BITS

1 2 3

1	2	3
10^2	10^1	10^0

$$\begin{array}{ccc} 1 & 2 & 3 \\ \hline 10^2 & 10^1 & 10^0 \end{array}$$

$$= 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

$$= 1 \times 100 + 2 \times 10 + 3 \times 1$$

$$= 123$$

4	1	2	3
?	10^2	10^1	10^0

4	1	2	3
?	10^2	10^1	10^0

$$= 4 \times 10^3 + 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

4 1 2 3

? 10^2 10^1 10^0

$$= 4 \times 10^3 + 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

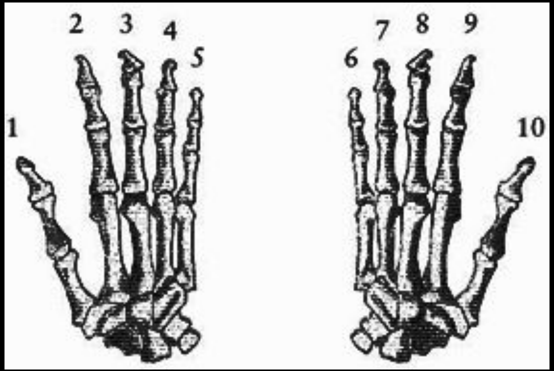
$$= 4 \times 1000 + 1 \times 100 + 2 \times 10 + 3 \times 1$$

$$\begin{array}{cccc} 4 & 1 & 2 & 3 \\ \hline ? & 10^2 & 10^1 & 10^0 \end{array}$$

$$= 4 \times 10^3 + 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

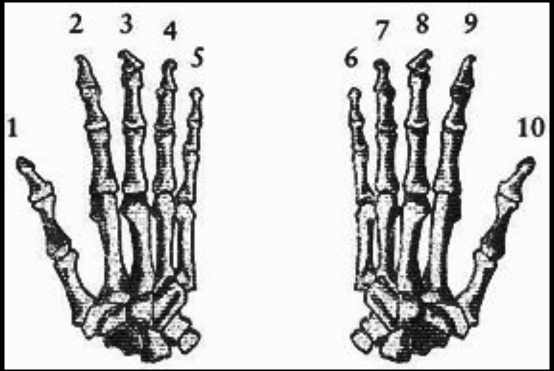
$$= 4 \times 1000 + 1 \times 100 + 2 \times 10 + 3 \times 1$$

$$= 4123$$

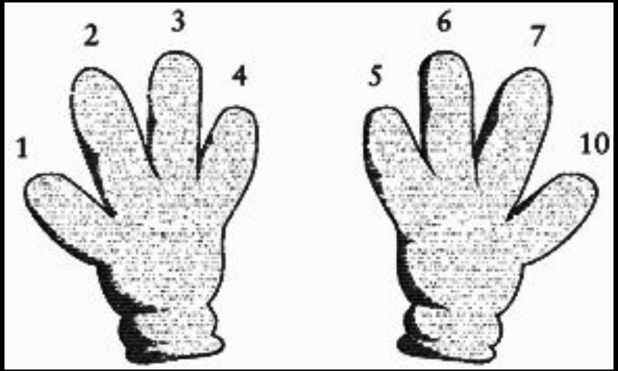


human hand

Image source: Petzold, Charles. Code: The Hidden Language of Computer Hardware and Software. 2nd ed., Microsoft Press, 2022.



human hand



cartoon character’s hand

Image source: Petzold, Charles. Code: The Hidden Language of Computer Hardware and Software. 2nd ed., Microsoft Press, 2022.

1 **2** **3** (octal)

1	2	3	(octal)
8^2	8^1	8^0	

$$1 \quad 2 \quad 3 \quad \text{(octal)}$$

$$8^2 \quad 8^1 \quad 8^0$$

$$= 1 \times 8^2 + 2 \times 8^1 + 3 \times 8^0$$

1 2 3 (octal)

8^2 8^1 8^0

$$= 1 \times 8^2 + 2 \times 8^1 + 3 \times 8^0$$

$$= 1 \times 64 + 2 \times 8 + 3 \times 1$$

$$1 \quad 2 \quad 3$$ (octal)

$$8^2 \quad 8^1 \quad 8^0$$

$$= 1 \times 8^2 + 2 \times 8^1 + 3 \times 8^0$$

$$= 1 \times 64 + 2 \times 8 + 3 \times 1$$

$= 83$ (decimal)

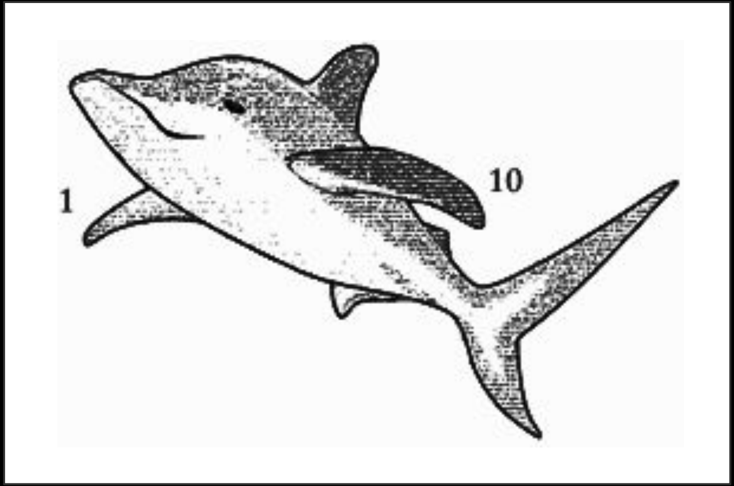
decimal		octal
8	$\longrightarrow$	?

decimal octal

? ← 7

decimal		octal
16	→	?

decimal		octal
?	←	100



what now?

Image source: Petzold, Charles. Code: The Hidden Language of Computer Hardware and Software. 2nd ed., Microsoft Press, 2022.

0, 1, …

0, 1, 10, …

0, 1, 10, 11, …

0, 1, 10, 11, 100, …

0, 1, 10, 11, 100, 101, …

0, 1, 10, 11, 100, 101, 110

1 1 0 (binary)

$1 \quad 1 \quad 0$ (binary)

$2^2 \quad 2^1 \quad 2^0$

$$1 \quad 1 \quad 0$$ (binary)

$$2^2 \quad 2^1 \quad 2^0$$

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

$$\frac{1 \quad\quad 1 \quad\quad 0}{2^2 \quad\quad 2^1 \quad\quad 2^0}$$ (binary)

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

$$= 1 \times 4 + 1 \times 2 + 0 \times 1$$

$$1 \quad 1 \quad 0$$ (binary)

$$2^2 \quad 2^1 \quad 2^0$$

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

$$= 1 \times 4 + 1 \times 2 + 0 \times 1$$

$= 6$ (decimal)

2 3 4 5 6

0, 1, 10, 11, 100, 101, 110

place value systems

$$N = d_n * R^{n-1} + \dots + d_2 * R^1 + d_1 * R^0$$

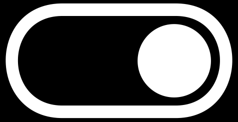
$d \in \{ 0, 1, \dots R\text{-}1 \}$

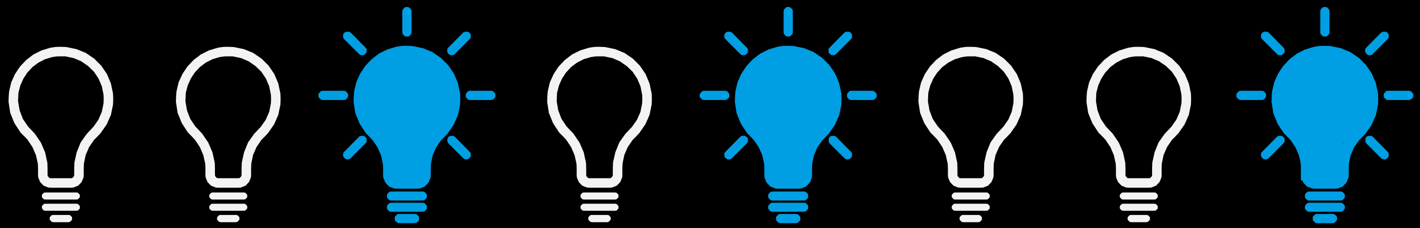
n = number of digits
R = base

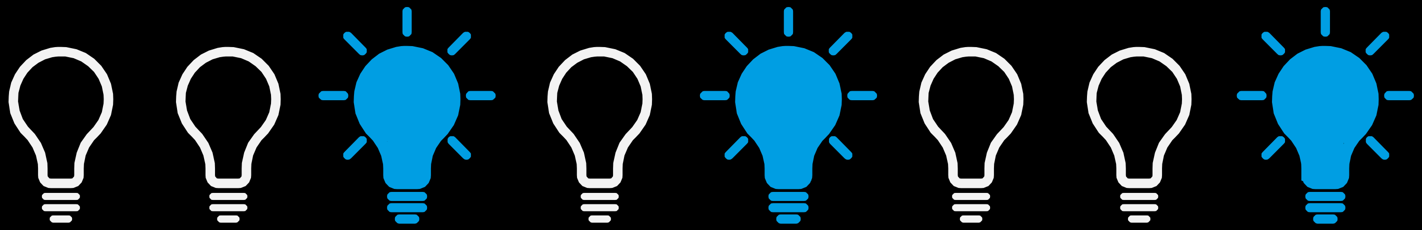
$R \geq 2$

bits

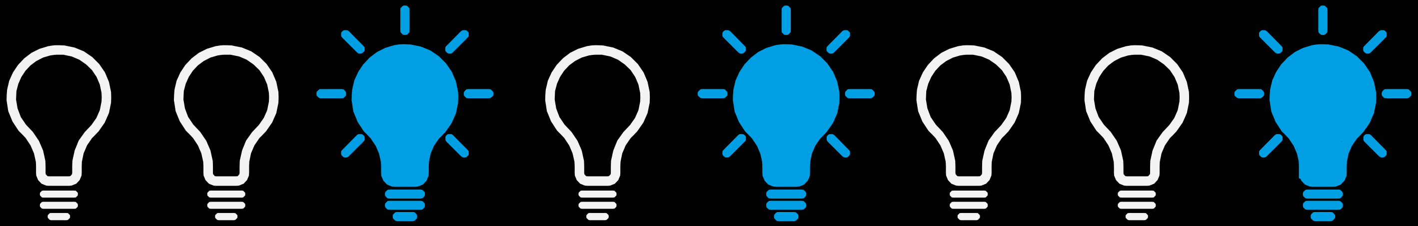
why do computers think binary?





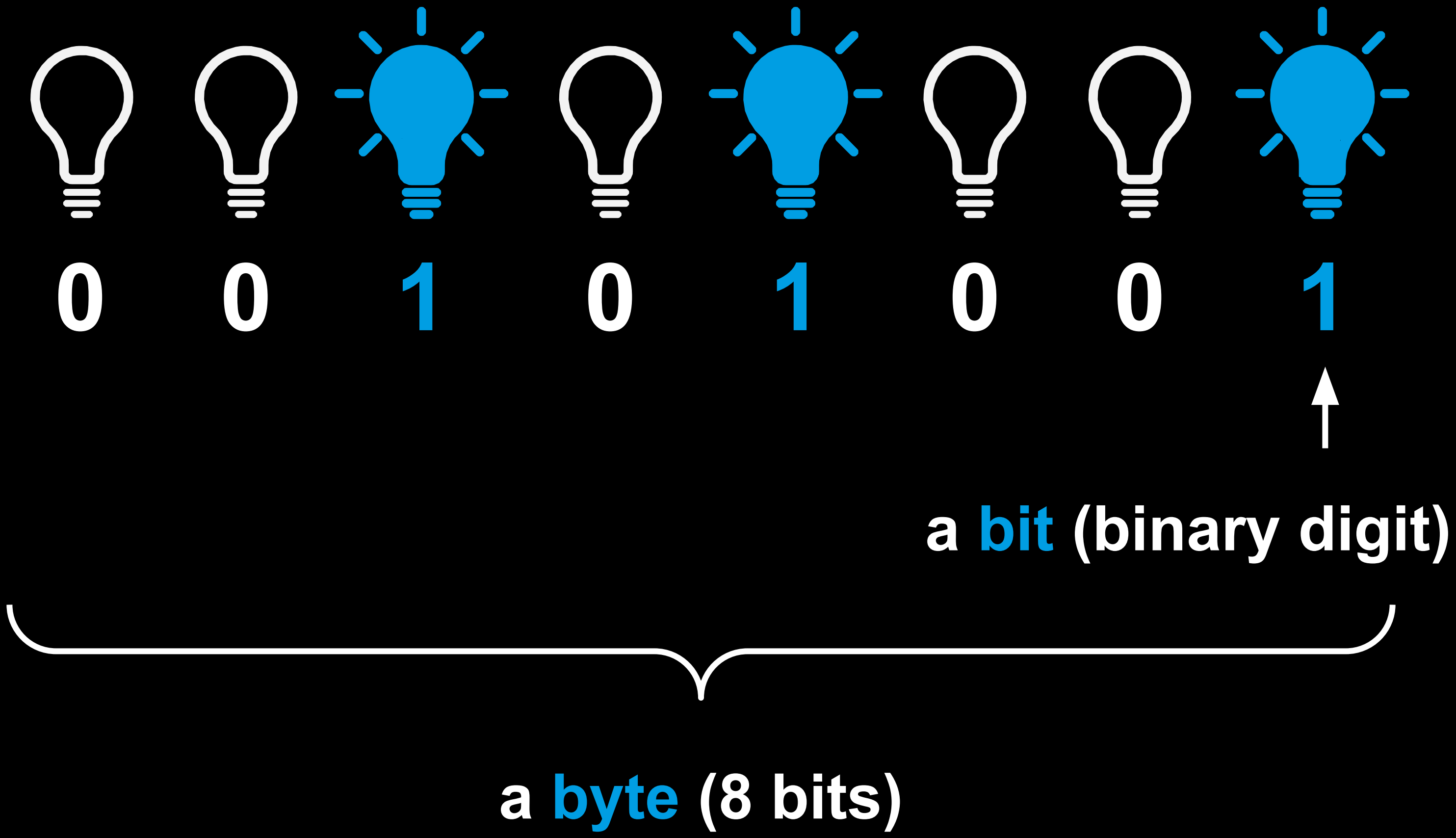


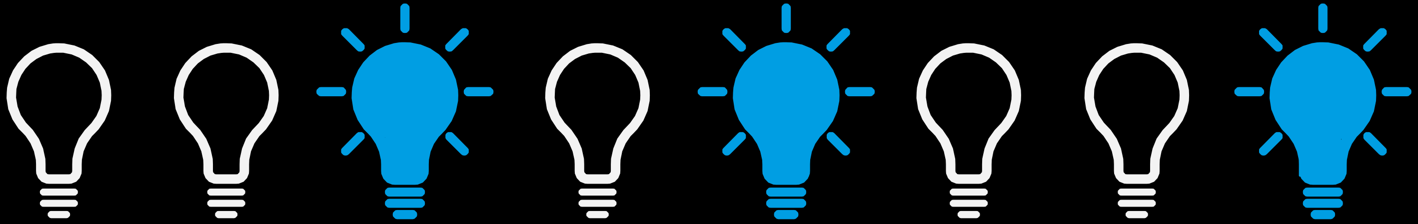
0 0 1 0 1 0 0 1



0 0 1 0 1 0 0 1

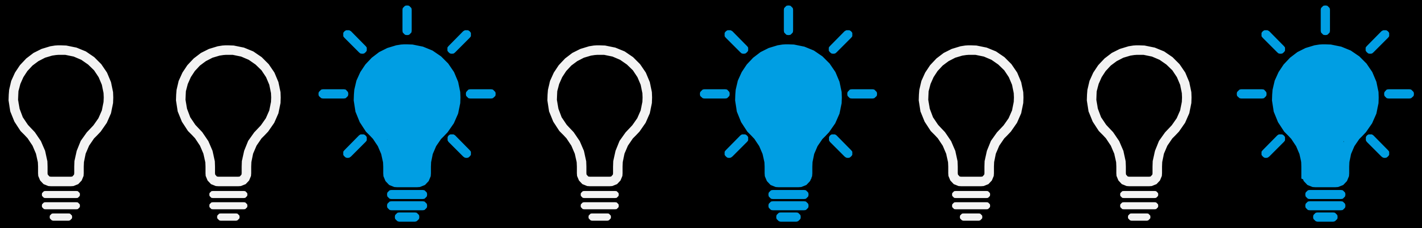
a bit (binary digit)


0 0 1 0 1 0 0 1
a bit (binary digit)
a byte (8 bits)

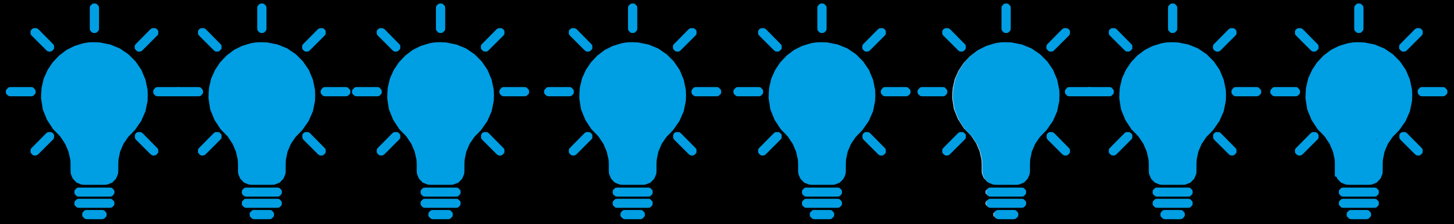


0 0 1 0 1 0 0 1

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



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



what can we store in one byte?

what comes after the byte?

2^{10} bytes = 1.024 bytes = 1 **Kibi**byte (KiB)

2^{20} bytes = 1.048.576 bytes = 1 **Mebi**byte (MiB)

2^{30} bytes = 1.073.741.824 bytes = 1 **Gibi**byte (GiB)

10^3 bytes = 1.000 bytes = 1 Kilobyte (KB)

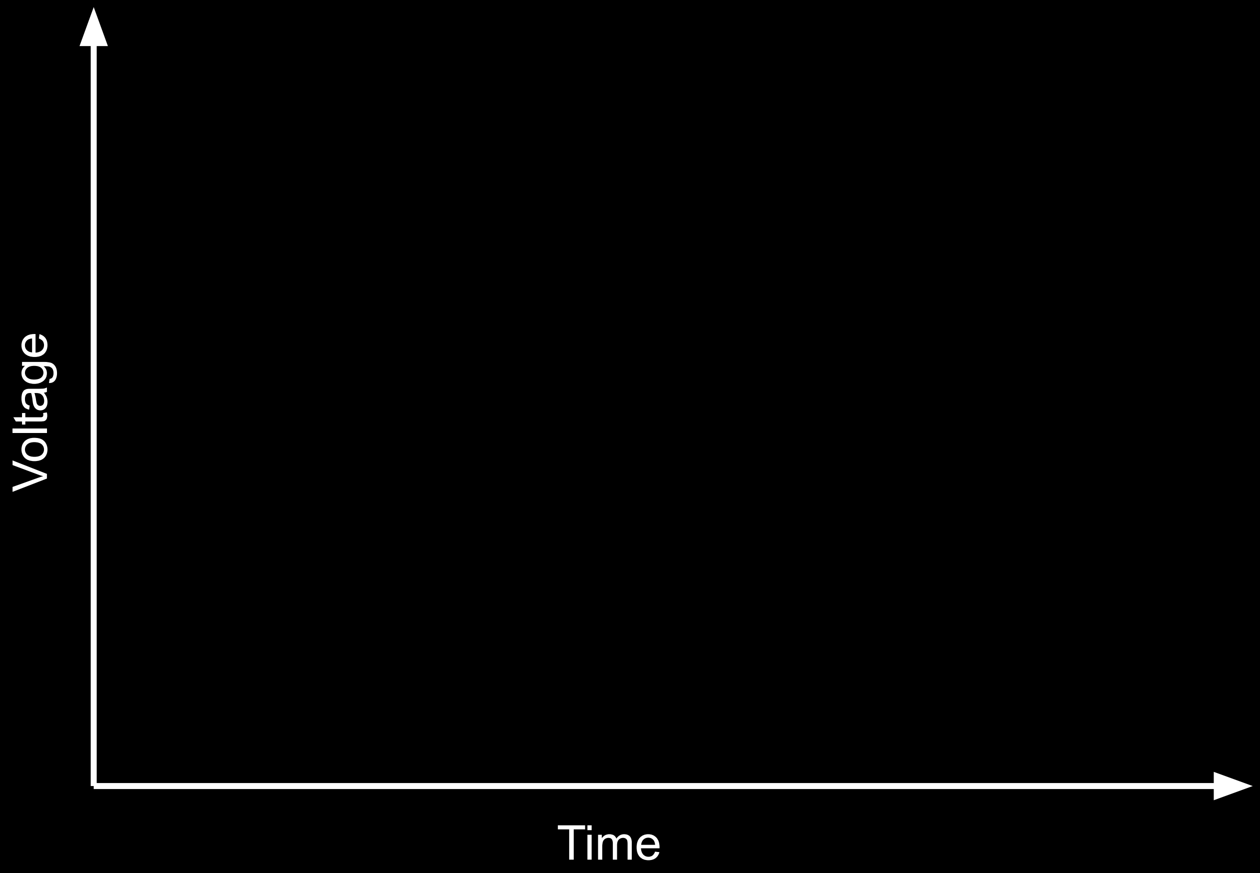
10^6 bytes = 1.000.000 bytes = 1 Megabyte (MB)

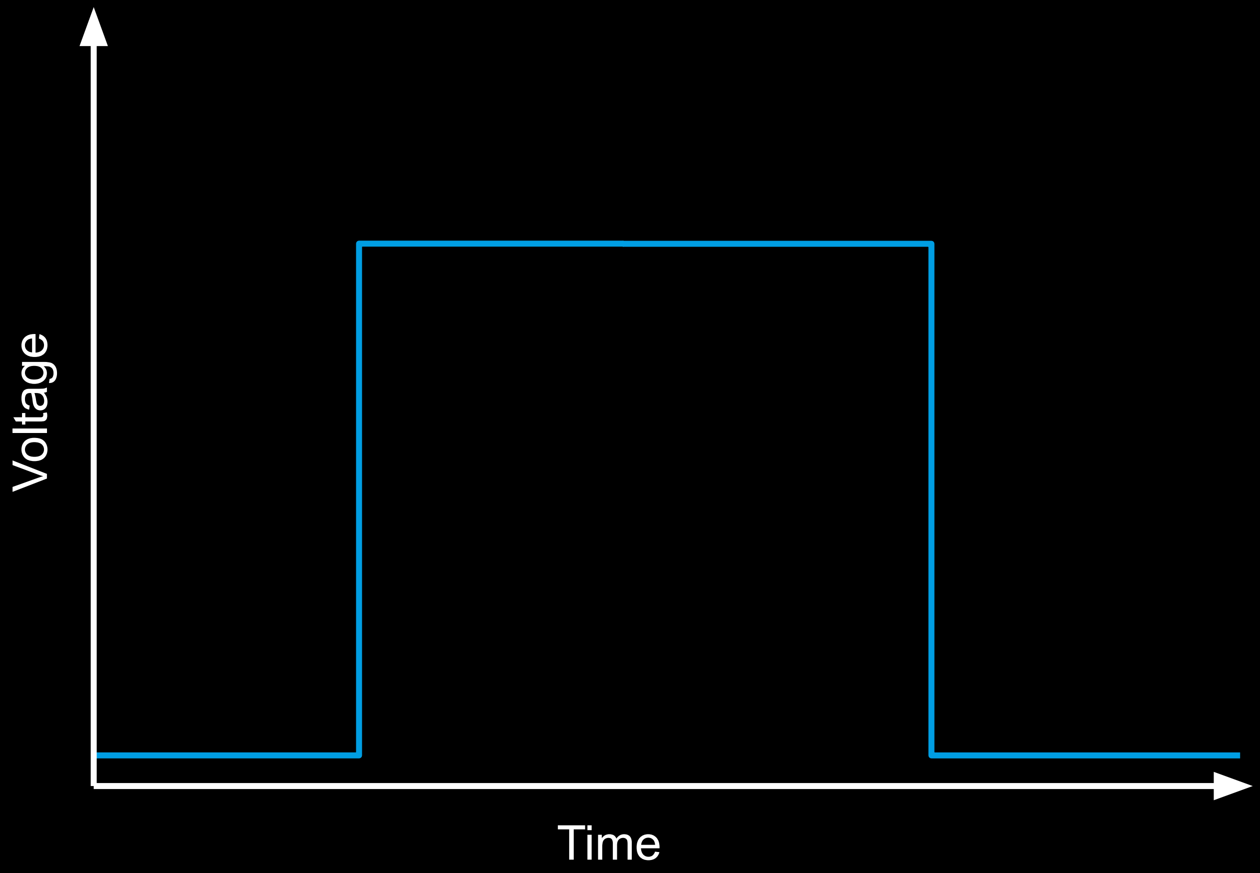
10^9 bytes = 1.000.000.000 bytes = 1 Gigabyte (GB)

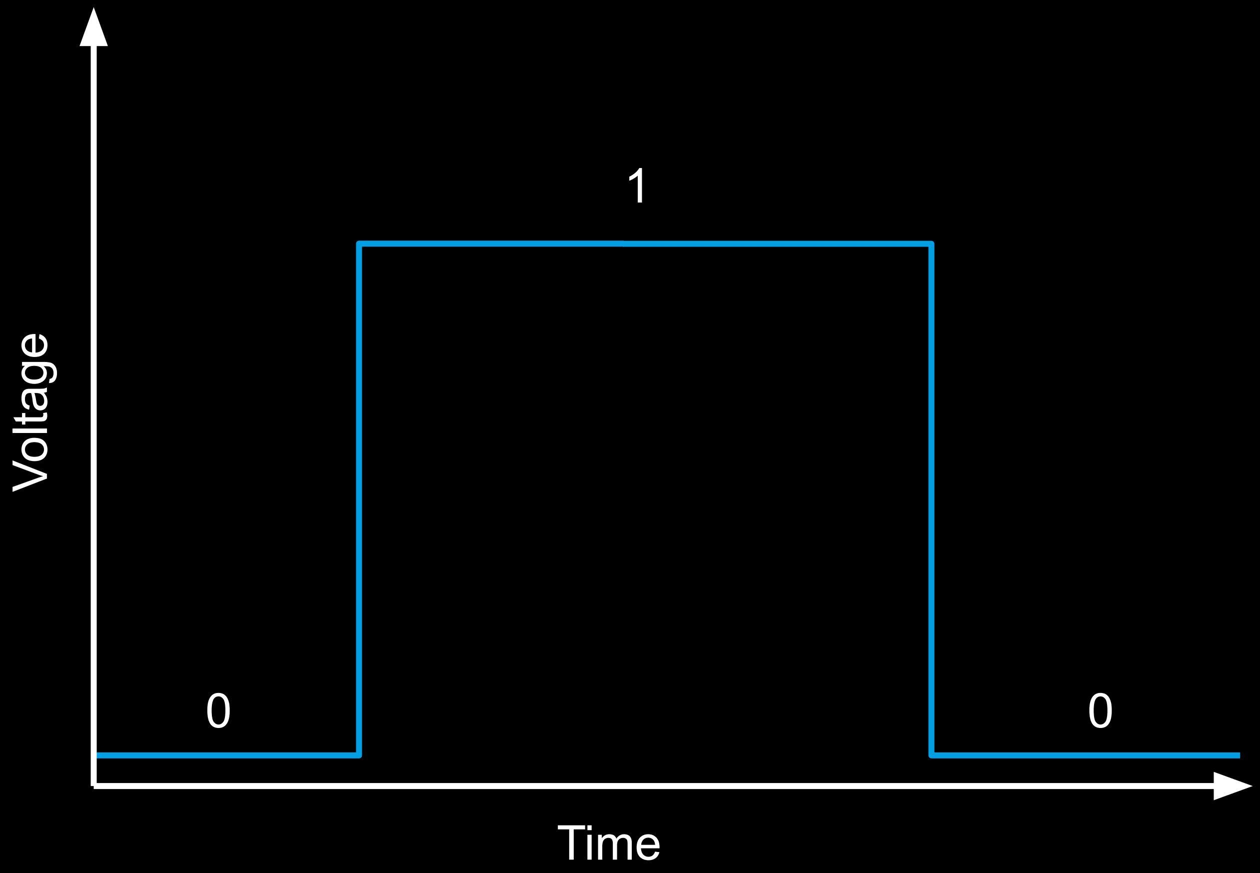
10^{12} bytes = ?

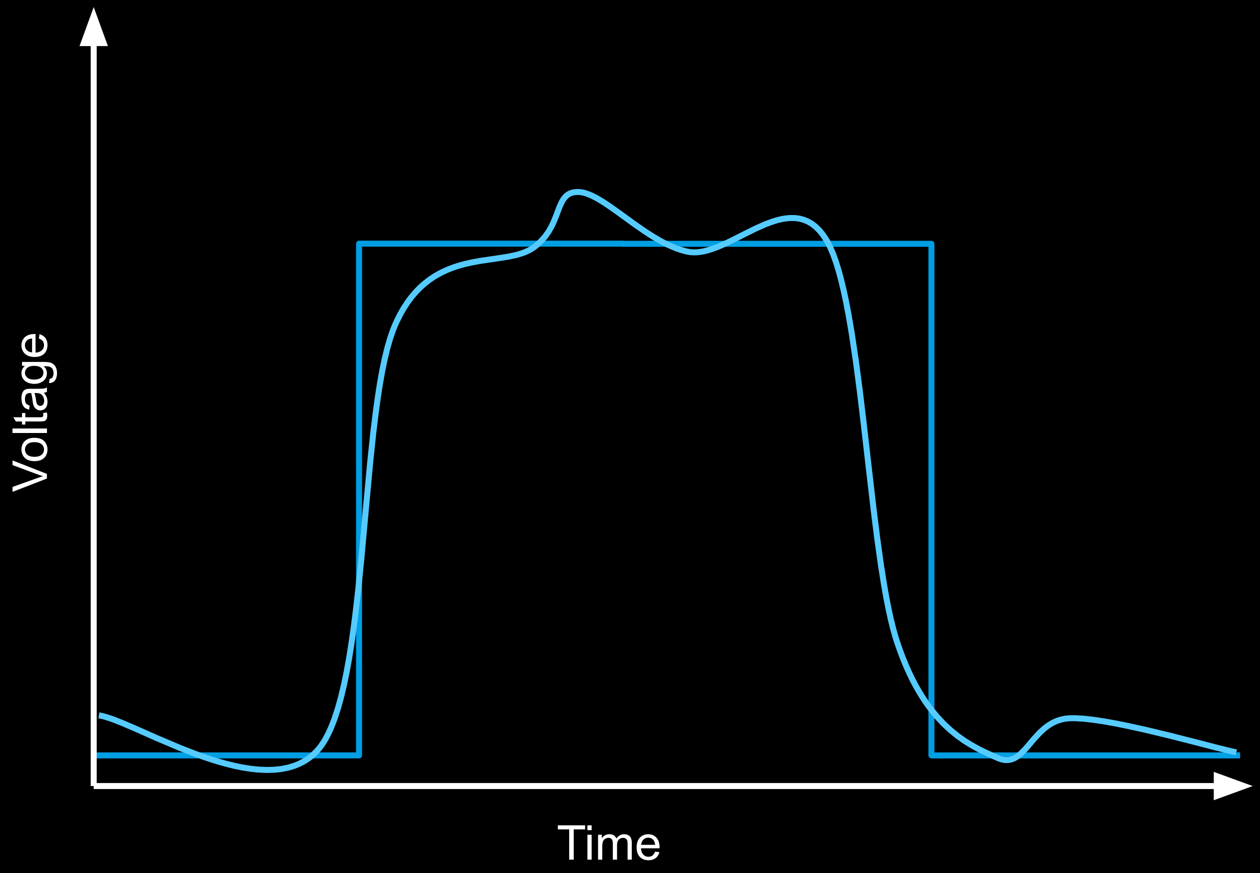
https://www.matheretter.de/wiki/zehnerpotenzen-namen how many bits are on a DVD with 4.7 GB capacity?

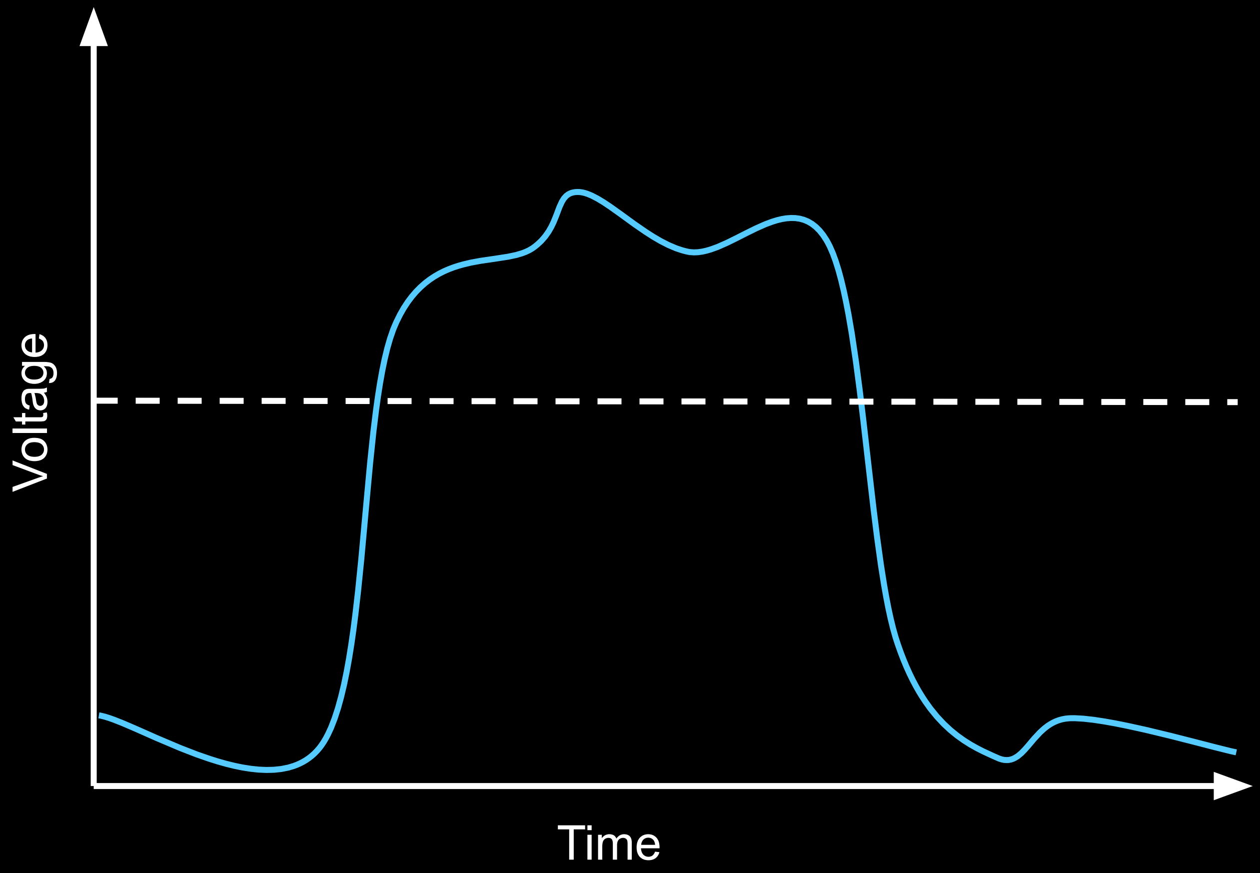
are we stuck with binary?

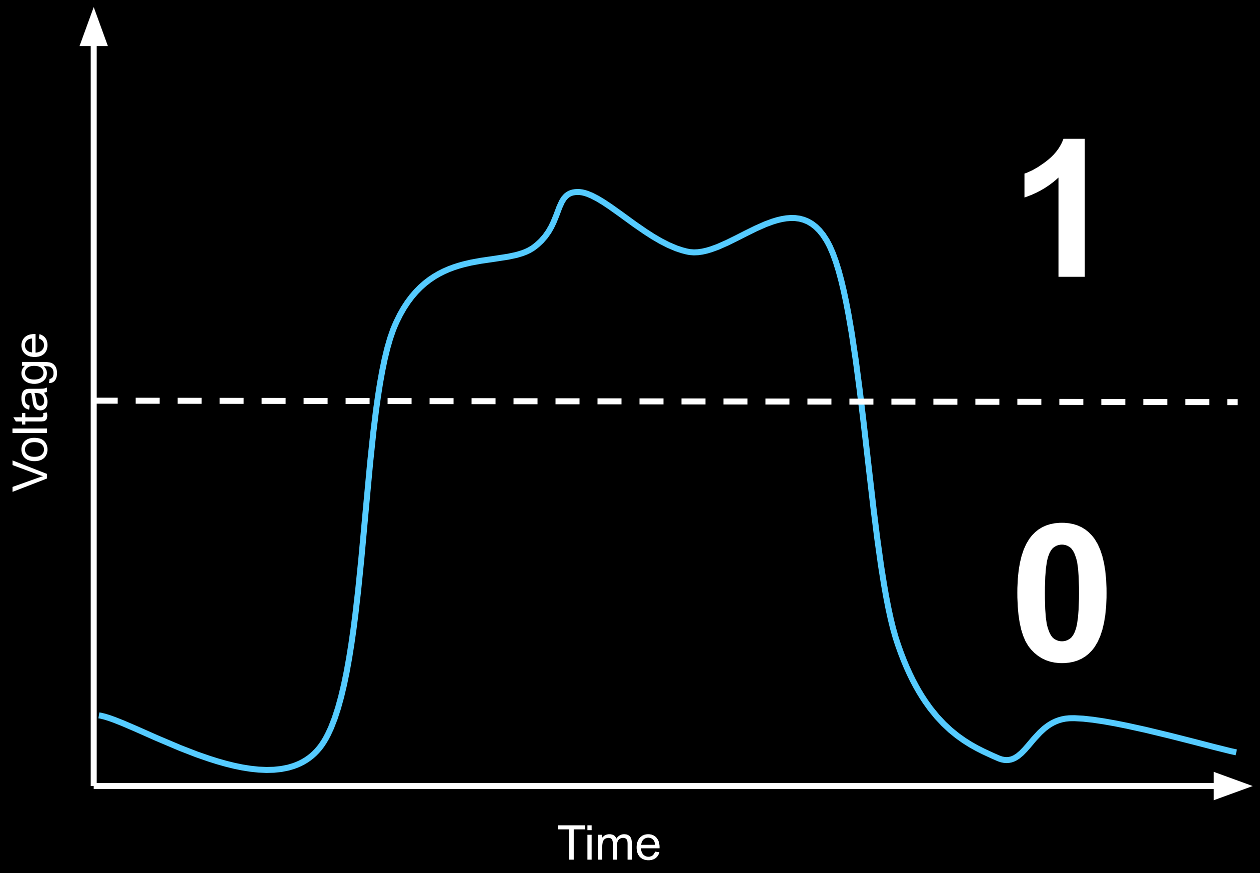

Voltage
Time

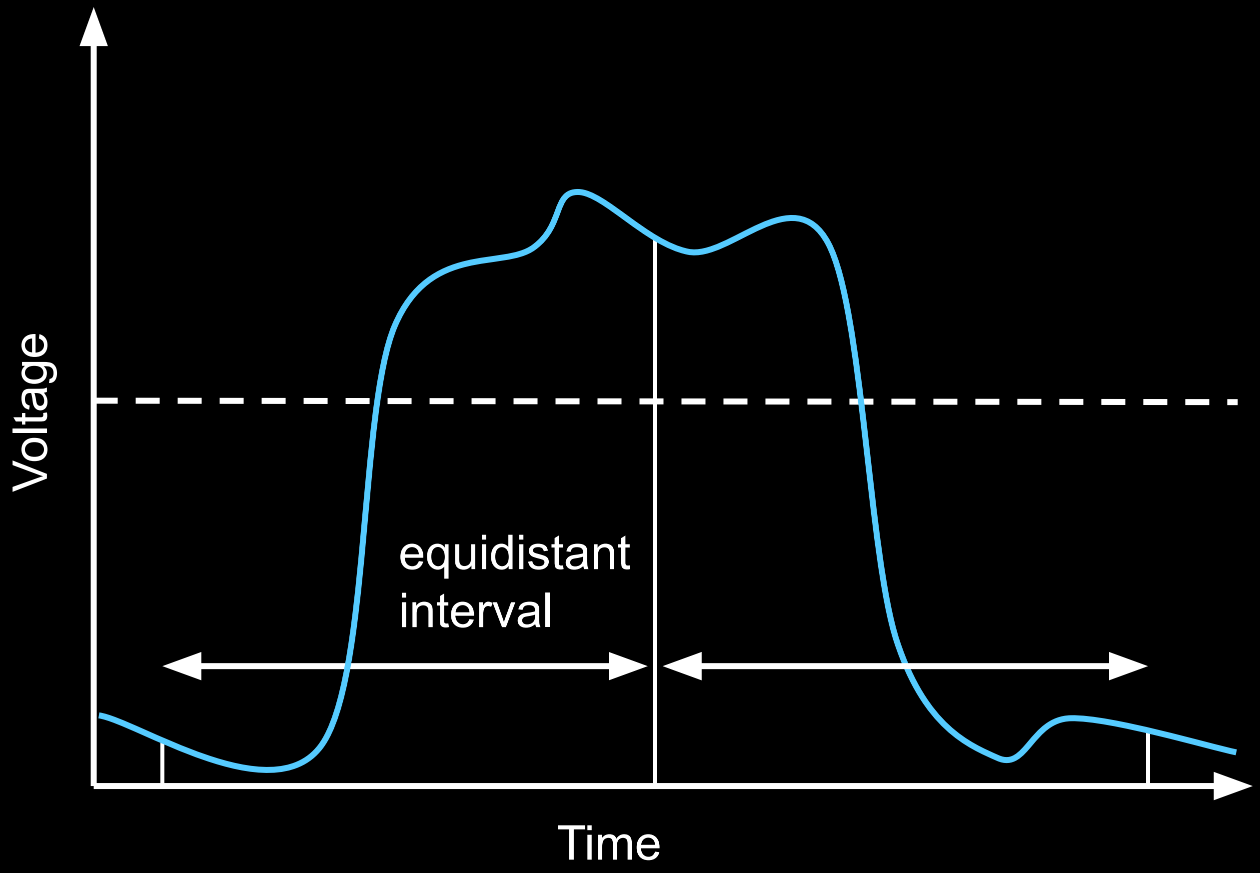

Voltage
Time

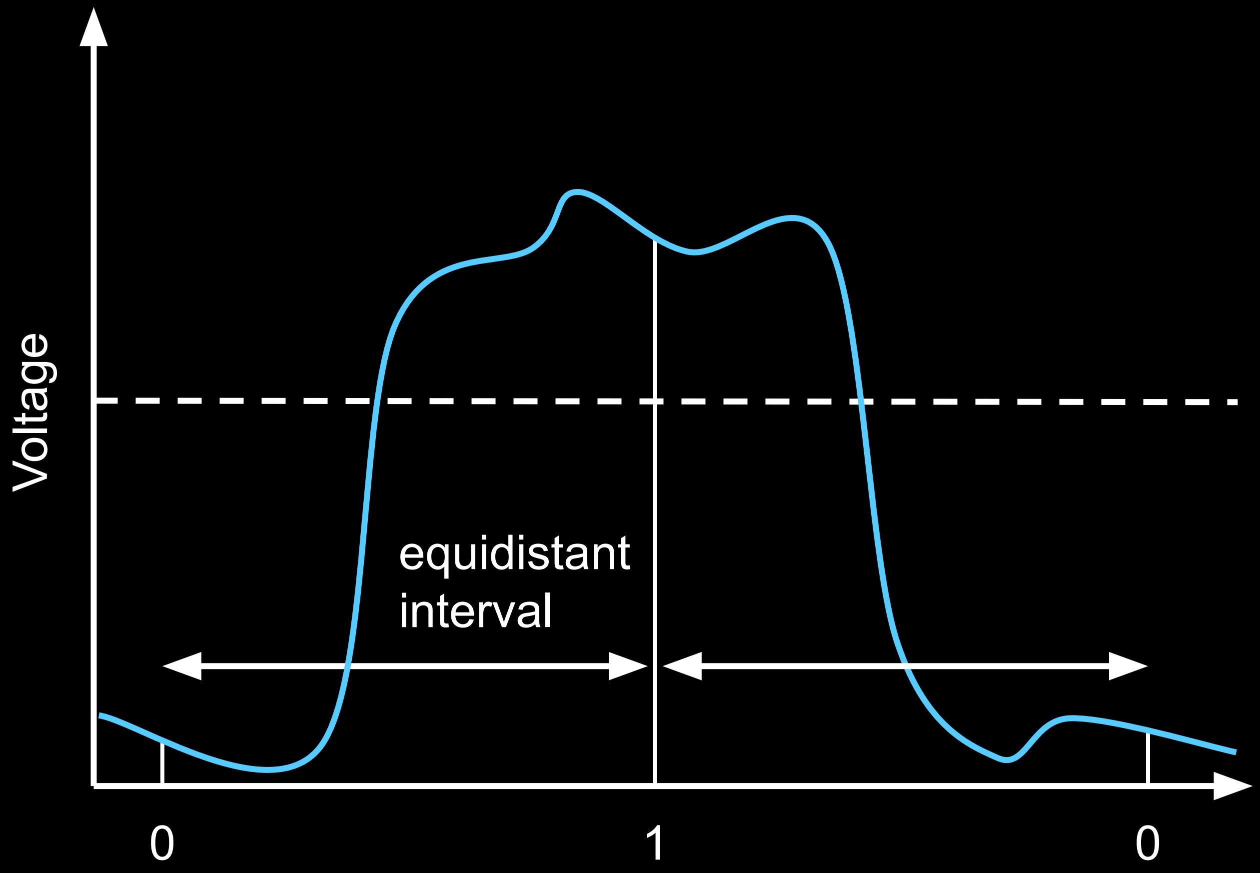

Voltage
1
0
0
Time

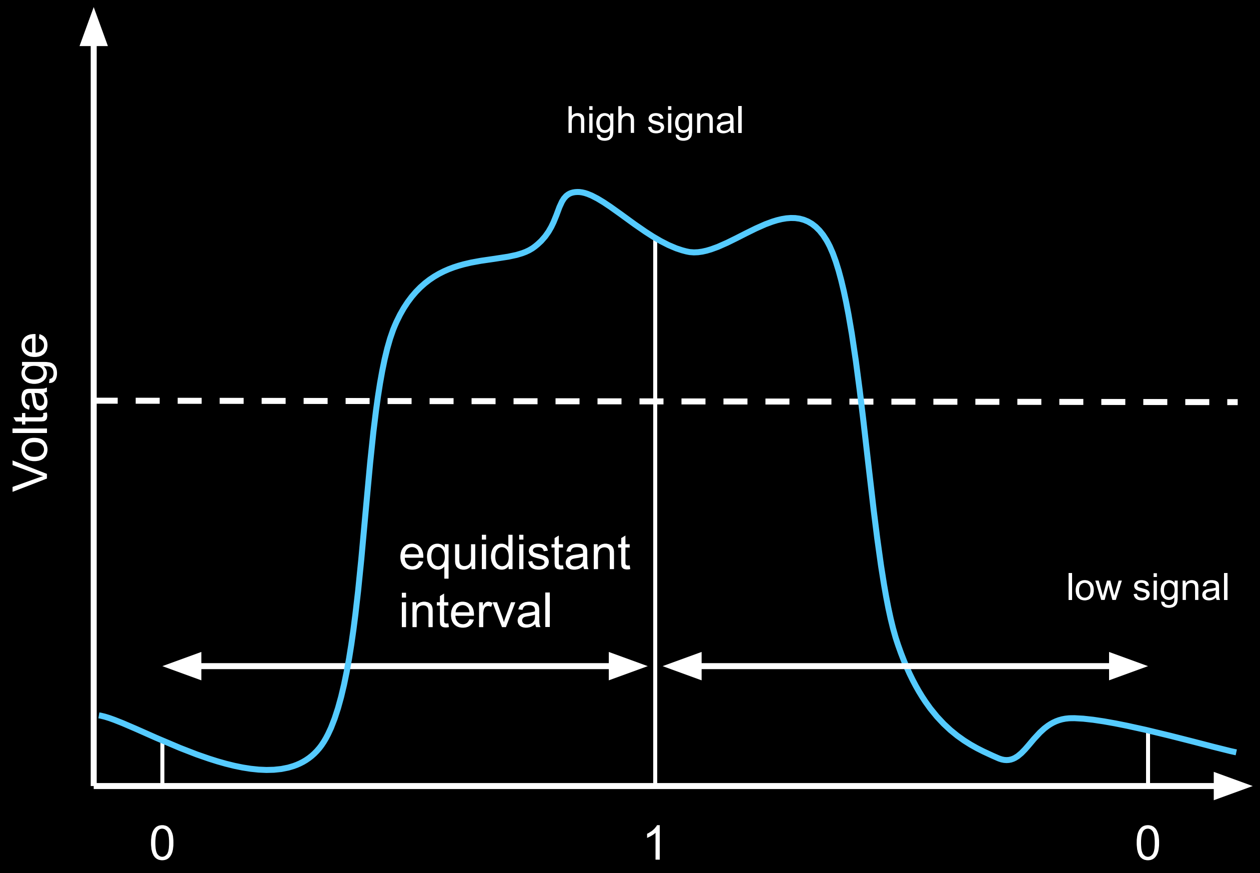

Voltage
Time


Voltage
Time


Voltage
Time
1
0

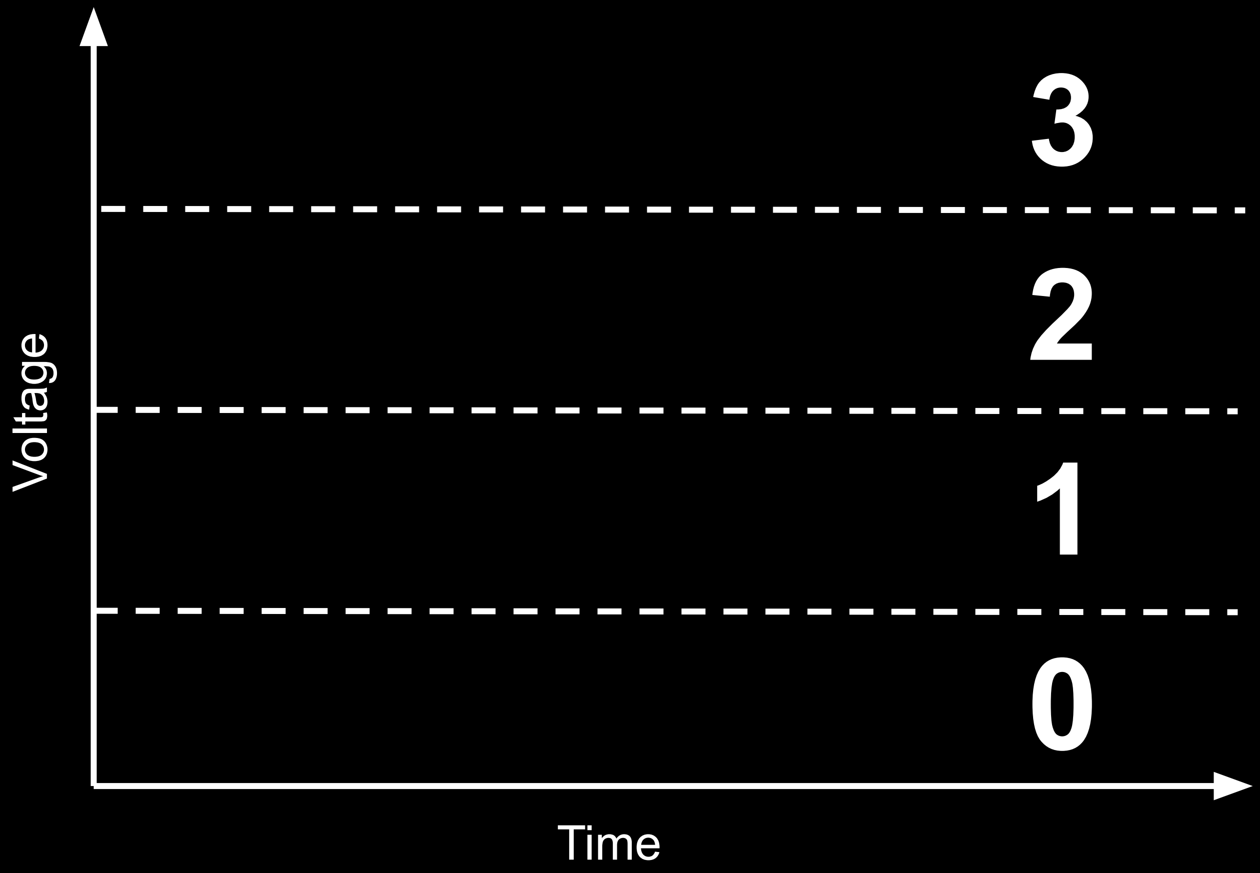

Voltage
equidistant
interval
Time


Voltage
equidistant
interval
0
1
0


high signal
Voltage
equidistant
interval
low signal
0
1
0

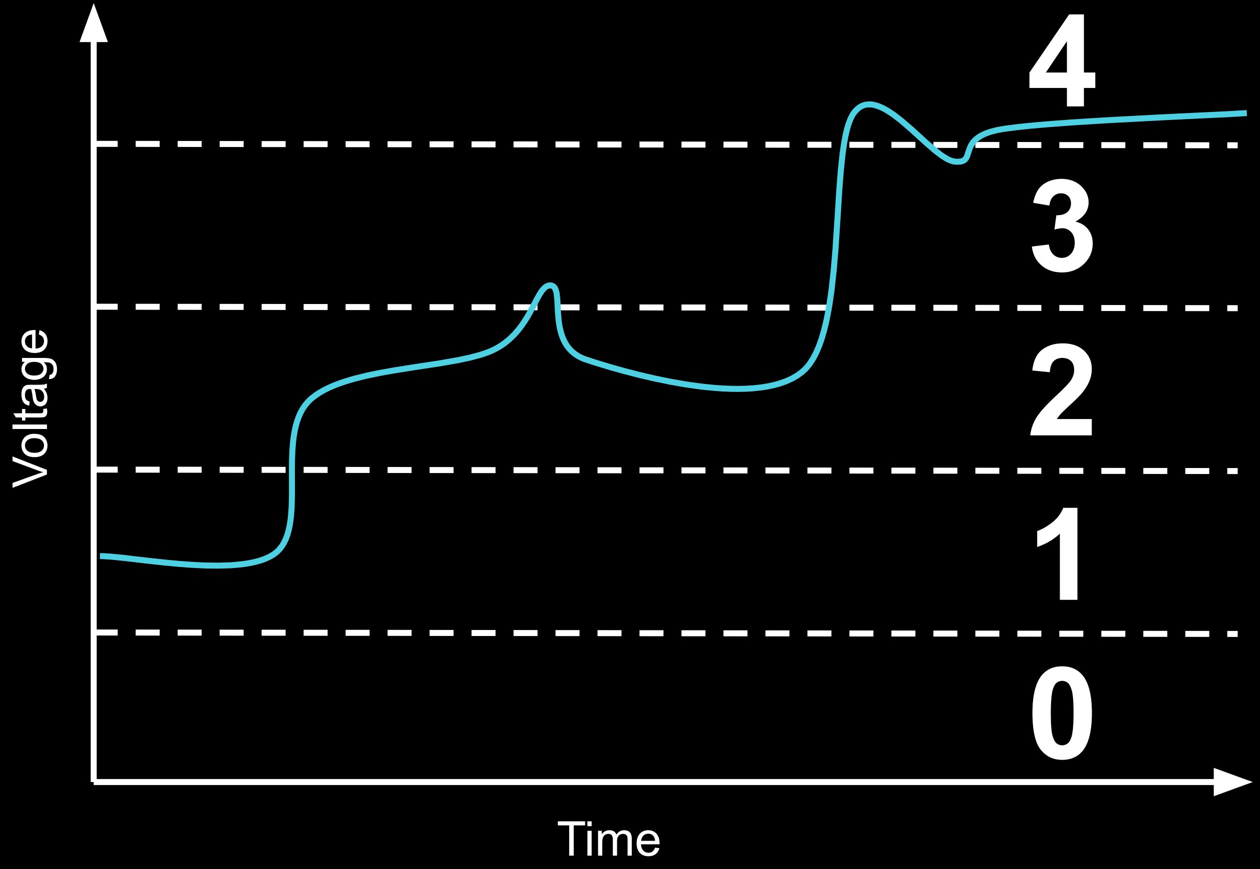
what about $R > 2$?

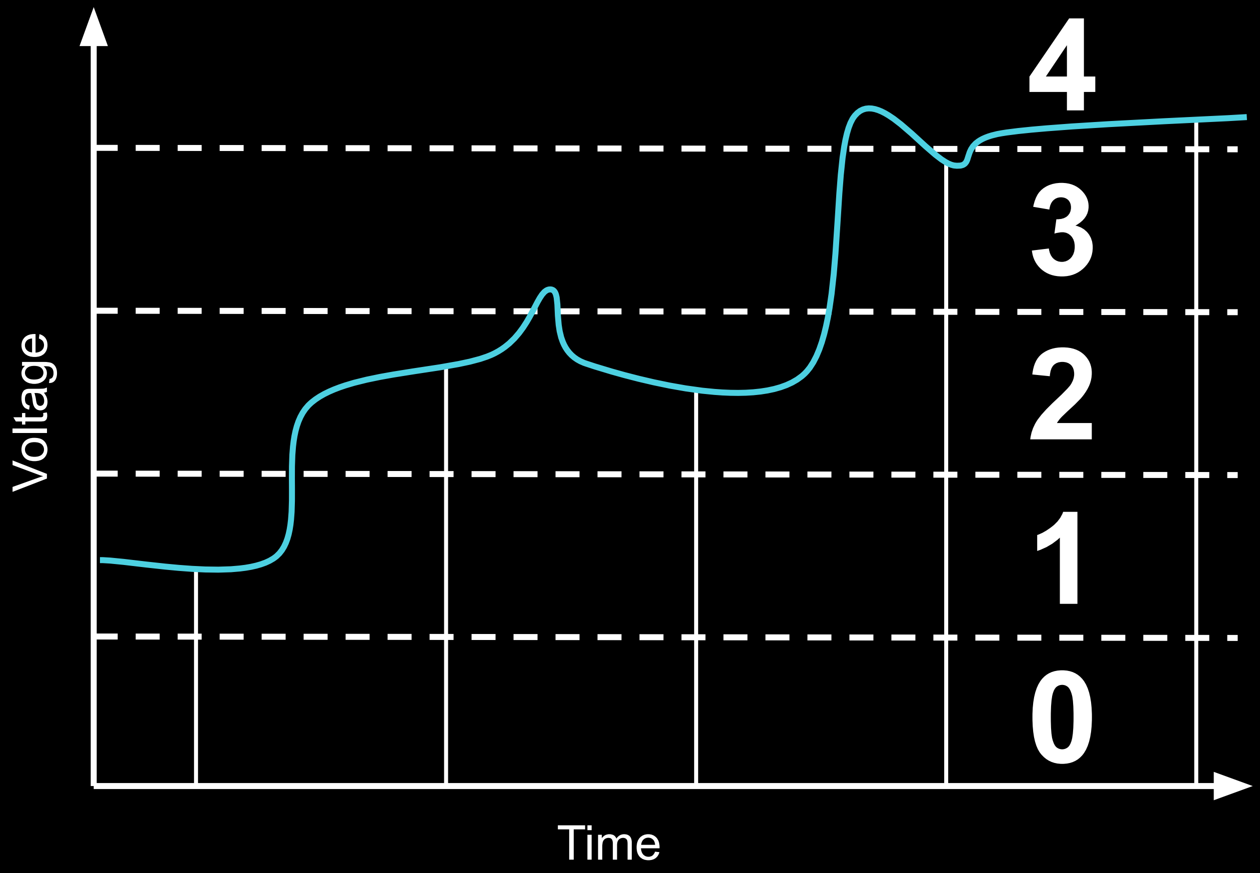

2
1
0
Voltage
Time

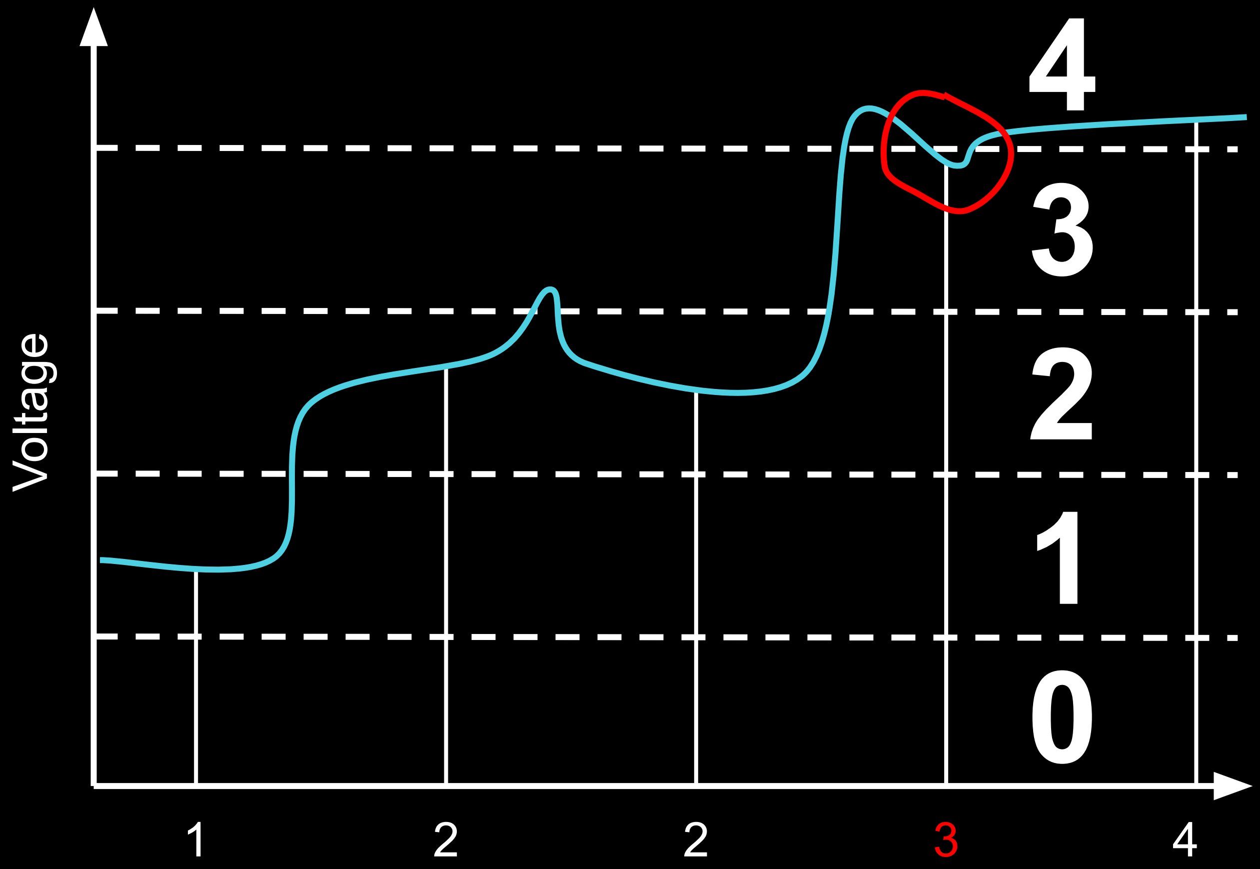


3
2
1
0
Voltage
Time


4
3
2
1
0
Voltage
Time


4
3
2
1
0
Voltage
Time


4
3
2
1
0
Voltage
Time


Voltage
4
3
2
1
0
1
2
2
3
4

a higher base means less hardware

a higher base means less hardware

but more complex devices

a higher base means less hardware

but more complex devices

and more errors