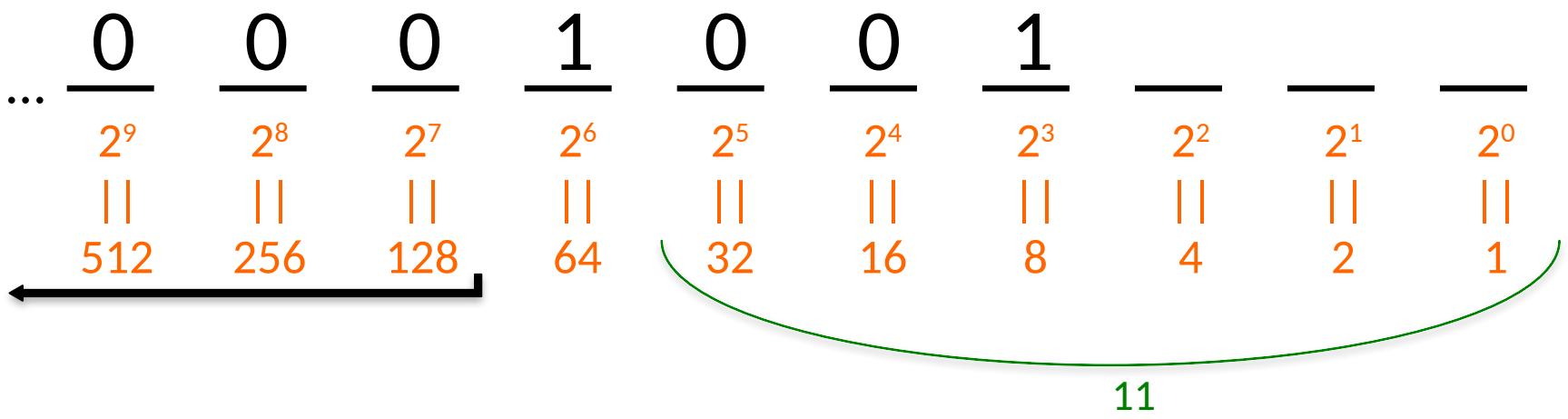


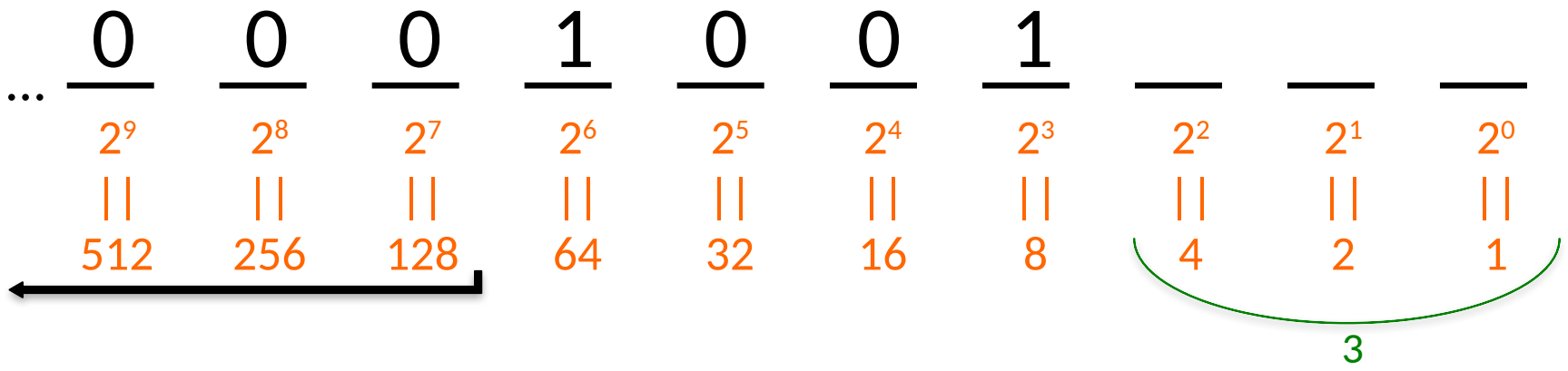
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

75	11
- 64	- 8
11	3

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

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



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75	11
- 64	- 8
11	3

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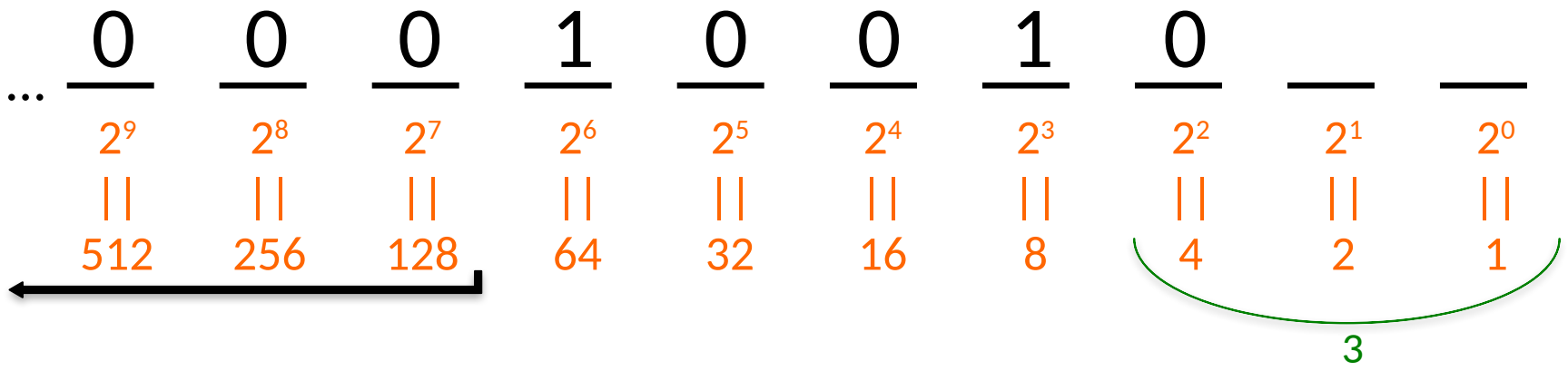

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11	3

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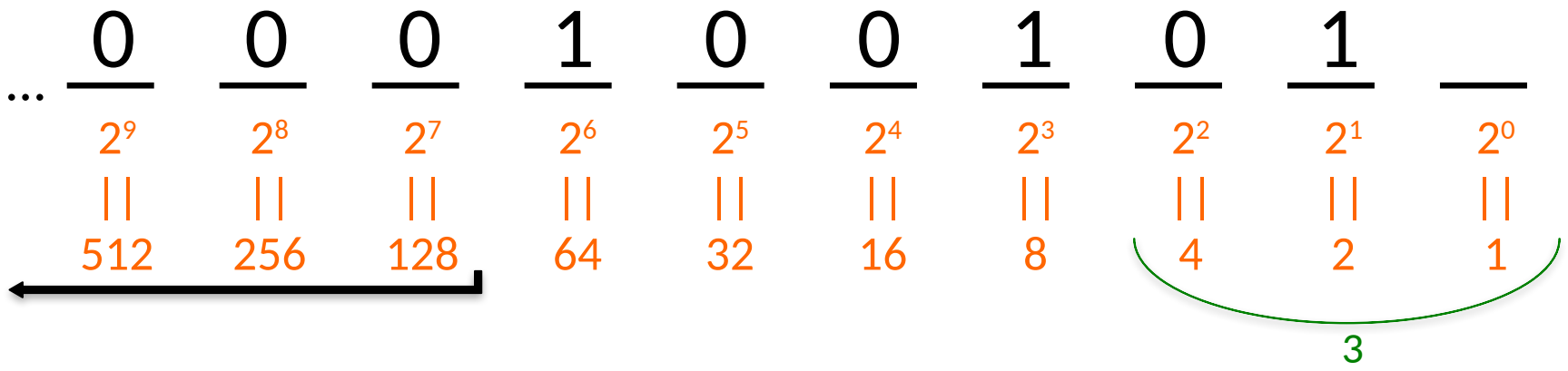

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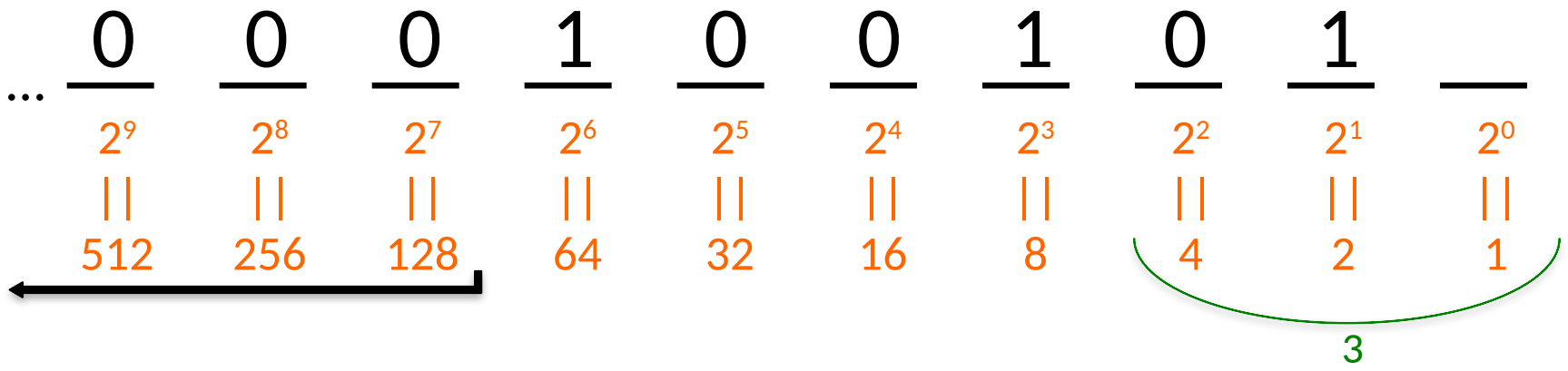
11	3

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

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



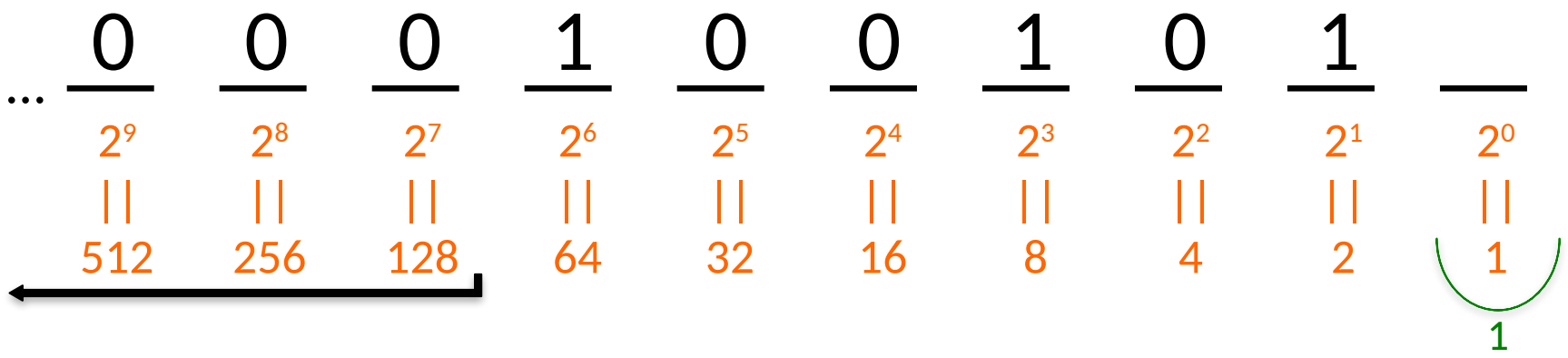
$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

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

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



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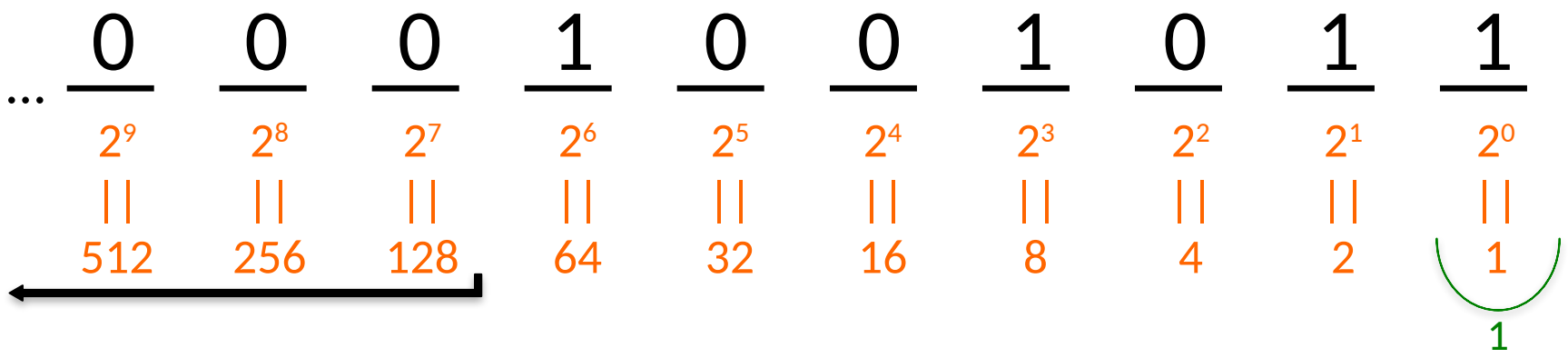


$1 + 2 + 4 + 8 + 16 + 32 = 63$

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

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

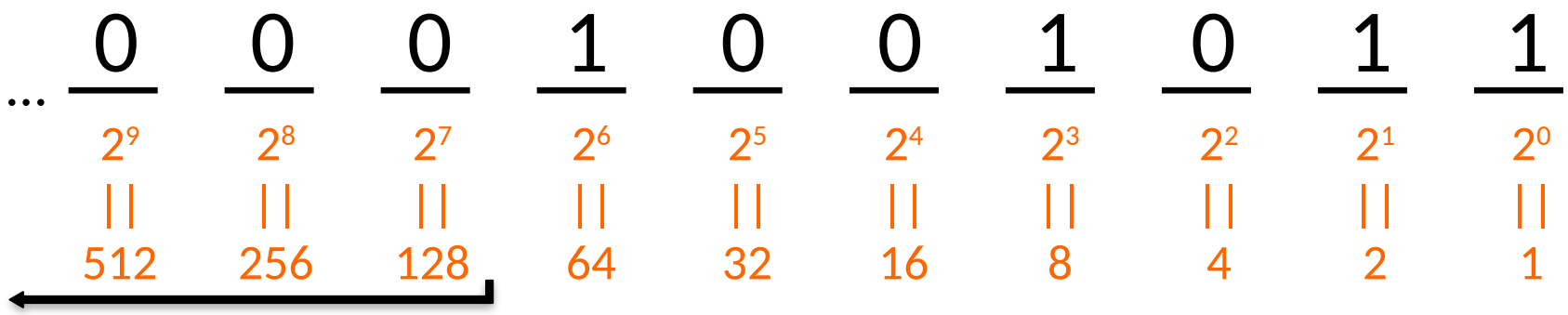
(ii) decimal ␣ base b (demonstrated on b=2)

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

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

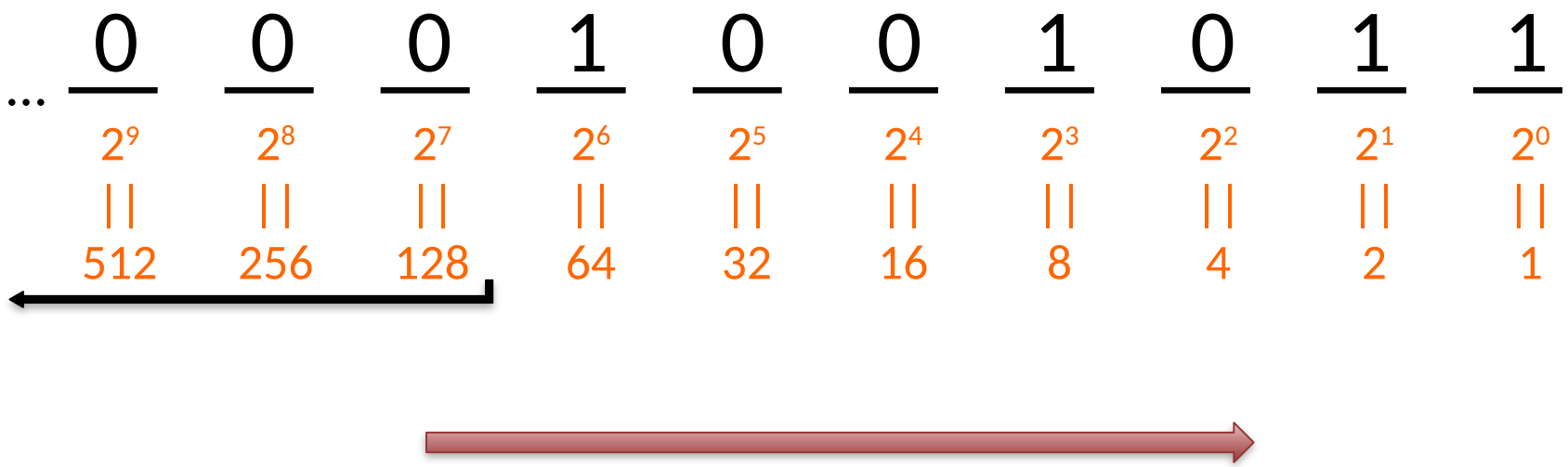
(ii) decimal ␣ base b (demonstrated on b=2)

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



(ii) decimal ␣ 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

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

(iii) binary ← hexadecimal

Hex Digit	4 bit binary

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

(iii) binary ← hexadecimal

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

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

(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	

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

(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	

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

(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	

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

(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	

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

(iii) binary ← hexadecimal

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

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

(iii) binary ← hexadecimal

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

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

(iii) binary ← hexadecimal

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

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

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

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

b 9

(iii) binary ← hexadecimal

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

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

(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

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

3 b 9

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

(iii) binary ← hexadecimal

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

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

3 b 9

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

(iii) binary ← hexadecimal

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

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

3 b 9

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

(iii) binary ← hexadecimal

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

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

3 b 9

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

(iii) binary ← hexadecimal

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

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

3 b 9

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

(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

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

3 b 9

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

3

(iii) binary ← hexadecimal

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

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

$(\underbrace{0}\underbrace{1101}_{d}\underbrace{1010011}_{3})_2 = (\quad)_{16}$

(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

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

3 b 9

$(01101101010011)_2 = (\quad)_{16}$

6 d 3

(iii) binary ← hexadecimal

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

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

3 b 9

$(0110110100011)_2 = (6d3)_{16}$

6 d 3

(iii) binary ⟵ hexadecimal

$(011011010011)_2$

(iii) binary ⟵ hexadecimal

$(011011010011)_2$ =

$= 1 \cdot 2^0$

(iii) binary ⟵ hexadecimal

$(011011010011)_2$ =

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

(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

$(011011010011)_2$ =

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

=

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

$= 1\cdot2^0+1\cdot2^1+0\cdot2^2+0\cdot2^3$

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← ~~h~~exadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

(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	$0011 = 1\cdot2^0 + 1\cdot2^1 + 0\cdot2^2 + 0\cdot2^3 = 3$
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

$(011011010011)_2$ =

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

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

3

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

$= (3)\cdot2^0$

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

$= (3)\cdot2^0$

(iii) binary ← hexadecimal

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

(iii) binary ← hexadecimal

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

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
1	0001
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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= $1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3$
e	1110
f	1111

(iii) binary ← hexadecimal

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

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

$= (3)\cdot2^0$

(iii) binary ← hexadecimal

$(011011010011)_2$ =

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

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

13

$= (3)\cdot2^0$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

(iii) binary ⟵ hexadecimal

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

(iii) binary ← hexadecimal

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

(iii) binary ← hexadecimal

Hex Digit	4 bit binary
0	0000
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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 = $0 \cdot 2^0 + 1 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3$
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

$(011011010011)_2 =$

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

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

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

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

6

(iii) binary ← ~~h~~exadecimal

$(011011010011)_2$ =

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

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

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

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

2^0

$=$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

$2^0 = 1$

$=$

(iii) binary ⟷ hexadecimal

$(011011010011)_2 =$

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

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

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

$2^0 = 1 = 16^0$

$=$

(iii) binary ← ~~hexadecimal~~

$(011011010011)_2$ =

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

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

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

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

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

2^4

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

(iii) binary ⟵ hexadecimal

$(011011010011)_2 =$

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

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

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

$2^4 = 16$

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

(iii) binary ⟷ hexadecimal

$(011011010011)_2 =$

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

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

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

$2^4 = 16 = 16^1$

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

(iii) binary ⟷ hexadecimal

$(011011010011)_2 =$

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

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

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

$= \quad (3)\cdot16^0 \quad + \quad (13)\cdot16^1$

(iii) binary ← ~~hexadecimal~~

$(011011010011)_2$ =

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

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

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

$= (3)\cdot16^0 + (13)\cdot16^1$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

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

$= \quad (3)\cdot16^0 \quad + \quad (13)\cdot16^1$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

$= \quad (3)\cdot16^0 \quad + \quad (13)\cdot16^1$

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

(iii) binary ← ~~hexadecimal~~

$(011011010011)_2$ =

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

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

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

$= \quad (3)\cdot16^0 \quad + \quad (13)\cdot16^1 \quad + \quad (6)\cdot16^2$

(iii) binary ← hexadecimal

$(011011010011)_2 =$

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

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

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

$= \quad (3)\cdot16^0 \quad + \quad (13)\cdot16^1 \quad + \quad (6)\cdot16^2$

$= (6d3)_{16}$

Addition

Addition

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

Addition

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

Addition

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

Addition

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

Addition

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

Addition

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

Addition

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

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

Addition

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

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

Addition

$$\begin{array}{r} {\scriptstyle 1\ 1} \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array} \qquad \begin{array}{r} {\scriptstyle 1} \\ 365_{8} \\ +\ 243_{8} \\ \hline 0_{8} \end{array}$$

Addition

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

$$\begin{array}{r} {\scriptstyle 1\ 1\ \ } \\ 365_{8} \\ +\ 243_{8} \\ \hline 30_{8} \end{array}$$

Addition

$$\begin{array}{r} {\scriptstyle 1\ 1\ \ } \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array} \qquad \begin{array}{r} {\scriptstyle 1\ 1\ \ } \\ 365_{8} \\ +\ 243_{8} \\ \hline 630_{8} \end{array}$$

Addition

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

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

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

Addition

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

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

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

Addition

$$\begin{array}{r} {}^{1\,1} \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array} \qquad \begin{array}{r} {}^{1\ \ 1} \\ 365_{8} \\ +\ 243_{8} \\ \hline 630_{8} \end{array} \qquad \begin{array}{r} 10011100_{2} \\ +\ 11011001_{2} \\ \hline 1_{2} \end{array}$$

Addition

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

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

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

Addition

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

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

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

Addition

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

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

$$\begin{array}{r} {\scriptstyle 1} \\ 10011100_{2} \\ +\ 11011001_{2} \\ \hline 0101_{2} \end{array}$$

Addition

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

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

$$\begin{array}{r} {\scriptstyle 1\ 1\ \ \ \ \ \ \ } \\ 10011100_{2} \\ +\ 11011001_{2} \\ \hline 10101_{2} \end{array}$$

Addition

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

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

$$\begin{array}{r} {\scriptstyle 1\ 1\ \ \ \ \ \ \ } \\ 10011100_{2} \\ +\ 11011001_{2} \\ \hline 110101_{2} \end{array}$$

Addition

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

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

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

Addition

$$\begin{array}{r} {}^{1\,1} \\ 325_{10} \\ +\ 692_{10} \\ \hline 1017_{10} \end{array} \qquad \begin{array}{r} {}^{1\ \,1} \\ 365_{8} \\ +\ 243_{8} \\ \hline 630_{8} \end{array} \qquad \begin{array}{r} {}^{1\quad\ \ 1\ 1} \\ 10011100_{2} \\ +\ 11011001_{2} \\ \hline 01110101_{2} \end{array}$$

Addition

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

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

$$\begin{array}{r} {\scriptstyle 1\ \ \ \ 1\ 1\ \ } \\ 10011100_{2} \\ +\ 11011001_{2} \\ \hline 101110101_{2} \end{array}$$

Subtraction

Subtraction

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

Subtraction

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

Subtraction

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

Subtraction

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

Subtraction

$$
\begin{array}{r}
{\scriptstyle 3\ 12} \\
4\not{2}\not{7}_{10} \\
-\ 192_{10} \\
\hline
5_{10}
\end{array}
$$

Subtraction

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

Subtraction

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

Subtraction

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

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

Subtraction

$$\begin{array}{r} {\scriptstyle 3\ 12} \\ 4\cancel{2}\cancel{7}_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array} \qquad \begin{array}{r} 536_{8} \\ -\ 351_{8} \\ \hline {\scriptstyle 8} \end{array}$$

Subtraction

$$\begin{array}{r} {\scriptstyle 3\ 12} \\ 42\cancel{7}_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array} \qquad \begin{array}{r} 536_{8} \\ -\ 351_{8} \\ \hline 5_{8} \end{array}$$

Subtraction

$$\begin{array}{r} {}^{3}\cancel{4}\,{}^{12}\cancel{2}7_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array} \qquad \begin{array}{r} {}^{13_8}\cancel{5}\cancel{3}6_{8} \\ -\ 351_{8} \\ \hline 5_{8} \end{array}$$

Subtraction

$$\begin{array}{r} {\scriptstyle 3\ 12} \\ 427_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array}$$

$$\begin{array}{r} {\scriptstyle 4\ 13_8} \\ 536_8 \\ -\ 351_8 \\ \hline 5_8 \end{array}$$

Subtraction

$$\begin{array}{r} {\scriptstyle 3\ 12} \\ 427_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array} \qquad \begin{array}{r} {\scriptstyle 4\ 13_8} \\ 536_8 \\ -\ 351_8 \\ \hline 65_8 \end{array}$$

Subtraction

$$\begin{array}{r} {\scriptstyle 3\ 12} \\ 427_{10} \\ -\ 192_{10} \\ \hline 235_{10} \end{array} \qquad \begin{array}{r} {\scriptstyle 4\ 13_8} \\ 536_8 \\ -\ 351_8 \\ \hline 165_8 \end{array}$$

Signed Numbers

Signed Numbers

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

Signed Numbers

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

Signed Numbers

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

$(-26)_{10}$

Signed Numbers

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

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

Signed Numbers

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

16 8 4 2 1

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

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

Signed Numbers

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

16 8 4 2 1

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

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

- Sign and Magnitude

Signed Numbers

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

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

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Signed Numbers

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

16 8 4 2 1

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

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

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1

Signed Numbers

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

16 8 4 2 1

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

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

- Sign and Magnitude

1000…011010

Signed Numbers

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

16 8 4 2 1

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

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

- Sign and Magnitude

  1000…011010

- Two's Complement

Two’s Complement

Two’s Complement

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

Two’s Complement

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

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

Two's Complement

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

- A positive integer is represented in its (k-1)-bit unsigned binary representation, padded with a 0 to its left
- The sum of a number and its additive inverse is 2^k

Two’s Complement

$(26)_{10}$

Two’s Complement

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

Two’s Complement

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

7 bits

Two’s Complement

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

7 bits

Two's Complement

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

Two’s Complement

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

7 bits

$(-26)_{10}$

Two's Complement

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

7 bits

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

Two's Complement

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

7 bits

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

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

26

-26

2^8

Two's Complement

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

7 bits

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

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

Two's Complement

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

7 bits

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

$$
\begin{array}{rr}
 & 0\,0\,0\,1\,1\,0\,1\,0 \\
+ & \\
 & 0 \\
\hline
 & 1\,0\,0\,0\,0\,0\,0\,0\,0
\end{array}
$$

26

-26

2^8

Two's Complement

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

7 bits

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

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

26

-26

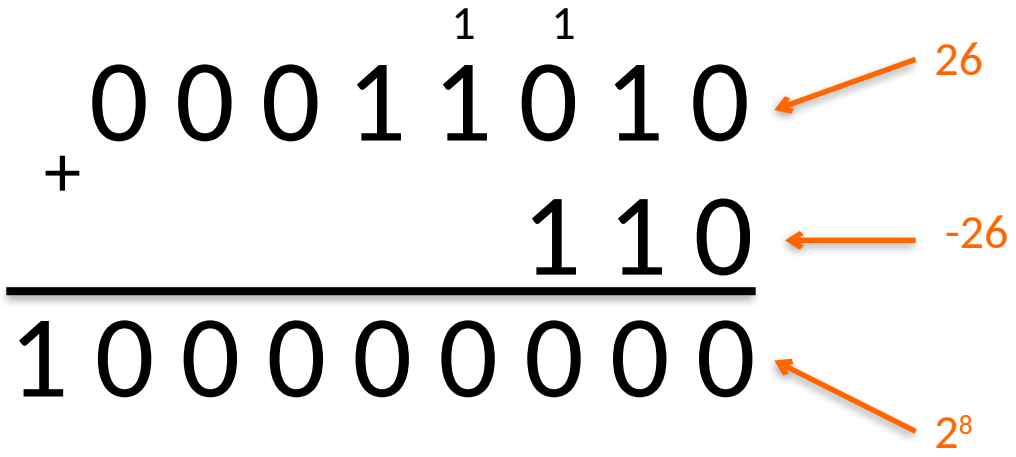
2^8

Two's Complement

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

7 bits

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

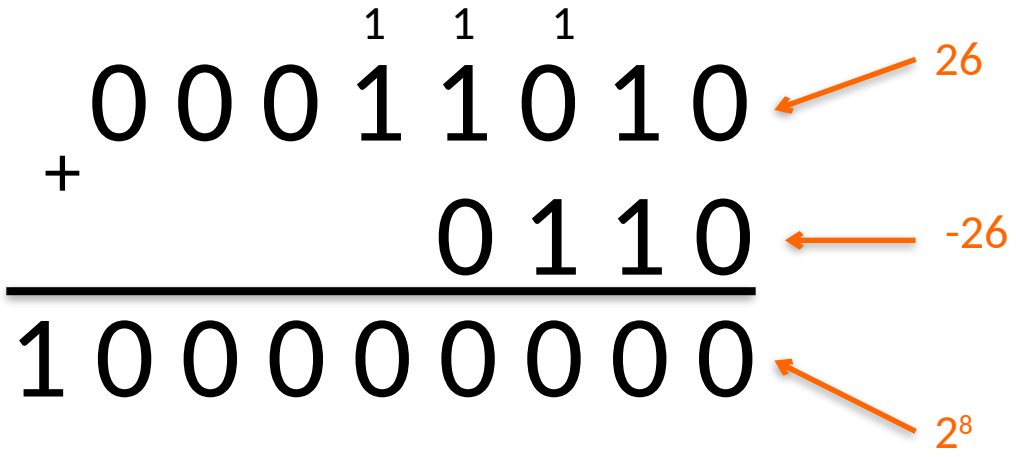


Two's Complement

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

7 bits

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

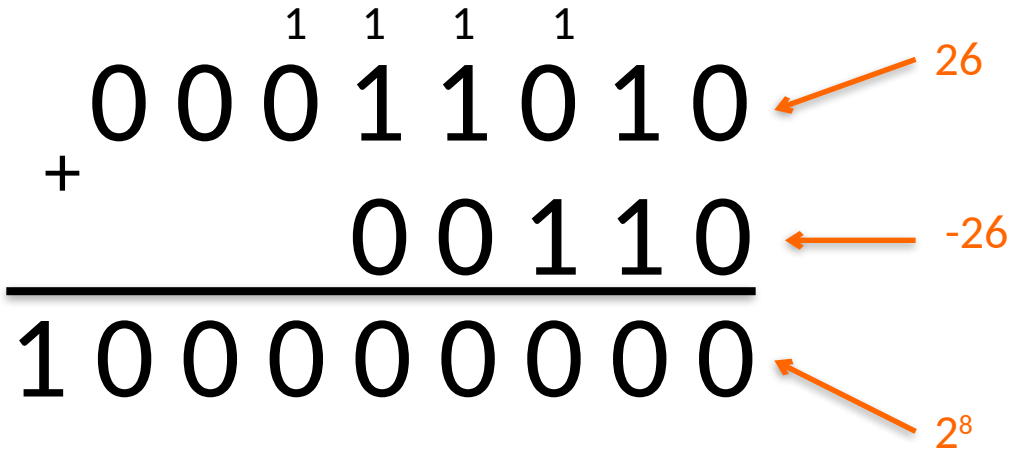


Two's Complement

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

7 bits

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

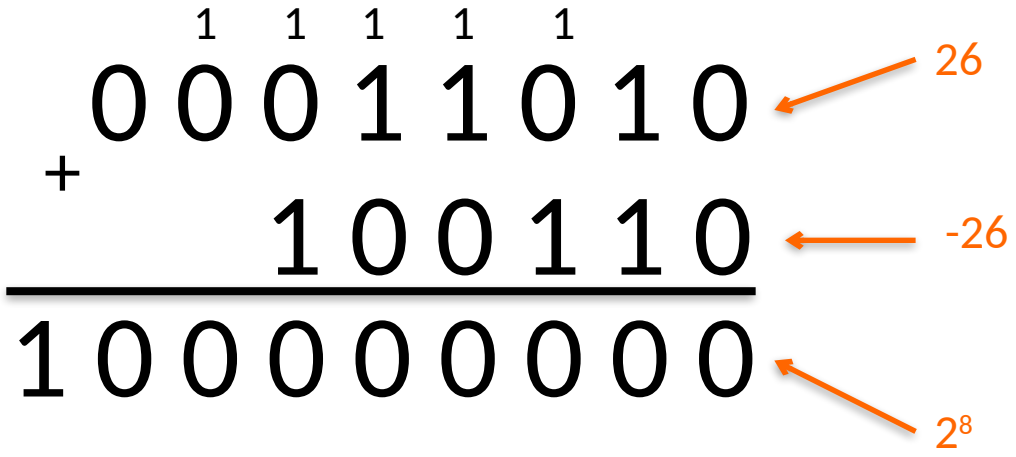


Two's Complement

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

7 bits

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

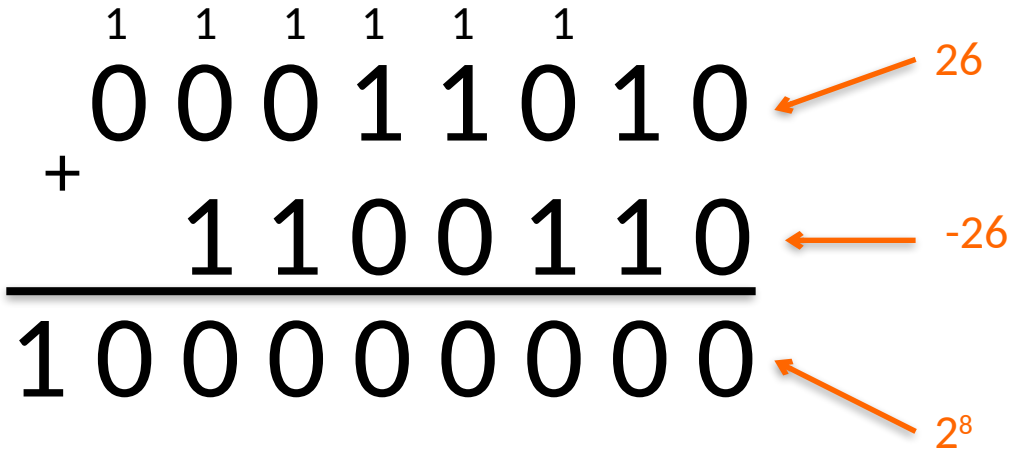


Two's Complement

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

7 bits

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

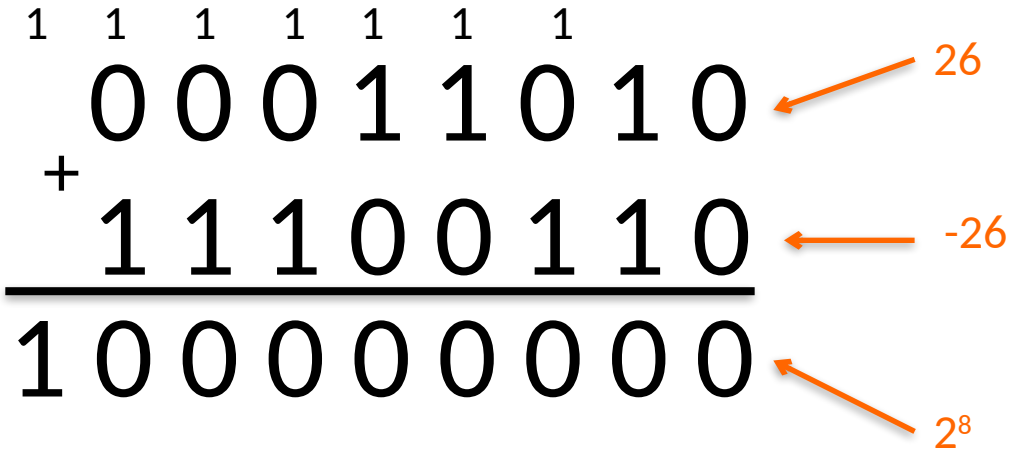


Two's Complement

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

7 bits

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

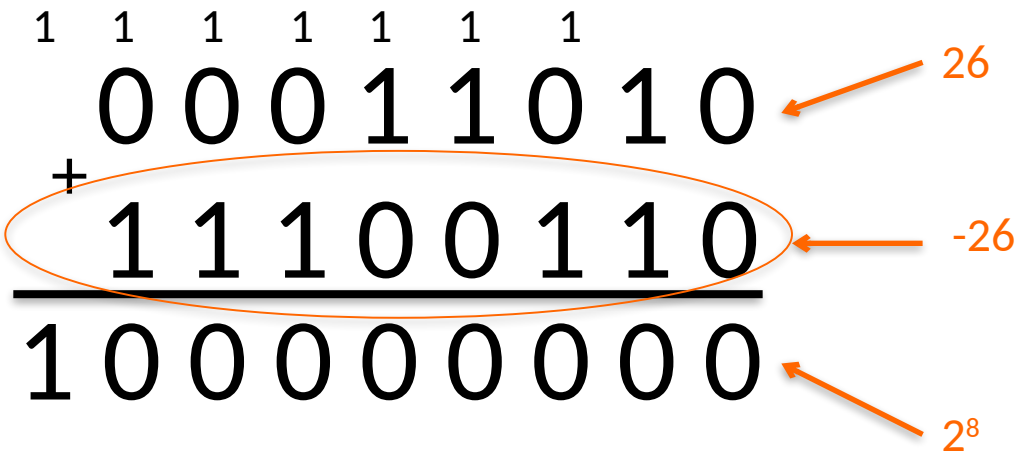


Two's Complement

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

7 bits

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

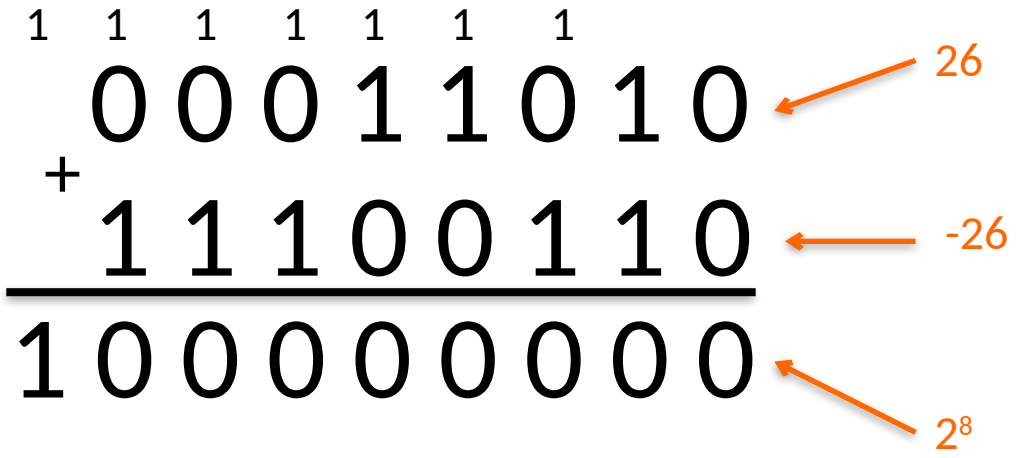


Two's Complement

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

7 bits

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



Two’s Complement

Two’s Complement

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

Two’s Complement

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

Two’s Complement

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

64 32 16 8 4 2 1

Two’s Complement

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

64 32 16 8 4 2 1

Two's Complement

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

64 32 16 8 4 2 1

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

Two's Complement

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

64 32 16 8 4 2 1

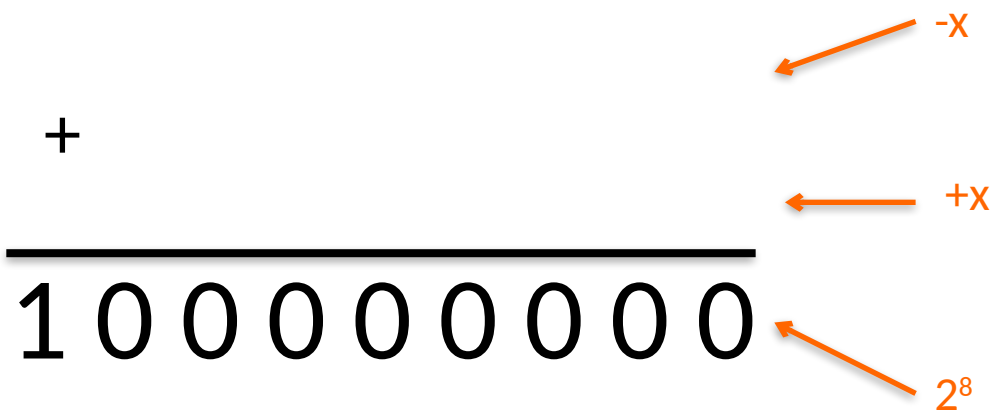
$(11101010)_{8\text{ bit 2's complement}} = (\quad)_{10}$

Two's Complement

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

64 32 16 8 4 2 1

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



Two's Complement

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

64 32 16 8 4 2 1

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

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

-x

+x

2^8

Two's Complement

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

64 32 16 8 4 2 1

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

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

-x

+x

2^8

Two's Complement

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

64 32 16 8 4 2 1

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

$$\begin{array}{rr} & {\scriptstyle 1} \\ & 1\,1\,1\,0\,1\,0\,1\,0 \\ + & 1\,0 \\ \hline & 1\,0\,0\,0\,0\,0\,0\,0\,0 \end{array}$$

-x

+x

2^8

Two's Complement

$$(0\underbrace{0}_{64}\underbrace{1}_{32}\underbrace{0}_{16}\underbrace{1}_{8}\underbrace{1}_{4}\underbrace{0}_{2}\underbrace{1}_{1})_{\text{8 bit 2's complement}} = (45)_{10}$$

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

$$\begin{array}{rcccccccccl}
 & & & & & 1 & & 1 & & & \\
 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & & \leftarrow -x \\
+ & & & & & & & & & & \\
 & & & & & & & 1 & 1 & 0 & \leftarrow +x \\
\hline
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \leftarrow 2^8
\end{array}$$

Two's Complement

$$(0\underbrace{0}_{64}\underbrace{1}_{32}\underbrace{0}_{16}\underbrace{1}_{8}\underbrace{1}_{4}\underbrace{0}_{2}\underbrace{1}_{1})_{\text{8 bit 2's complement}} = (45)_{10}$$

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

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

-x

+x

2^8

Two's Complement

$$(0\underbrace{0}_{64}\underbrace{1}_{32}\underbrace{0}_{16}\underbrace{1}_{8}\underbrace{1}_{4}\underbrace{0}_{2}\underbrace{1}_{1})_{\text{8 bit 2's complement}} = (45)_{10}$$

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

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

-x

+x

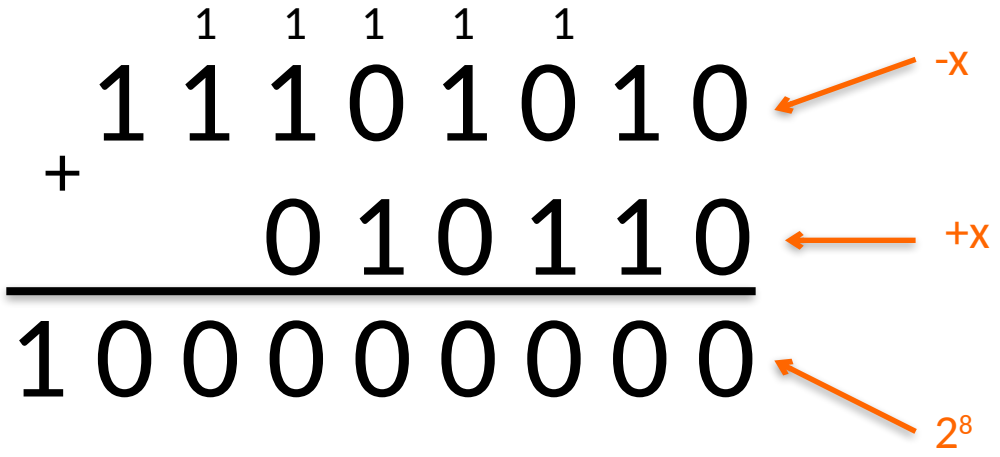
2^8

Two's Complement

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

64 32 16 8 4 2 1

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

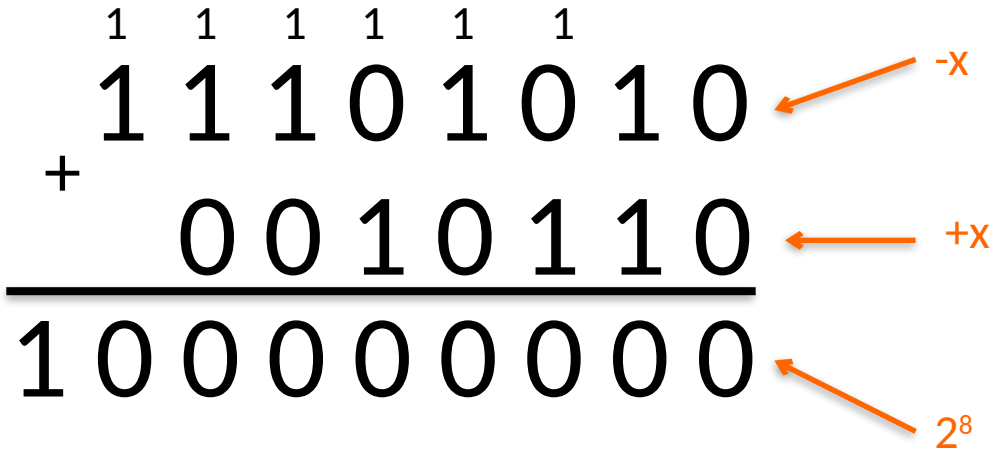


Two's Complement

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

64 32 16 8 4 2 1

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



Two's Complement

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

64 32 16 8 4 2 1

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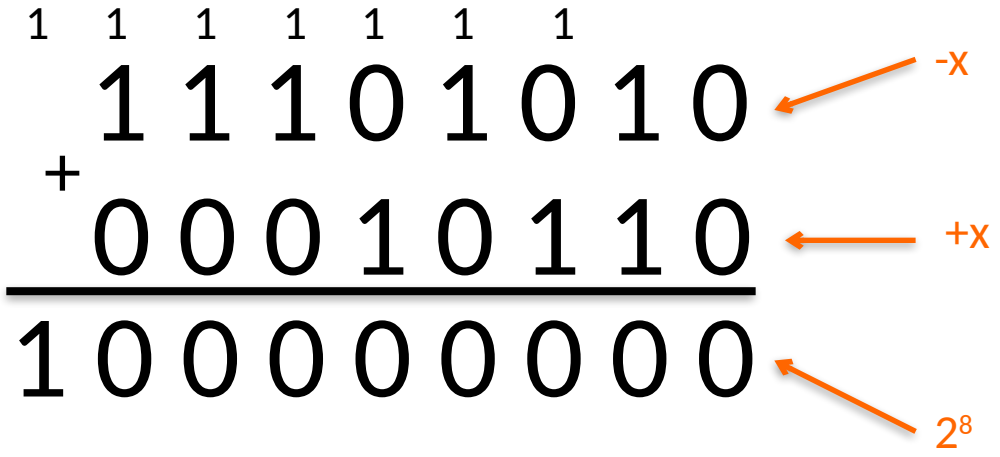
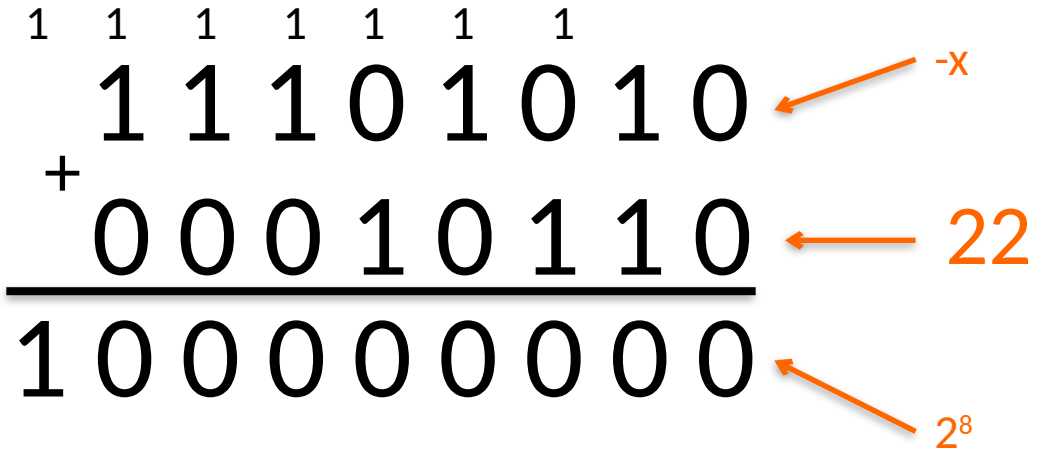


Two's Complement

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

64 32 16 8 4 2 1

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

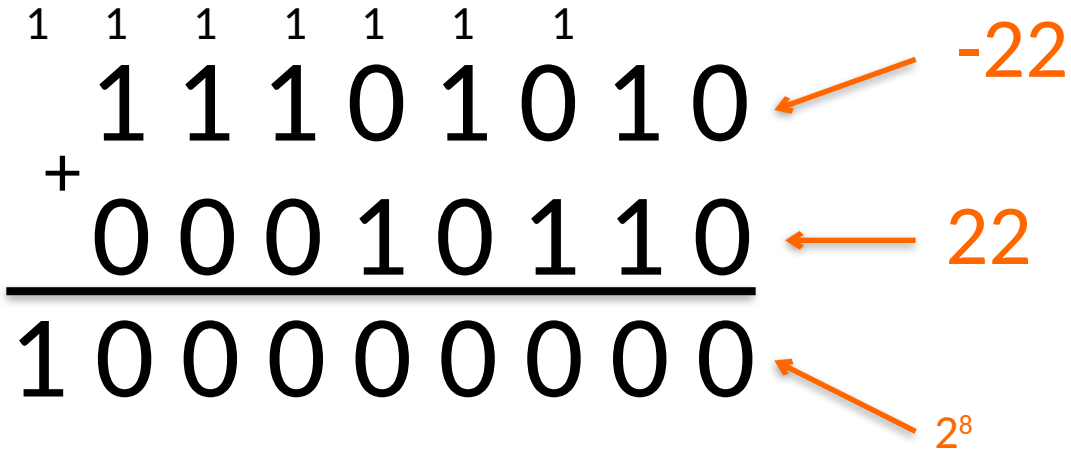


Two's Complement

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

64 32 16 8 4 2 1

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



Two's Complement

$$(0\underbrace{0}_{64}\underbrace{1}_{32}\underbrace{0}_{16}\underbrace{1}_{8}\underbrace{1}_{4}\underbrace{0}_{2}\underbrace{1}_{1})_{\text{8 bit 2's complement}} = (45)_{10}$$

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

$$\begin{array}{rcccccccccl}
 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & & & \\
 & & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & \leftarrow -22 \\
+ & & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & \leftarrow 22 \\
\hline
 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \leftarrow 2^8
\end{array}$$