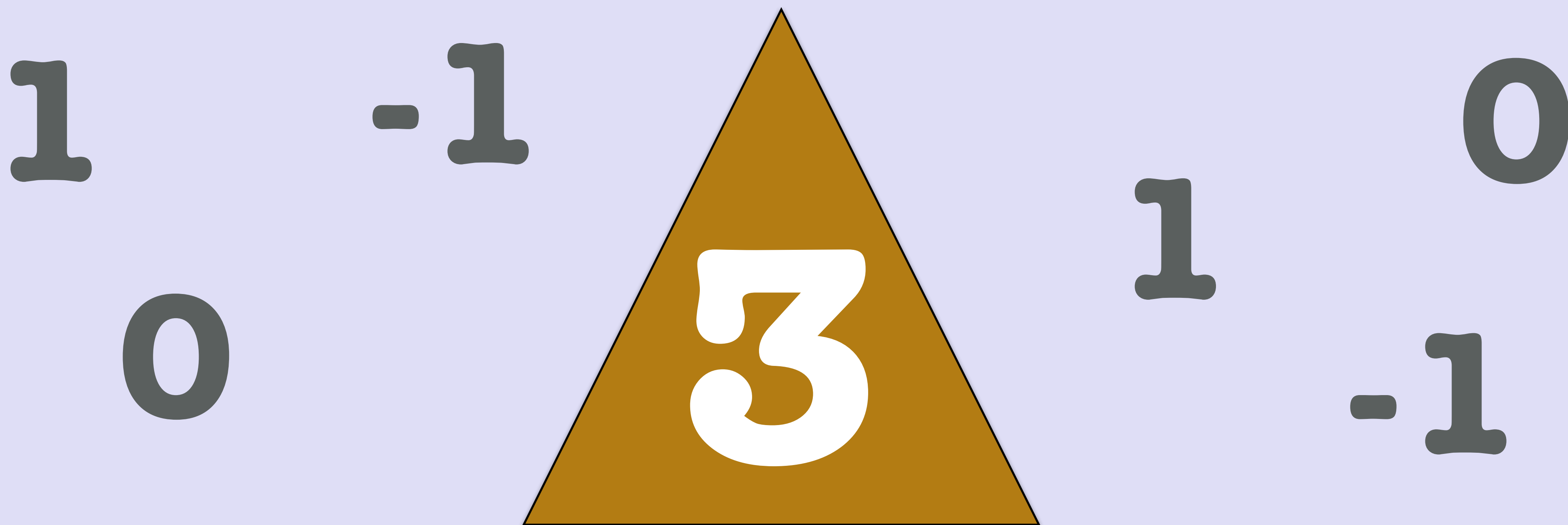# TRINARY NUMERAL SYSTEM

• The trinary numeral system has two types:
  The balanced trinary system in which a trit has the values -1, 0 and 1.
  The unbalanced trinary system in which a trit has the values 0, 1 and 2.

• In this presentation I will only focus on the balanced trinary system.

• Trit means **Tr**inary Dig**it**, analogous to bit and has the following values: -1, 0 and 1.

0

• Tryte means **Tr**inary B**yte**, analogous to byte.
  A tryte consists of 3 trits.

-1	0	1

TRINARY NUMERAL SYSTEM

- 1 byte = 2^8 = 256 combinations

- 1 tryte = 3 trits = 3^3 = 27 combinations

- 5 trits = 3^5 = 243 combinations

- 5 trits is NOT equal to 1 byte

BALANCED TRINARY SYSTEM CALCULATION

- Convert tryte **-1, 1, 0** to integer:

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

- Convert tryte **1, -1, 1** to integer:

  $1 \times 3^0 + -1 \times 3^1 + 1 \times 3^2 = 7$

BALANCED TRINARY SYSTEM CALCULATION

- What is the maximum value a tryte can have (not the number of combinations)?

- Answer: 13

- If you thought $3^3 - 1 = 26$ you are thinking in the binary system.

- If you have 2 bits in a binary system, you have the following combinations:
```
00 = 0x2¹ + 0x2⁰ = 0
01 = 0x2¹ + 1x2⁰ = 1
10 = 1x2¹ + 0x2⁰ = 2
11 = 1x2¹ + 1x2⁰ = 3      Max value = 2² – 1
```

BALANCED TRINARY SYSTEM CALCULATION

- If you have 2 **trits** in a balanced trinary system, you have the following combinations:

```
 0, 0 =  0x3⁰ +  0x3¹ =  0
 0, 1 =  0x3⁰ +  1x3¹ =  3
 0,-1 =  0x3⁰ + -1x3¹ = -3
 1, 0 =  1x3⁰ +  0x3¹ =  1
 1, 1 =  1x3⁰ +  1x3¹ =  4
 1,-1 =  1x3⁰ + -1x3¹ = -2
-1, 0 = -1x3⁰ +  0x3¹ = -1
-1, 1 = -1x3⁰ +  1x3¹ =  2
-1,-1 = -1x3⁰ + -1x3¹ = -4
```

- The values in the trinary system are balanced around zero:

```
-4, -3, -2, -1, 0, 1, 2, 3, 4   Max value = (3² - 1) / 2
```

BALANCED TRINARY SYSTEM CALCULATION

- A tryte has 3 trits, so the maximum value will be $(3^3 - 1) / 2 = 13$ and it has $3^3 = 27$ combinations.

- A tryte will have the following values:
  -13, -12, …-2, -1, 0, 1, 2, … 12, 13

- Convert the following two trytes **-1, -1, -1, 1, 0, 0** to an integer:

  -1 × 3^0 + **-1** × 3^1 + **-1** × 3^2 **+** **1** × 3^3 + **0** × 3^4 + **0** × 3^5

  -13 **+** 27 = 14

IOTA TRYTE ALPHABET

- IOTA uses the balanced trinary system

- To make the trytes more human readable the IOTA development team created the tryte alphabet: 9ABCDEFGHIJKLMNOPQRSTUVWXYZ.

- The tryte alphabet consists of 26 letters of the latin alphabet plus the number 9. The tryte alphabet has a total of 27 characters.

- Because 1 tryte has 3^3 = 27 combinations, each tryte can be represented by a character in the tryte alphabet.

IOTA TRYTE ALPHABET

Tryte	Dec	Char		Tryte	Dec	Char
0, 0, 0	0	9				
1, 0, 0	1	A		-1,-1,-1	-13	N
-1, 1, 0	2	B		0,-1,-1	-12	O
0, 1, 0	3	C		1,-1,-1	-11	P
1, 1, 0	4	D		-1, 0,-1	-10	Q
-1,-1, 1	5	E		0, 0,-1	-9	R
0,-1, 1	6	F		1, 0,-1	-8	S
1,-1, 1	7	G		-1, 1,-1	-7	T
-1, 0, 1	8	H		0, 1,-1	-6	U
0, 0, 1	9	I		1, 1,-1	-5	V
1, 0, 1	10	J		-1,-1, 0	-4	W
-1, 1, 1	11	K		0,-1, 0	-3	X
0, 1, 1	12	L		1,-1, 0	-2	Y
1, 1, 1	13	M		-1, 0, 0	-1	Z

IOTA TRYTE ALPHABET

- IOTA seeds, addresses, hashes, etc are trytes which are represented by characters from the tryte alphabet.

- For example the integer 14, converted into trytes: **-1, -1, -1, 1, 0, 0**
  Convert the trytes using the tryte alphabet:
  -1, -1, -1 = N
   1, 0, 0 = A
  Thus integer 14 converted into trytes: NA

- The word "Zoo" converted into trytes looks like: ICCDCD
  The ASCII value of Z = 90, converted to trytes: **0,0,1,0,1,0 = IC**
  The ASCII value of o = 111, converted to trytes: **0,1,0,1,1,0 = CD**

IOTA SEED

- An IOTA seed contains 81 characters which is the same as 81 trytes.

- For example:
C9RQFODNSAEOZVZKEYNVZDHYUJSA9QQRCUJVBJD9KHAKPTAKZSNNKLJHE
FFVK9AWVDAUJRYYKHGWQIAWF

- Each tryte has 27 combinations, which means an IOTA seed has:
$27^{81} = \ {\sim}8.71 \times 10^{115}$ combinations

- In comparison a Bitcoin random number has:
$2^{256} = {\sim}1.15 \times 10^{77}$ combinations