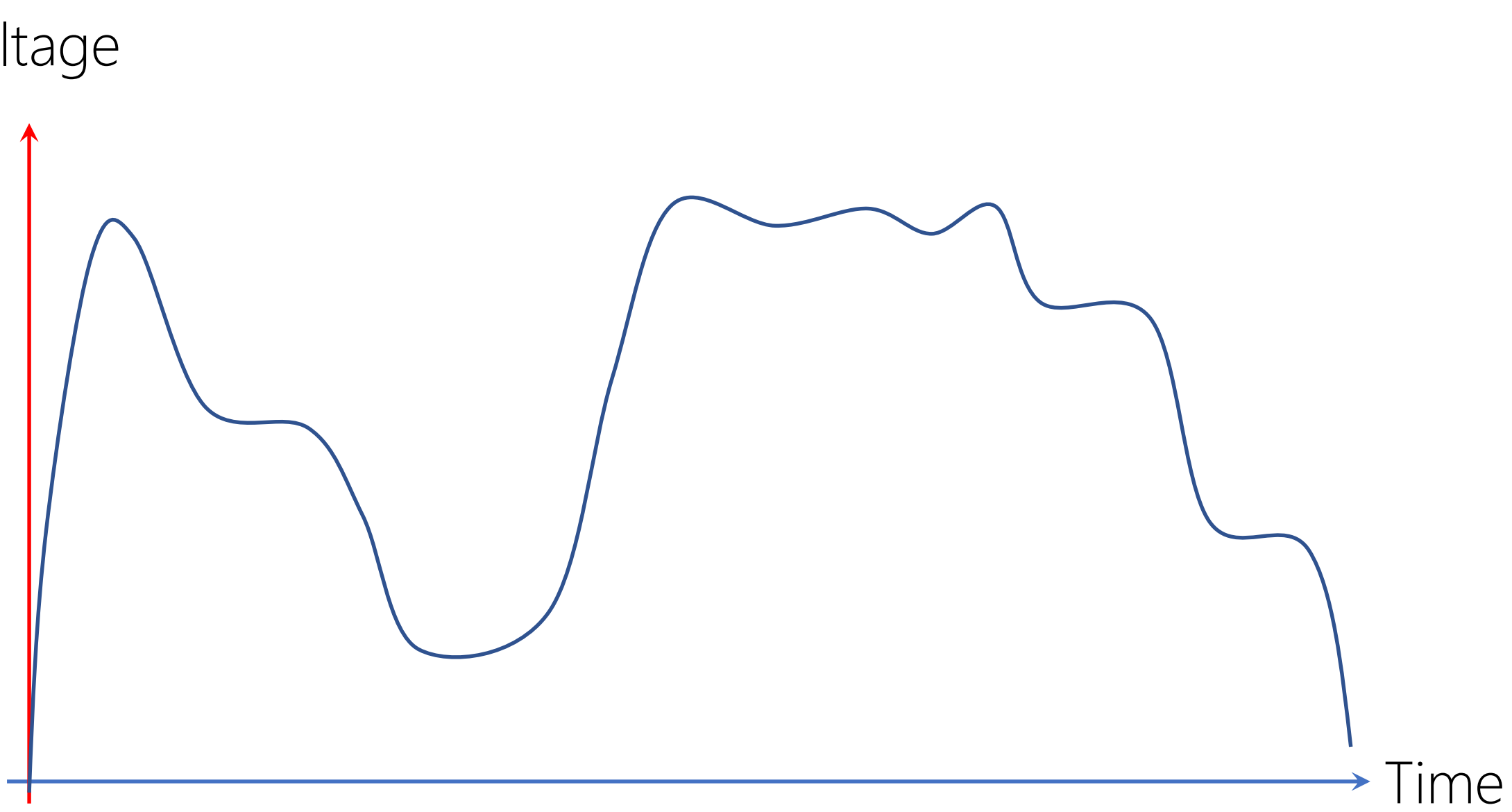
ANALOG SYSTEMS

Continuous


Voltage
Time

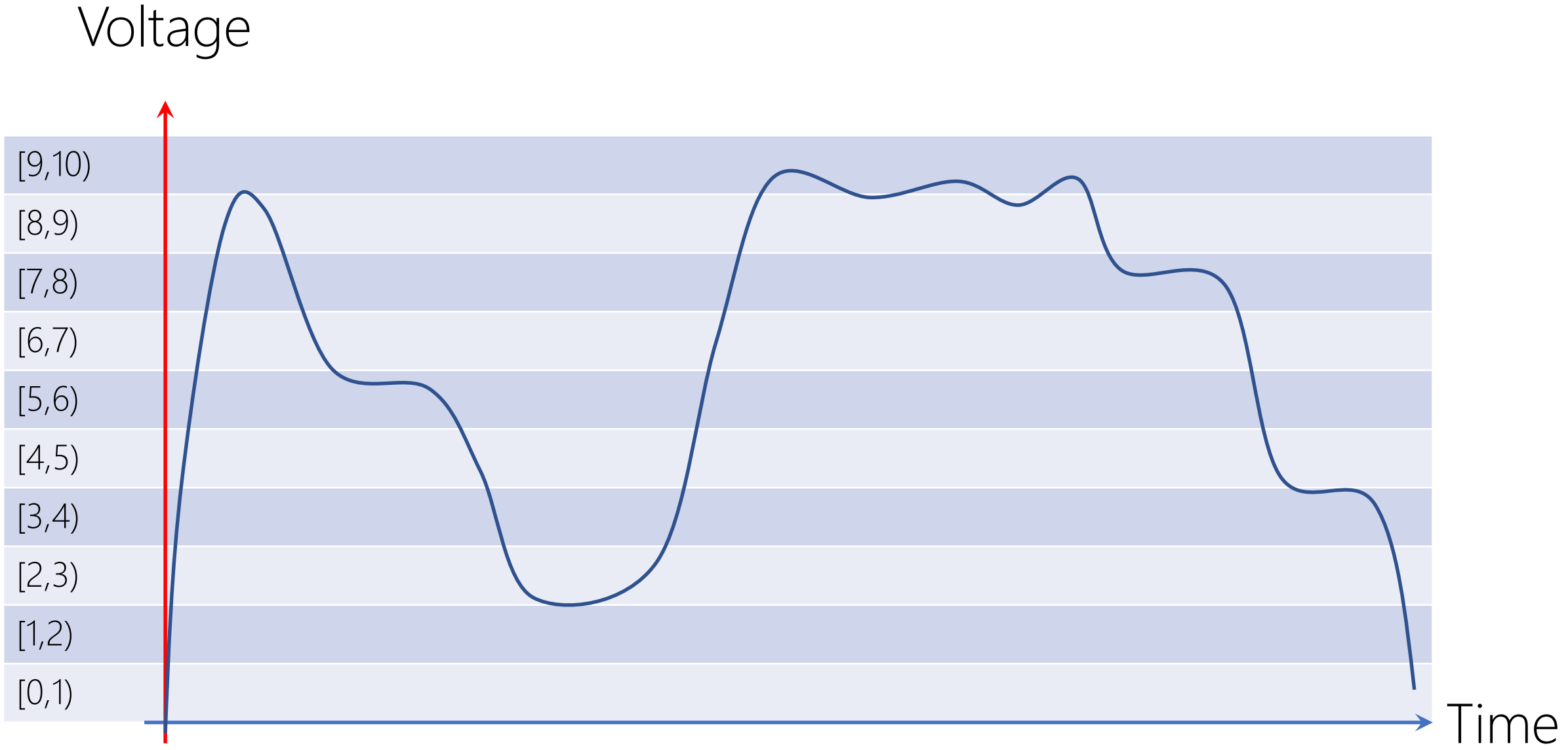
DIGITAL SYSTEMS

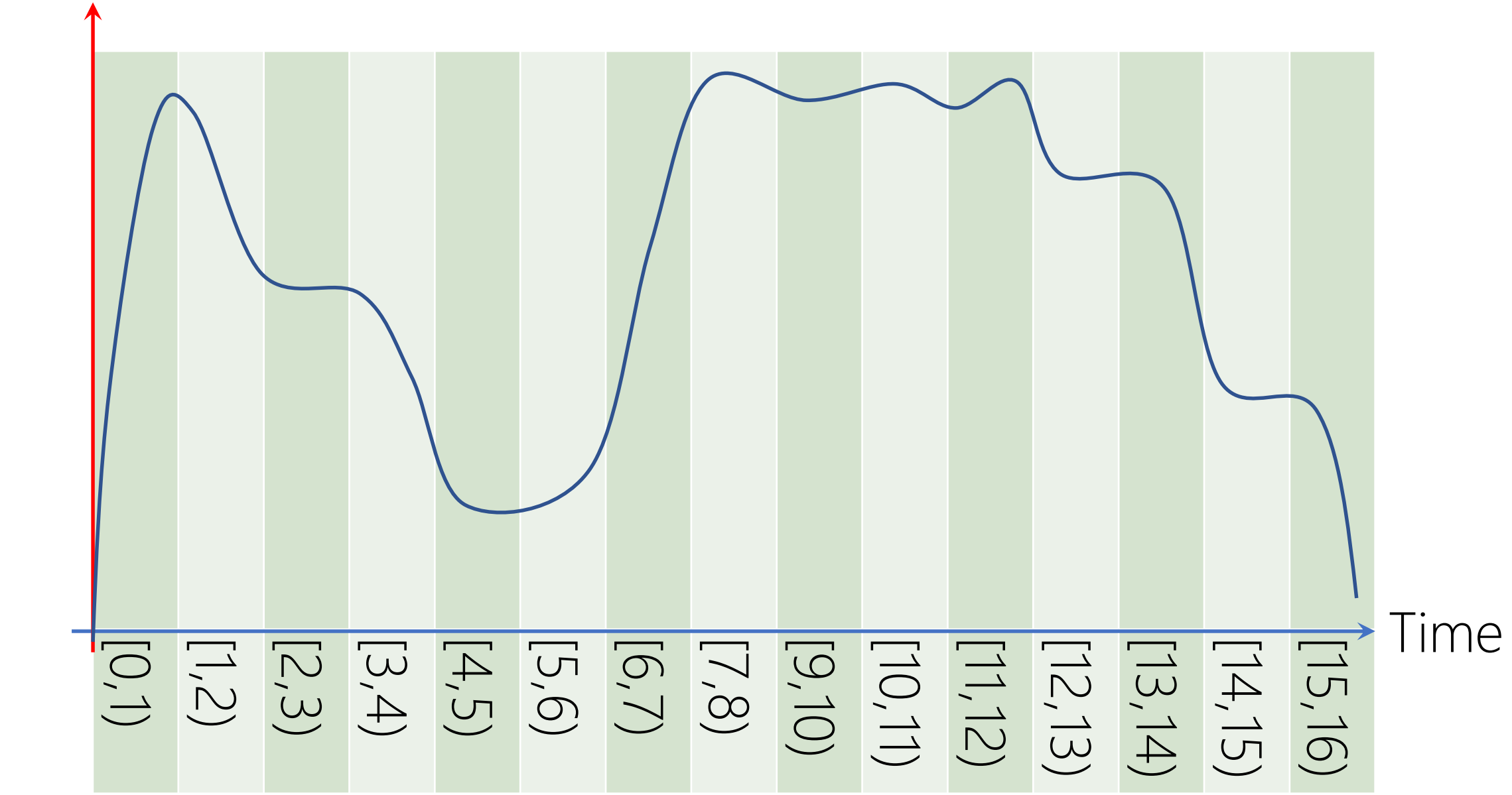
Discrete

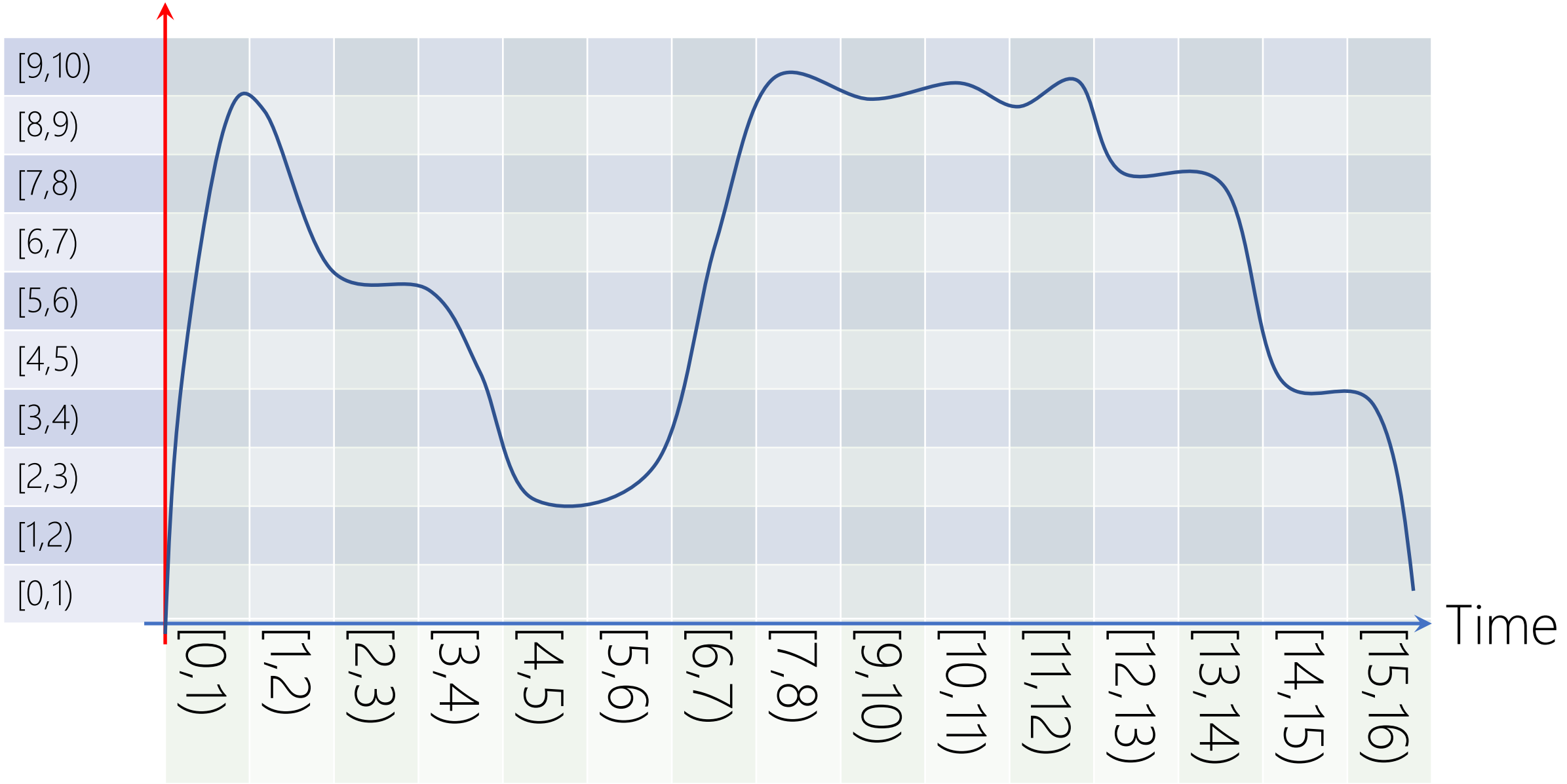
ELECTRICITY NUMBER SYSTEM

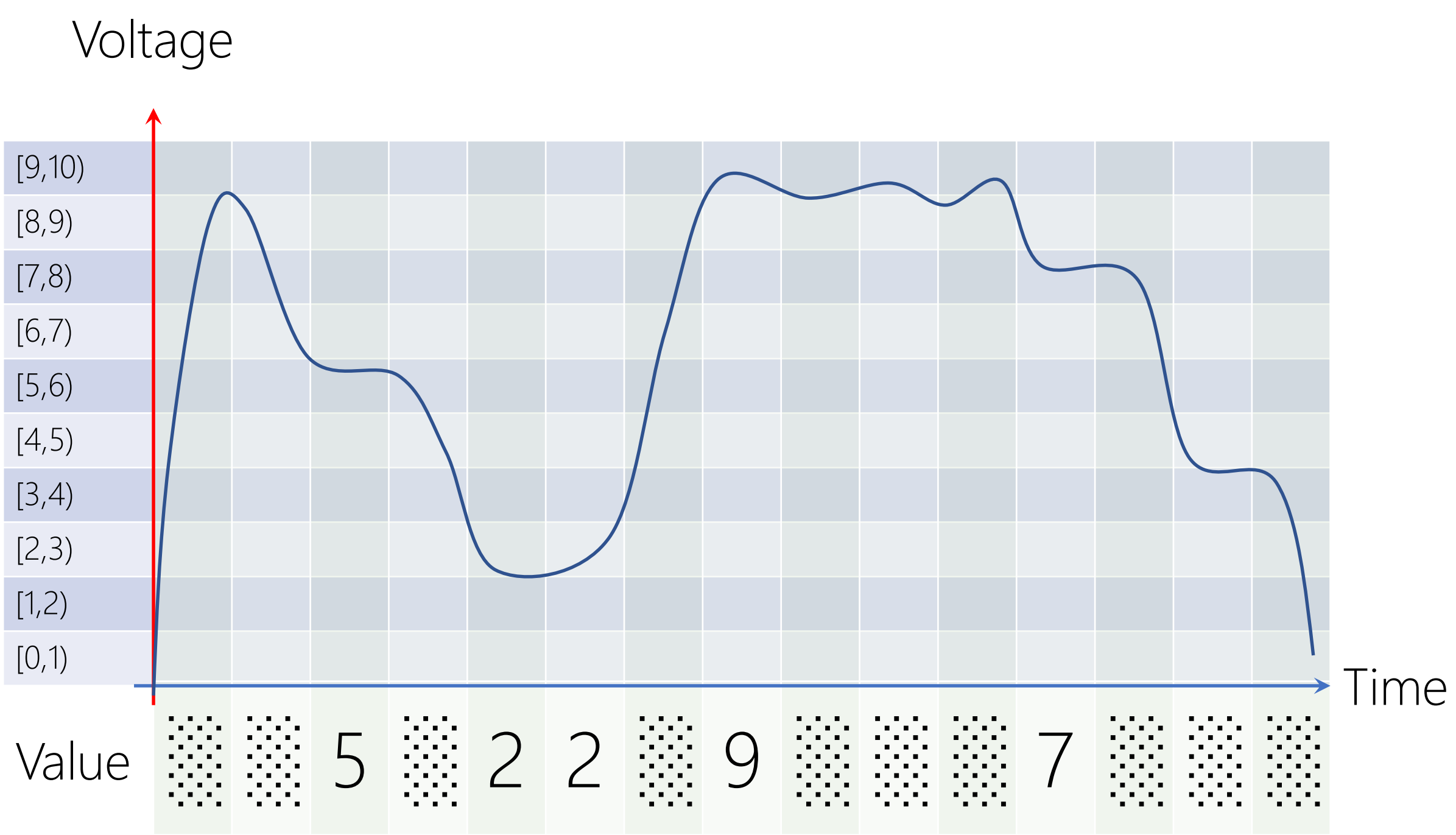
BASE-?

BASE-10

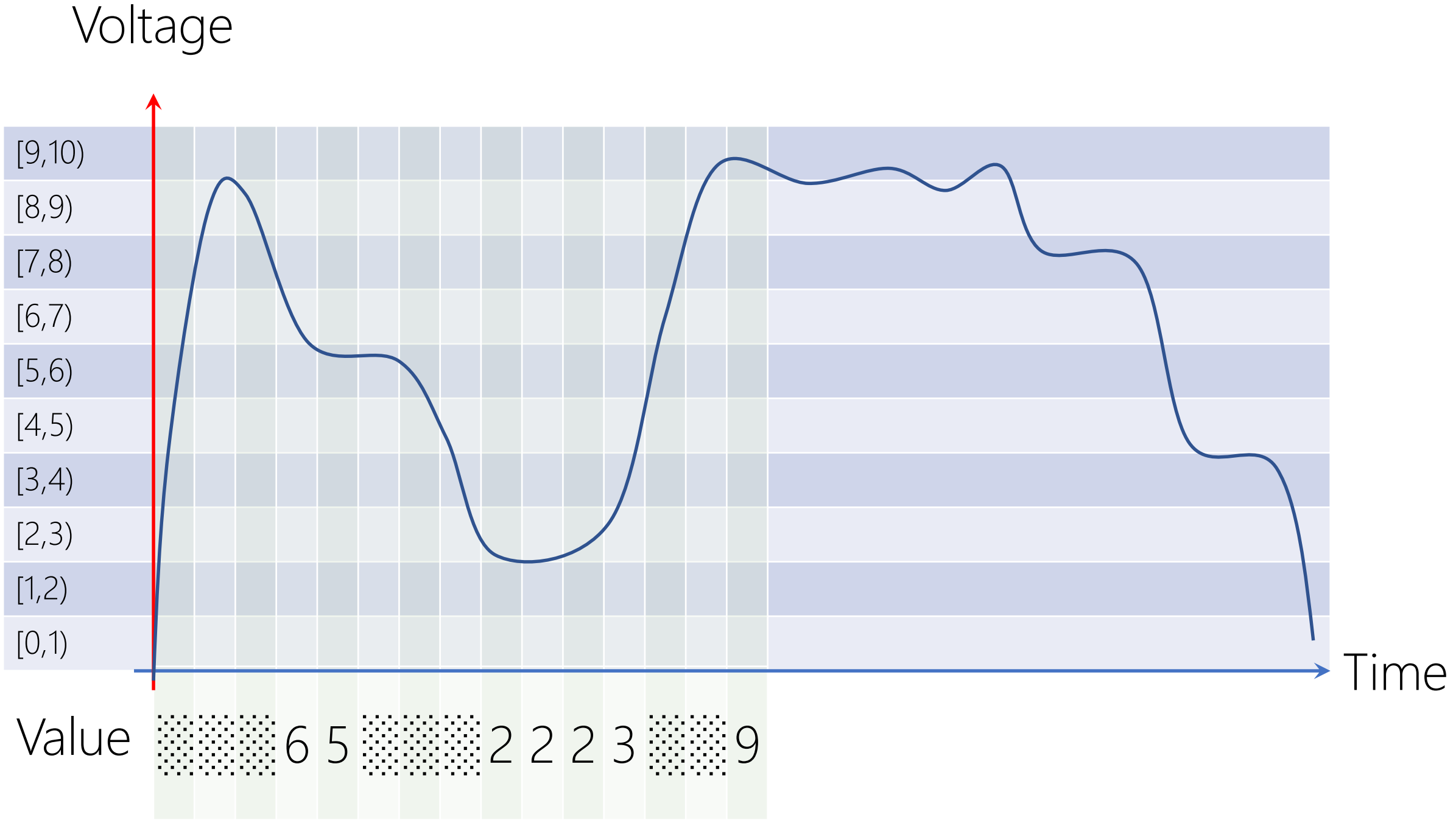

Voltage
[9,10)
[8,9)
[7,8)
[6,7)
[5,6)
[4,5)
[3,4)
[2,3)
[1,2)
[0,1)
Time

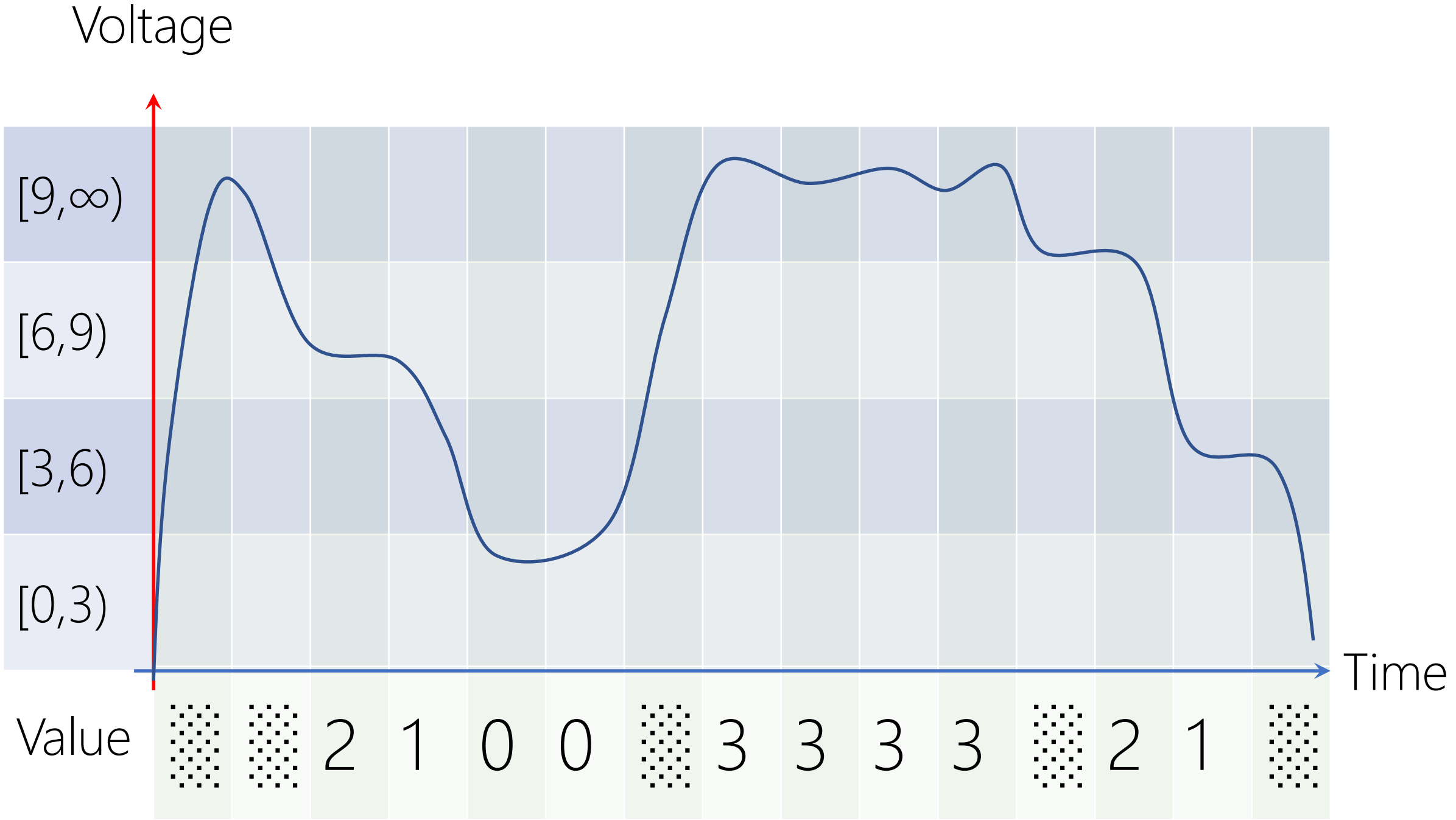

Voltage
Time
[0,1)
[1,2)
[2,3)
[3,4)
[4,5)
[5,6)
[6,7)
[7,8)
[9,10)
[10,11)
[11,12)
[12,13)
[13,14)
[14,15)
[15,16)

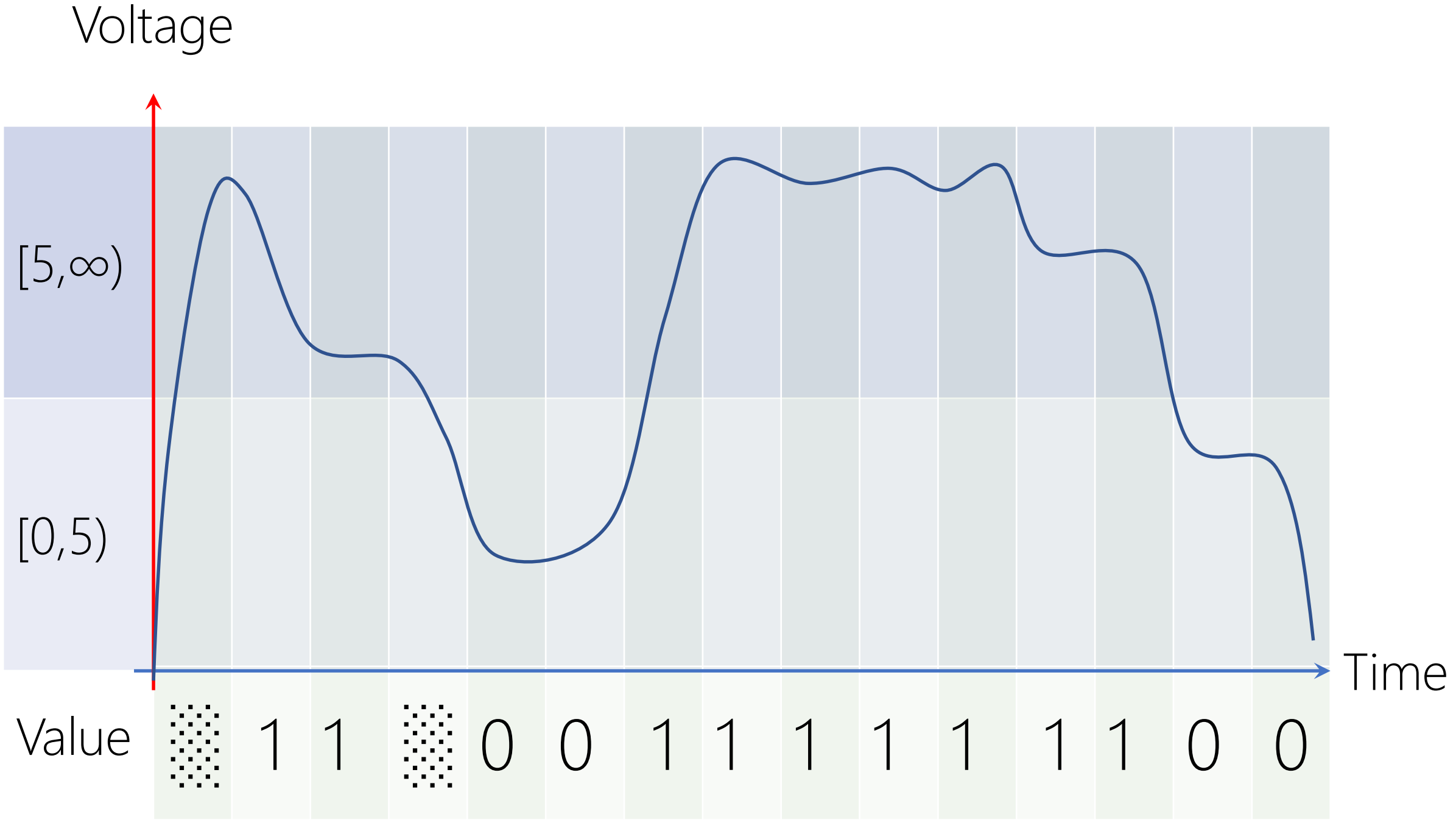

Voltage
[9,10)
[8,9)
[7,8)
[6,7)
[5,6)
[4,5)
[3,4)
[2,3)
[1,2)
[0,1)
Time
[0,1)
[1,2)
[2,3)
[3,4)
[4,5)
[5,6)
[6,7)
[7,8)
[9,10)
[10,11)
[11,12)
[12,13)
[13,14)
[14,15)
[15,16)


Voltage
[9,10)
[8,9)
[7,8)
[6,7)
[5,6)
[4,5)
[3,4)
[2,3)
[1,2)
[0,1)
Time
Value
5
2
2
9
7

GRANULARITY


Voltage
[9,10)
[8,9)
[7,8)
[6,7)
[5,6)
[4,5)
[3,4)
[2,3)
[1,2)
[0,1)
Time
Value
6 5
2 2 2 3
9


Voltage
[9,∞)
[6,9)
[3,6)
[0,3)
Time
Value
2 1 0 0 3 3 3 3 2 1


Voltage
[5,∞)
[0,5)
Time
Value
1 1 0 0 1 1 1 1 1 1 1 0 0

RELIABILITY

Robust to Noise

Fundamentally Hardware | Engineering Problem

TERNARY COMPUTER

https://en.wikipedia.org/wiki/Ternary_computer

Balanced Trinary {−1,0,1}

Entirely from *Wood*!

Thomas Fowler 1840

More History and Etymology → https://en.wikipedia.org/wiki/Computer

DECIMAL COMPUTER

https://en.wikipedia.org/wiki/Decimal_computer

They are not actually base-10! We'll cover them later.

TRUE VS. FALSE

George Boole (/bu:l/)

Mathematician
Philosopher
Logician

The Laws of Thought (1854)

Boolean Algebra!

Claude Elwood Shannon

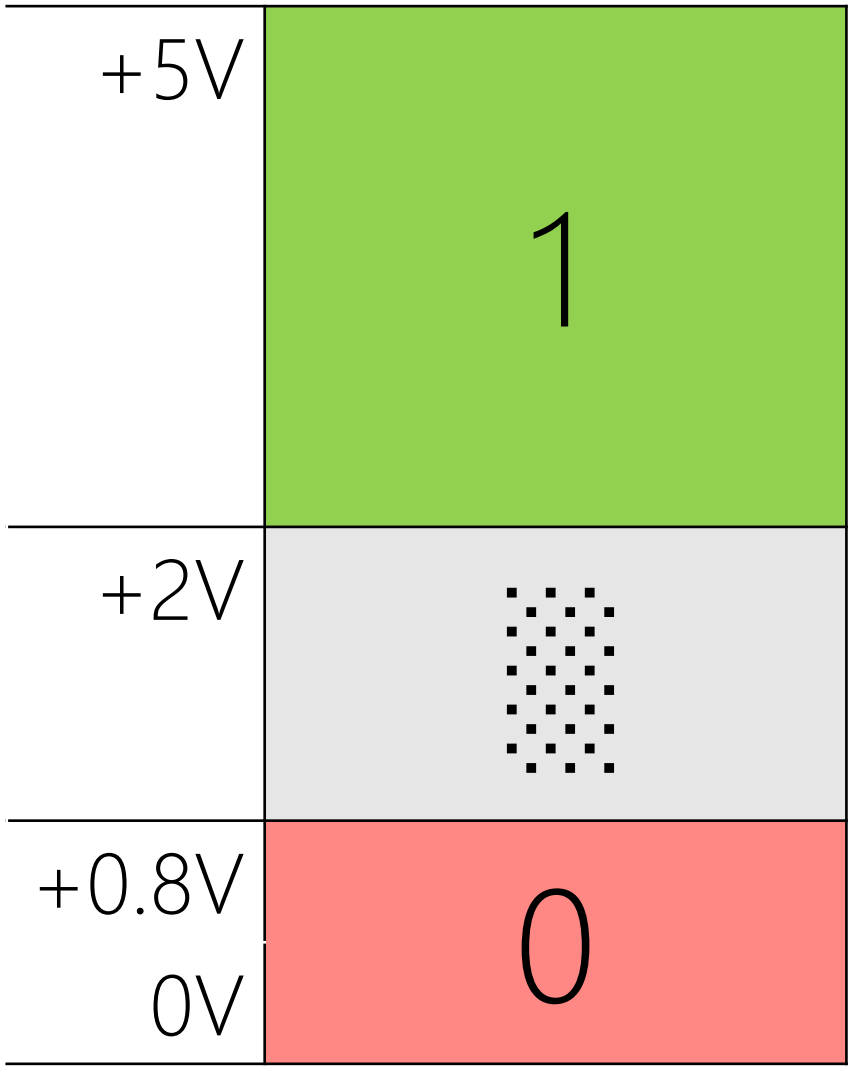
Mathematician
Electrical Engineer
Cryptographer

M.Sc. Thesis (1937)

A Symbolic Analysis of Relay and Switching Circuits

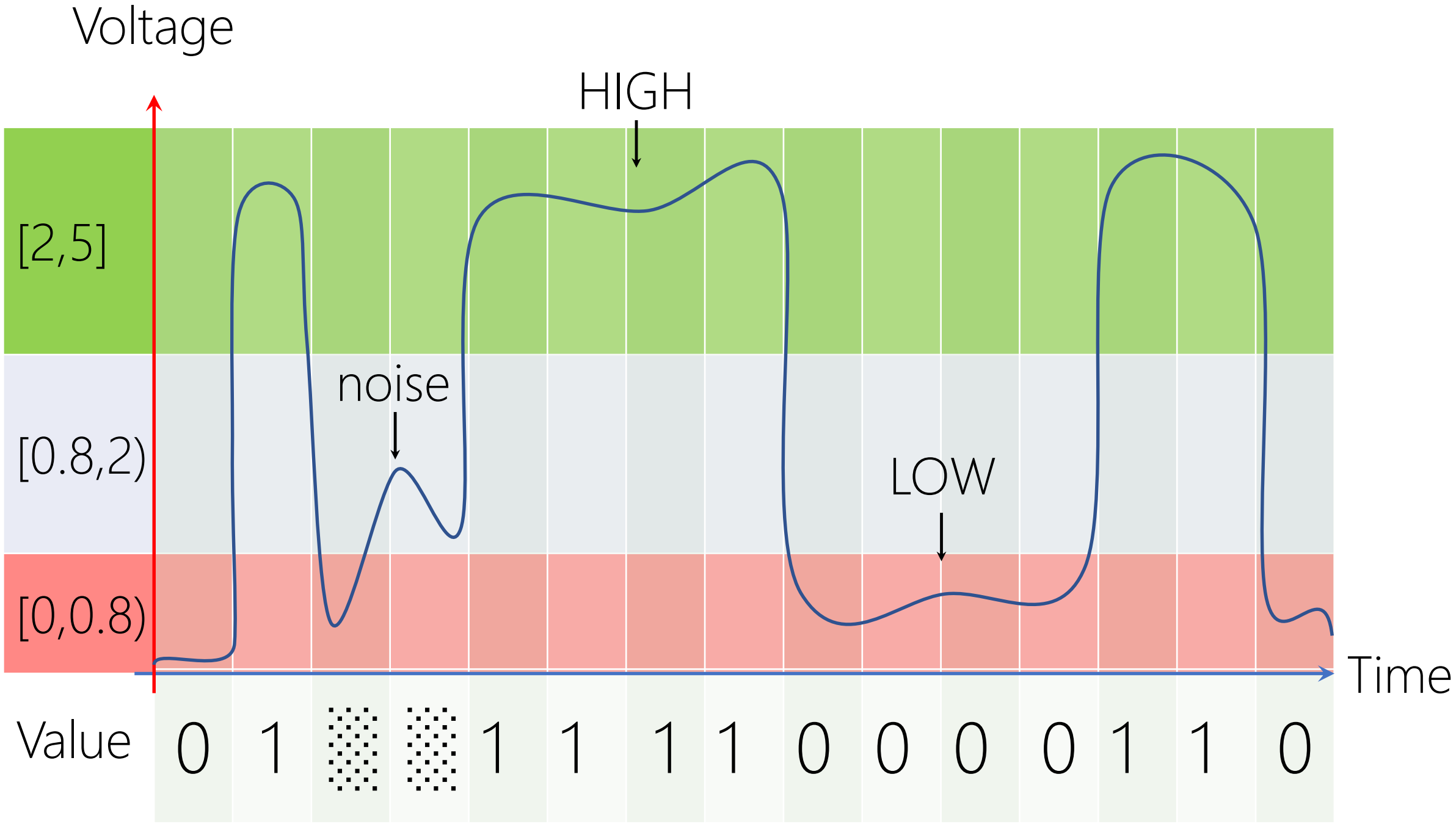
Switching Algebra!

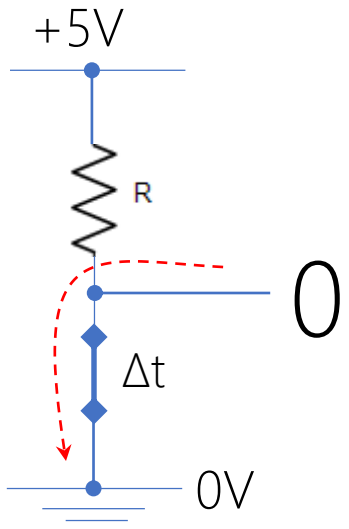
BINARY COMPUTER



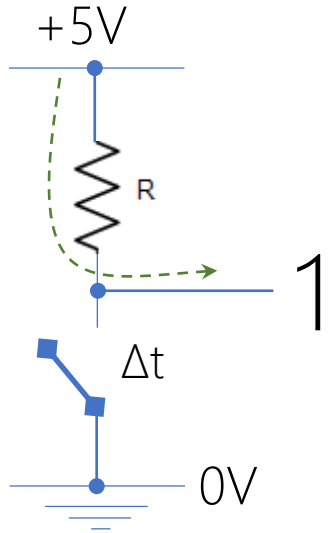
POSITIVE LOGIC

https://www.electronics-tutorials.ws/logic/logic_1.html

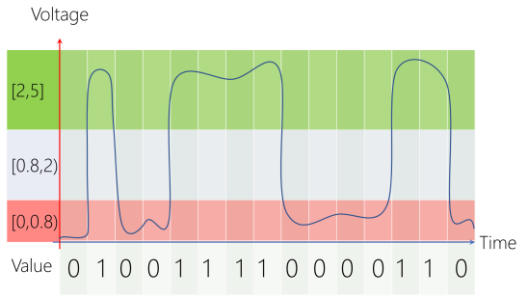

Voltage
HIGH
[2,5]
noise
[0.8,2)
LOW
[0,0.8)
Time
Value
0 1 1 1 0 0 0 0 1 1 0

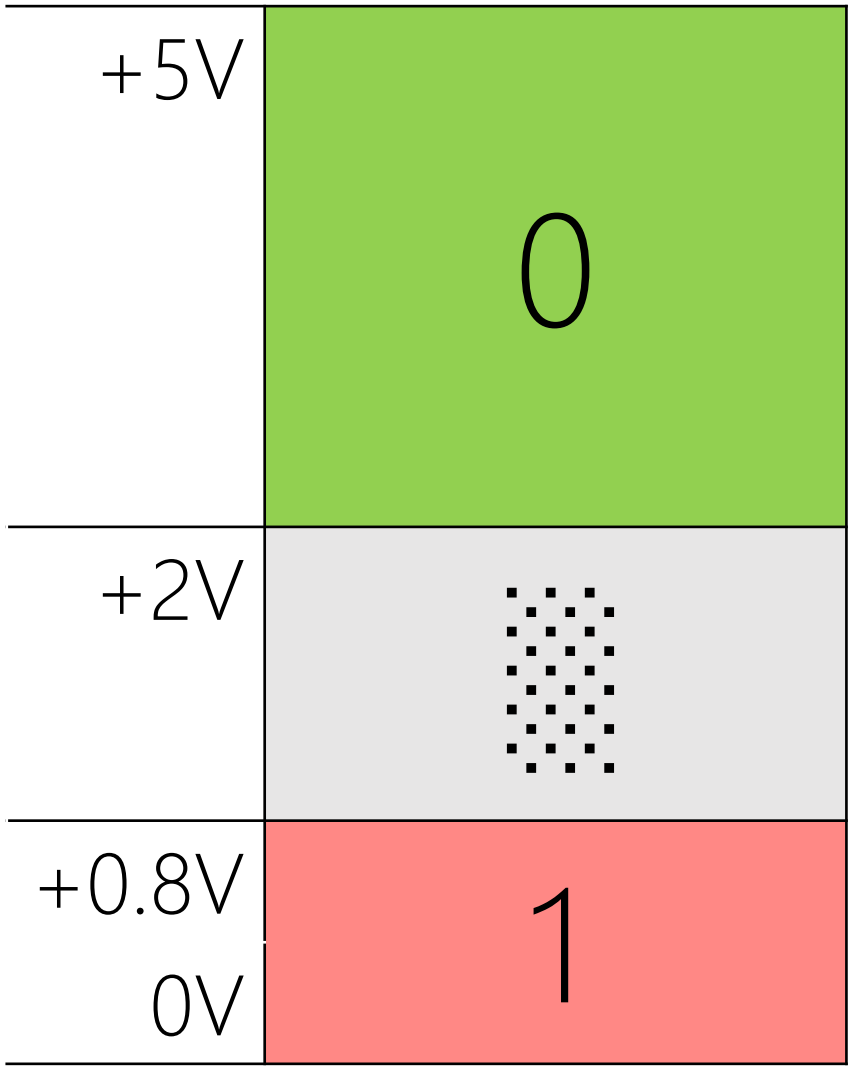


Earth (Ground)



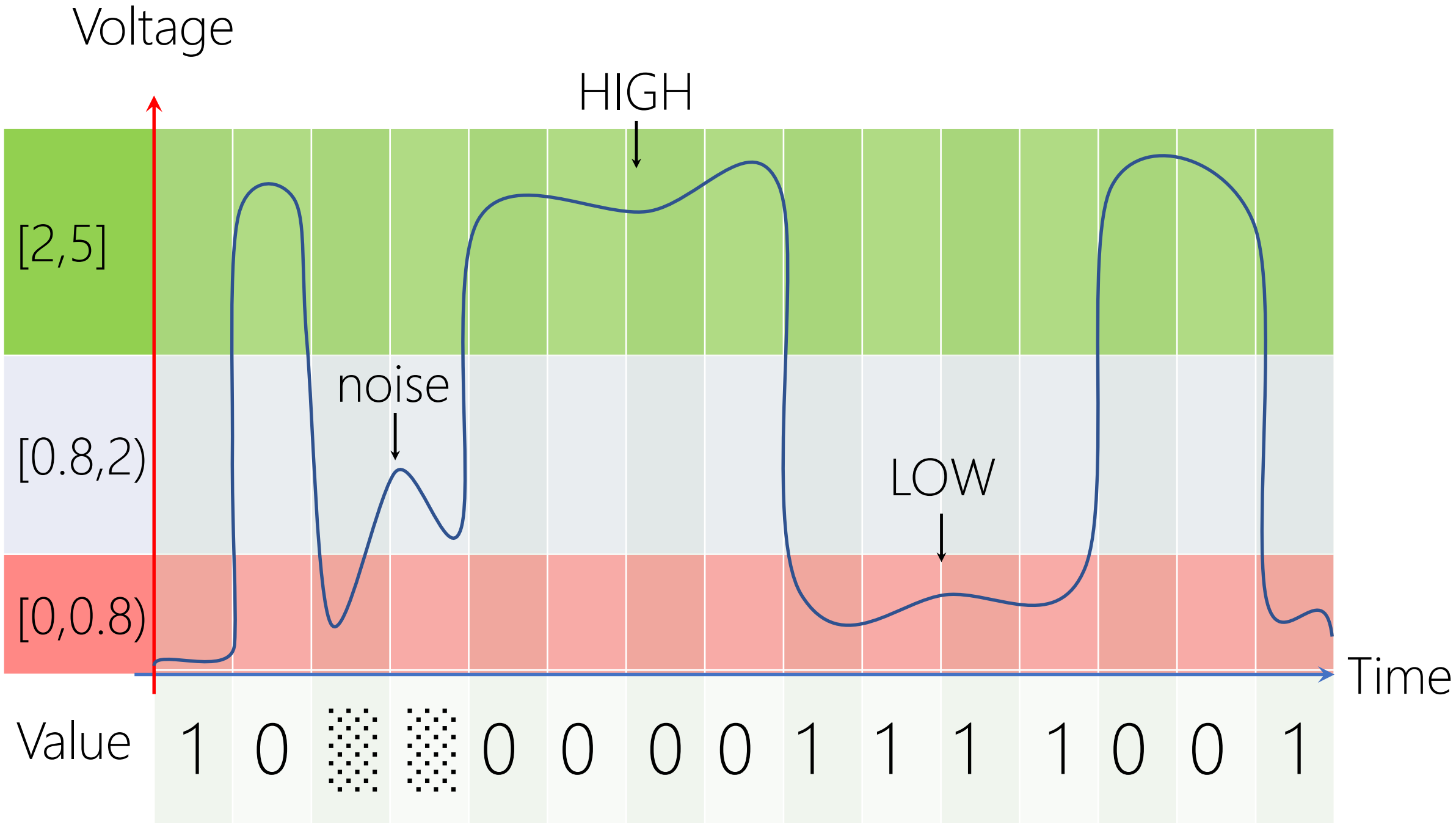
Earth (Ground)

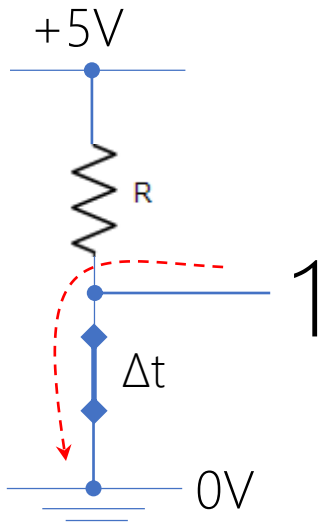




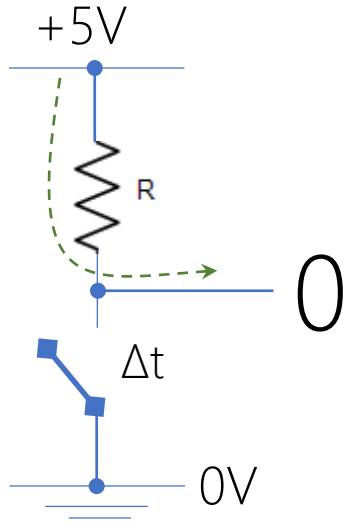
NEGATIVE LOGIC

https://www.electronics-tutorials.ws/logic/logic_1.html

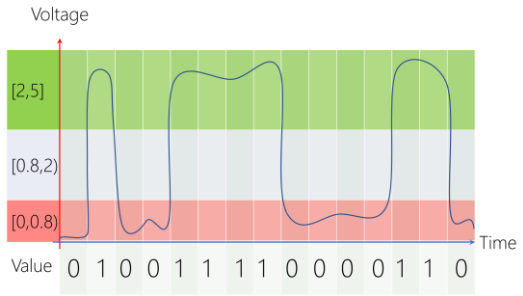

Voltage
HIGH
[2,5]
noise
[0.8,2)
LOW
[0,0.8)
Time
Value
1 0 0 0 0 1 1 1 1 0 0 1



Earth (Ground)



Earth (Ground)



DESIGN COMPUTER

Positive Logic
Button-Up Approach

DESIGN COMPUTER

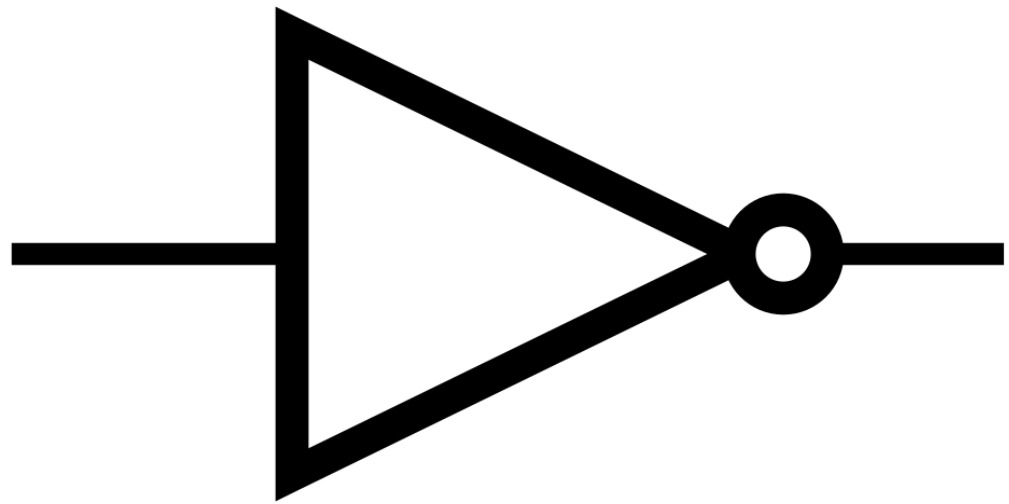
Positive Logic
Button-Up Approach

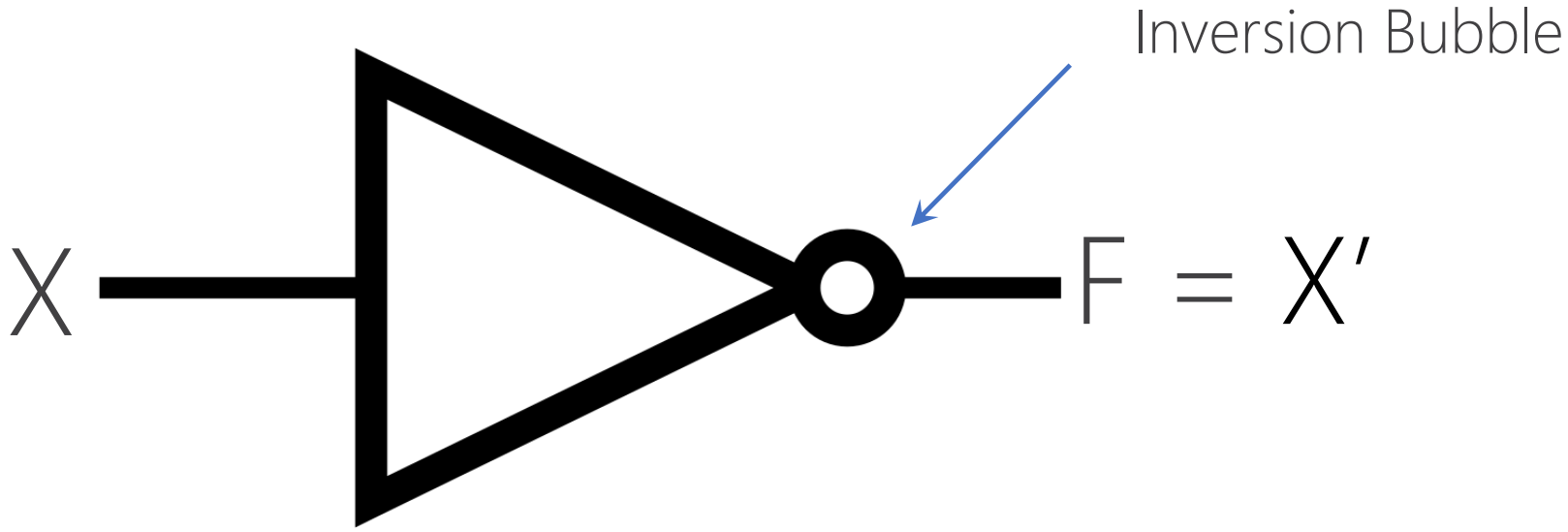
Finding simpler, but equivalent, computers reduces the overall cost!
Rely primarily on mathematical methods in Boolean algebra!

BUILD COMPUTER

Electrical and Computer Engineering

LOGIC GATES

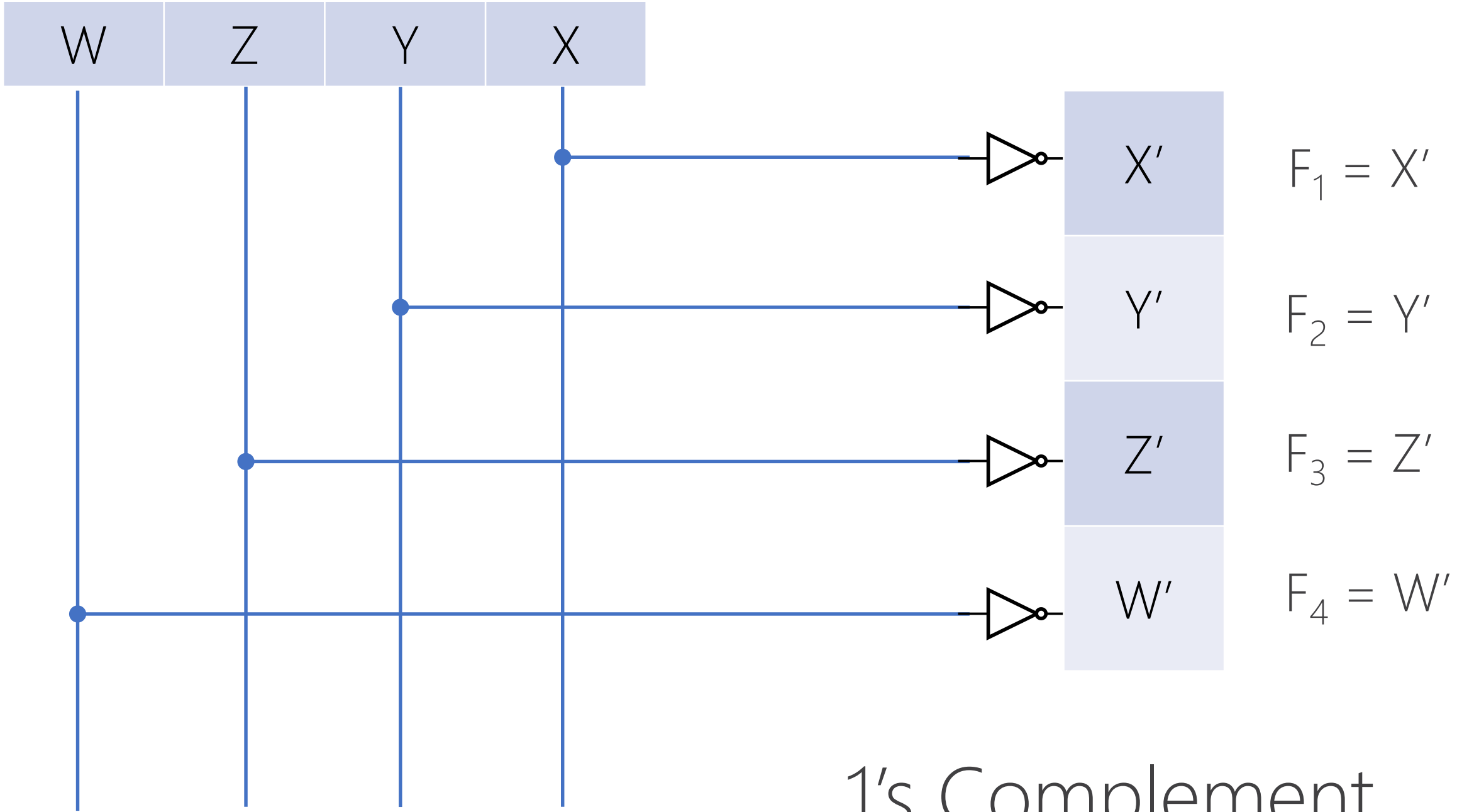




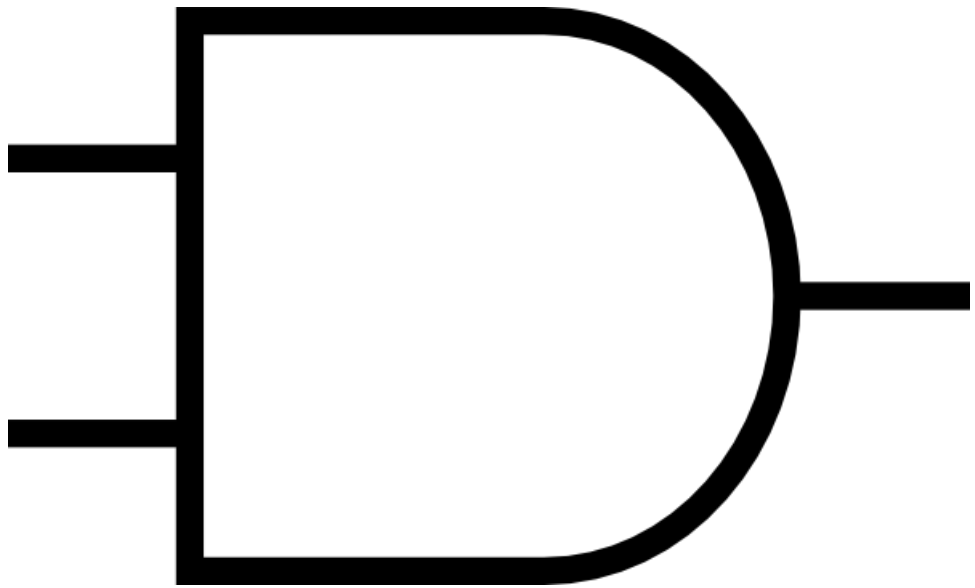
X	NOT X	Invertor X	X′	$\overline{X}$
0	1			
1	0			

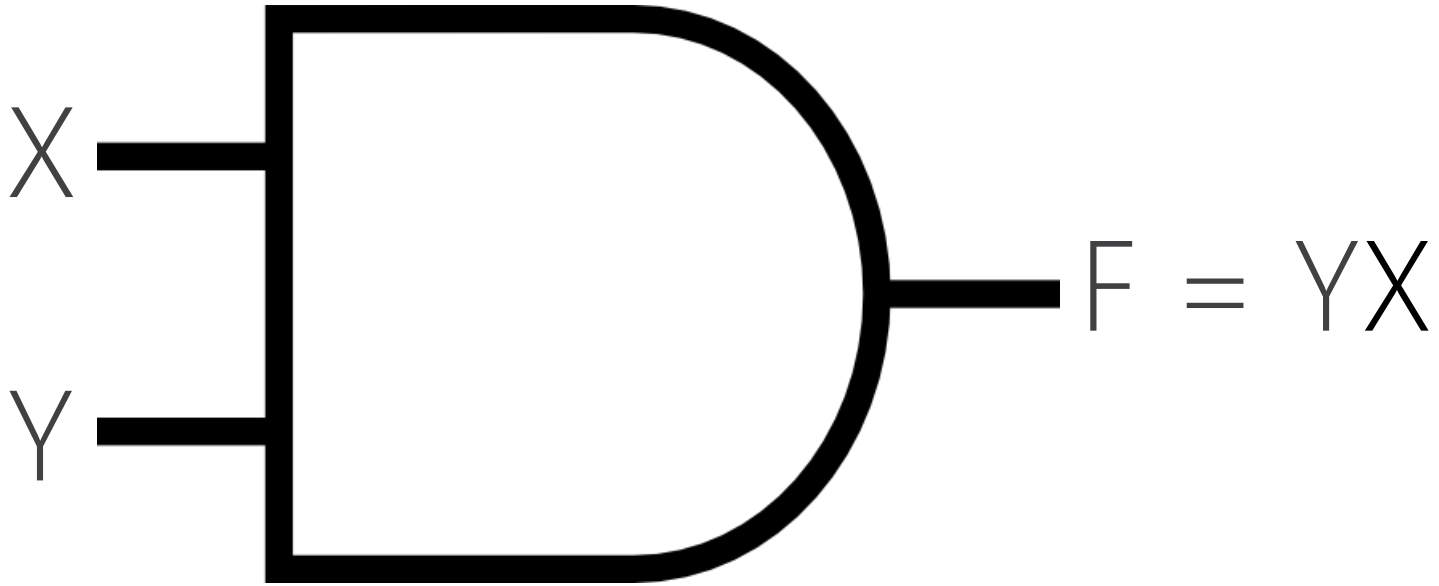
Boolean Expression/Function: F = X′

> *inverse of X gives F* <

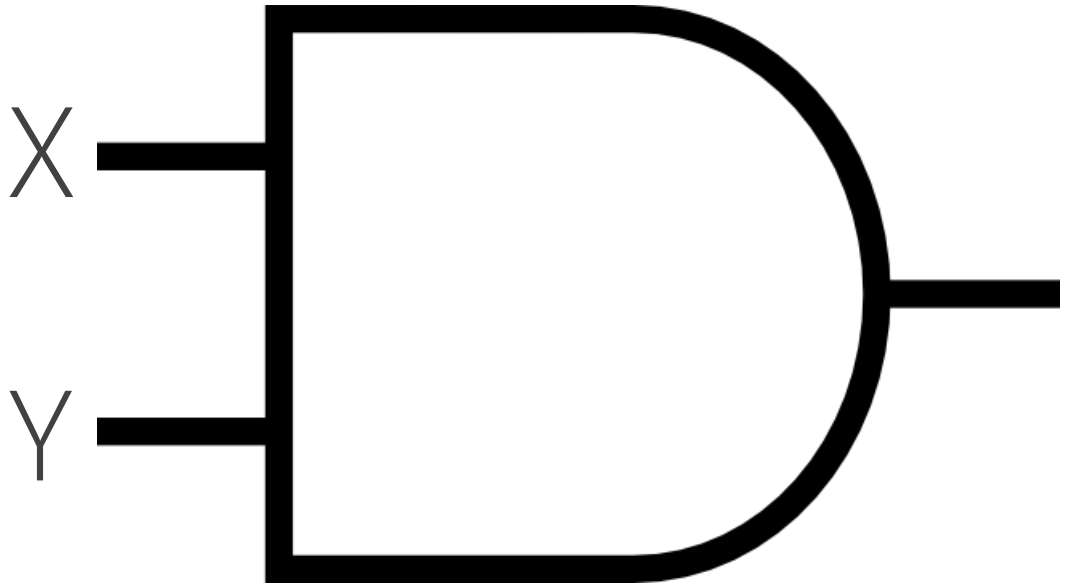


1's Complement





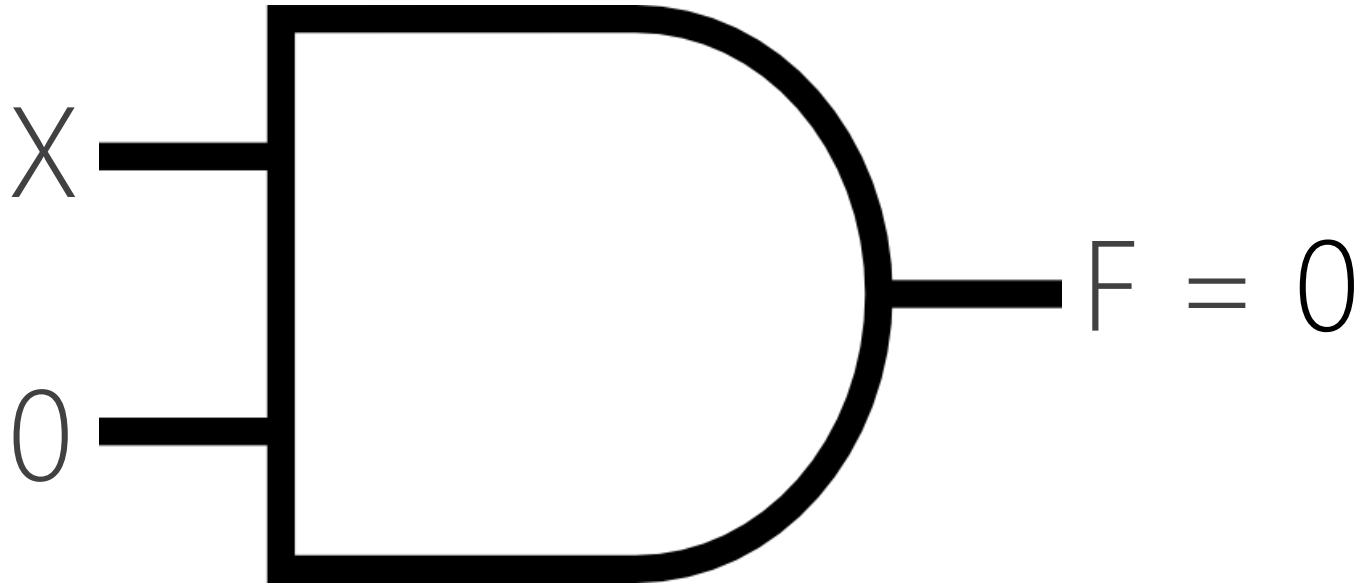
Y	X	X AND Y	Y · X	Y * X
0	0		0	
0	1		0	
1	0		0	
1	1		1	



F = YX = XY

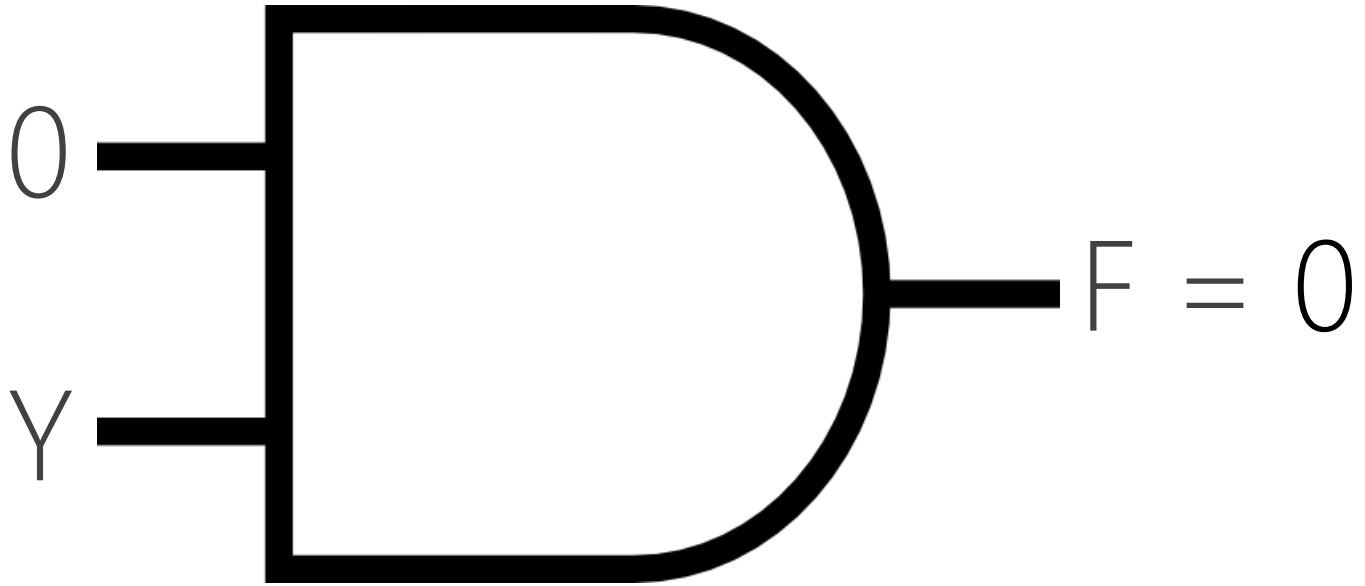
Commutative

X	Y	Y AND X	X · Y	X * Y
0	0		0	
0	1		0	
1	0		0	
1	1		1	



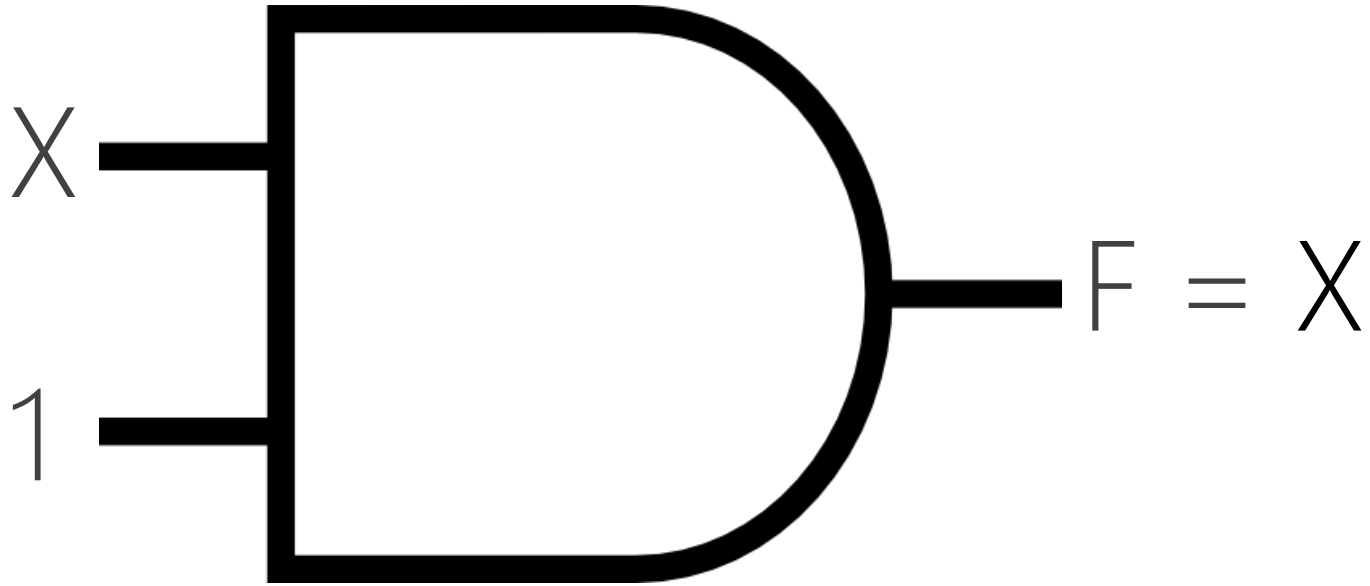
Y	X	YX
0	1	0
0	0	0

$$F = X0 = 0$$



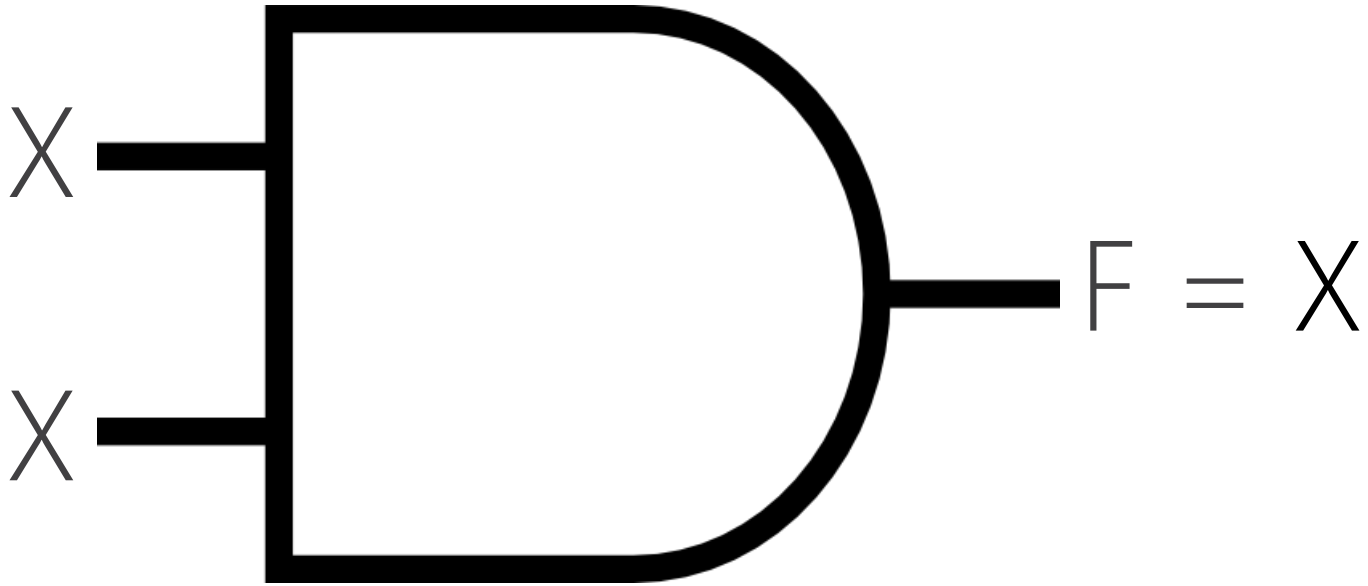
Y	X	YX
0	0	0
1	0	0

$$F = 0Y = 0$$



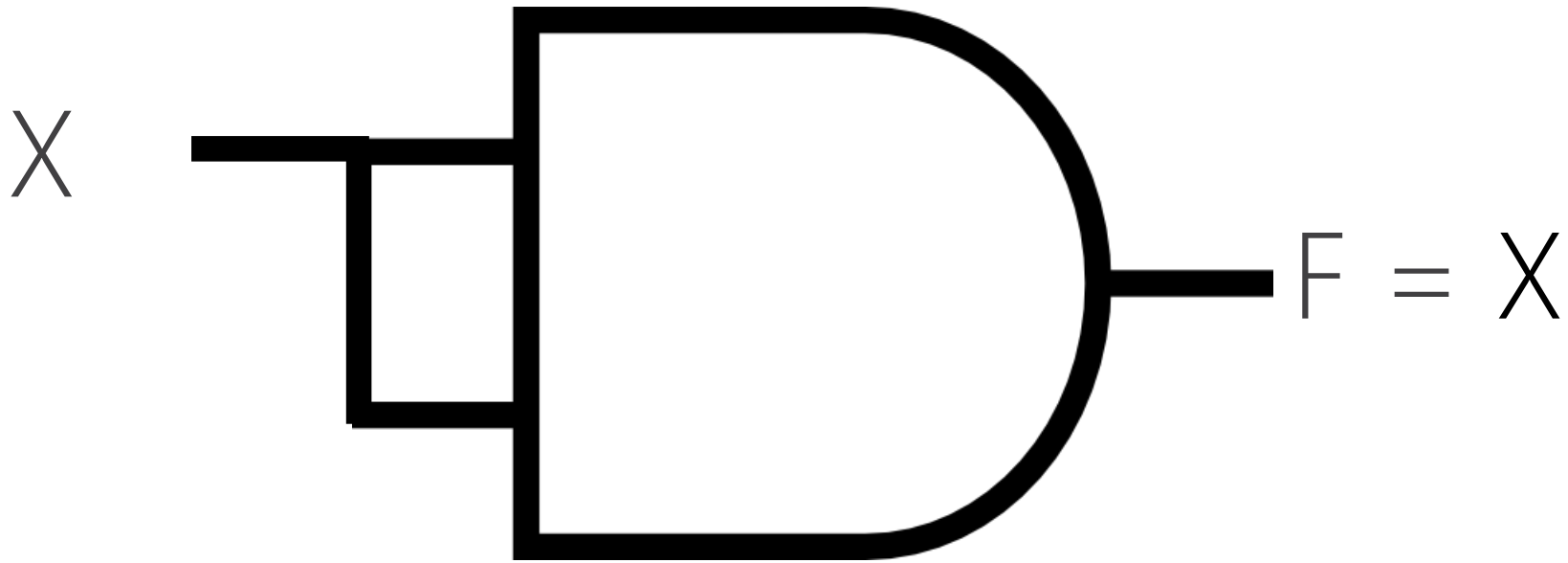
Y	X	YX
1	0	0
1	1	1

$$F = X1 = 1111X1111 = X$$



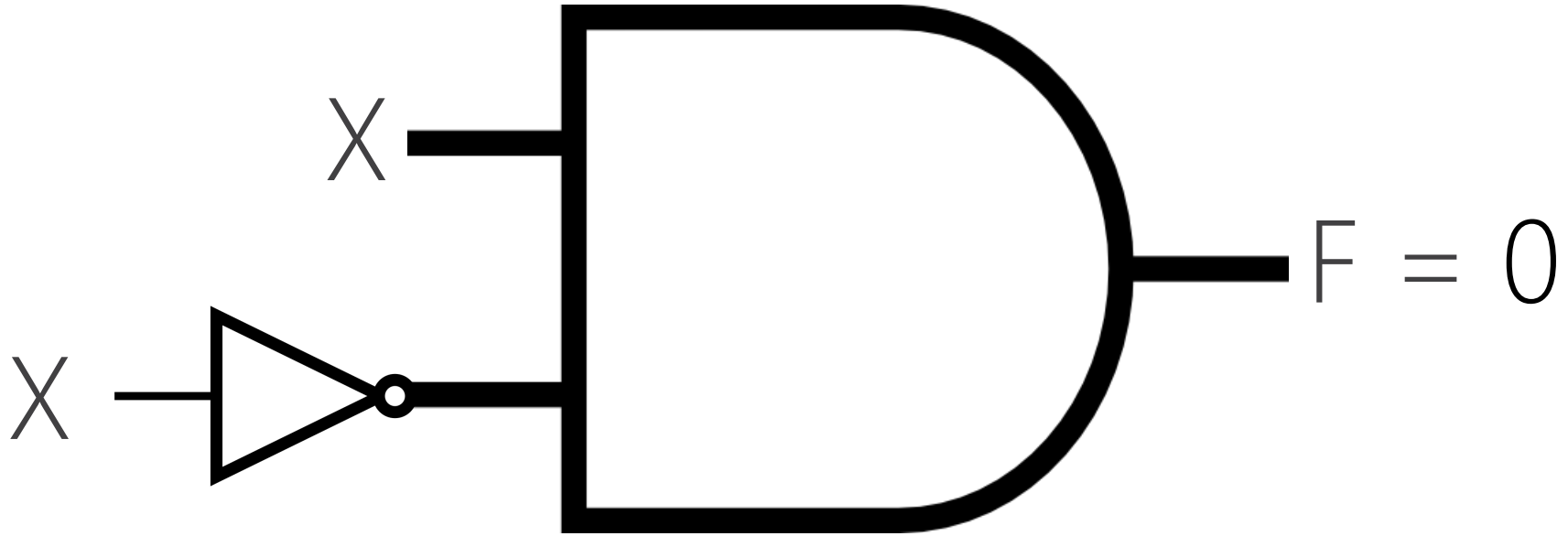
X	X	XX
0	0	0
1	1	1

$$F = XX = X$$



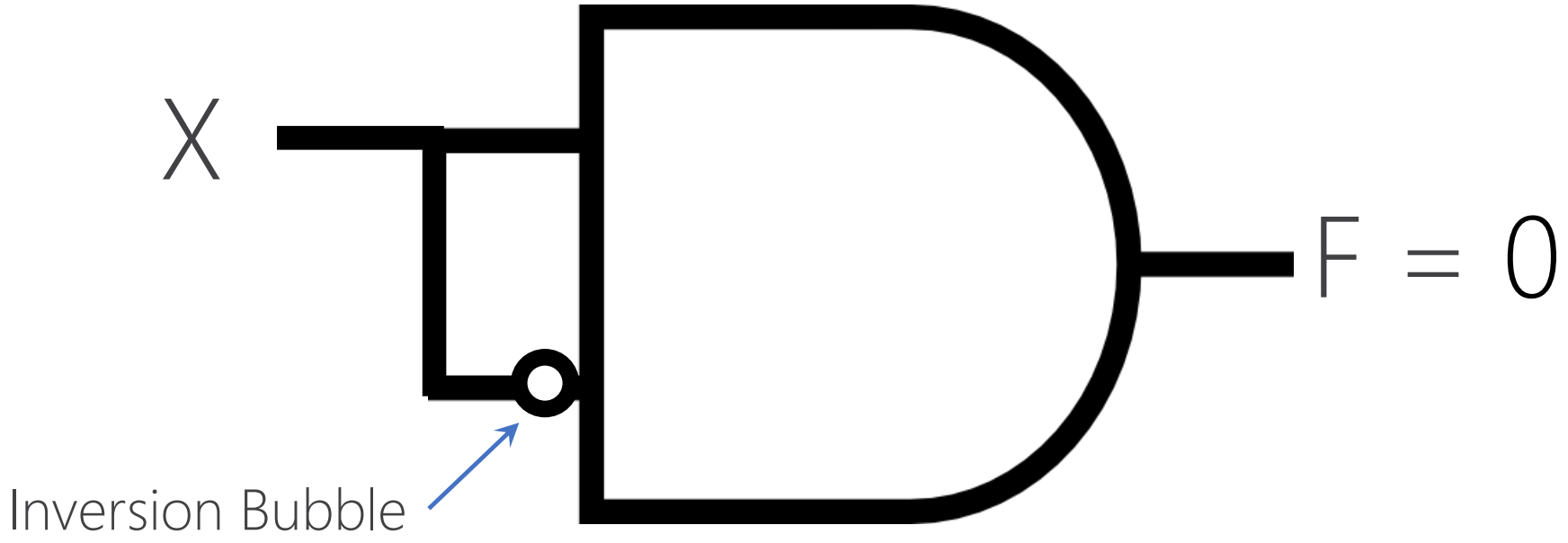
X	X	XX
0	0	0
1	1	1

$$F = XX = X$$



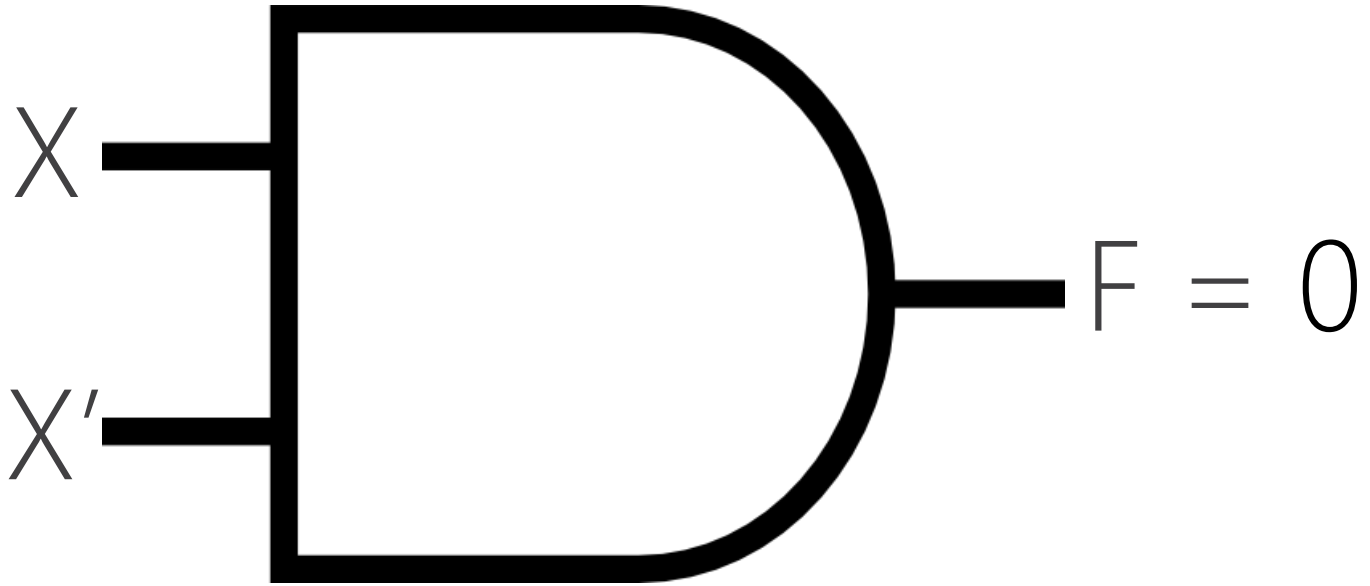
X′	X	X′X
1	0	0
0	1	0

$$F = XX' = 0$$



X′	X	X′X
1	0	0
0	1	0

$$F = XX' = 0$$



X′	X	X′X
1	0	0
0	1	0

$$F = XX' = 0$$

3-INPUT AND