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Art without Engineering is dreaming. Engineering without Art is calculating.
- Steven K. Roberts

BINARY NUMBERS

March 25 2018

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Overview & Introduction

- This lesson is designed to introduce you to the Binary (base 2) number system. Binary is used in all modern computer systems and logical operations
- You learn how to convert numbers from the Decimal (base 10) to Binary (base 2).
- You will also learn how to add and multiply in Binary.

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SEE APPENDIX A, FOR LICENSING & ATTRIBUTION INFORMATION

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https://creativecommons.org/faq/#what-does-some-rights-reserved-mean

WHAT YOU WILL KNOW...

- Prior Knowledge
  - You should have an understanding of how the Base 10 number system works
  - How and why we carry when we count from 9 to 10 or 99 to 100
  - Understand the concept of the "One's", "Ten's" and "Hundred's" place values.

- What You Will Know & Be Able To Do
  - You will be able to count in Binary
  - How to convert numbers from Binary (base 2) to Decimal (base 10) and from Decimal to Binary
  - You will know how to add in Binary
  - How to multiply in Binary

How will you be measured

- You will be asked to participate in class discussion, and I will evaluate your understanding based on your answers
- You will answer questions in online quizzes and or worksheets and points assigned based on right/wrong answers

New Words or Concepts...

- Binary
- Number System
- Place Value
- Digit
- Bits, Bytes, Words

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"LET'S PLAY A GAME"

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I NEED A VOLUNTEER…

- Pick A Number Between “0” And “64”
  - So Not “0” or “64”, But Some Whole Number In Between…
- Write It Down
- Show It Around… But Don’t Let Me See It
- Place it Face Down On Your Table
- Now, Tell Me “Yes” Or “No” If Your Number Is On The Next 6 Slides
- Ready…

IS YOUR NUMBER ON THIS CARD?

1	3	5	7	9	11	13	15
17	19	21	23	25	27	29	31
33	35	37	39	41	43	45	47
49	51	53	55	57	59	61	63

IS YOUR NUMBER ON THIS CARD?

2	3	6	7	10	11	14	15
18	19	22	23	26	27	30	31
34	35	38	39	42	43	46	47
50	51	54	55	58	59	62	63

IS YOUR NUMBER ON THIS CARD?

4	5	6	7	12	13	14	15
20	21	22	23	28	29	30	31
36	37	38	39	44	45	46	47
52	53	54	55	60	61	62	63

IS YOUR NUMBER ON THIS CARD?

8	9	10	11	12	13	14	15
24	25	26	27	28	29	30	31
40	41	42	43	44	45	46	47
56	57	58	59	60	61	62	63

IS YOUR NUMBER ON THIS CARD?

16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

IS YOUR NUMBER ON THIS CARD?

32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

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YOUR NUMBER IS.....

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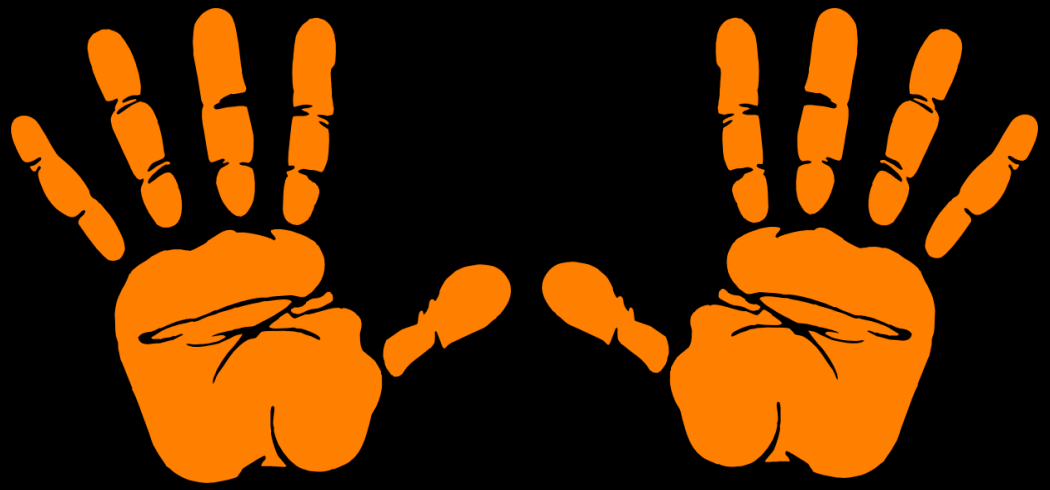
WHY DO WE COUNT TO 10?

- Because We Have 10 Fingers…
- What If We Had 3 fingers?
- How About If We Only Had 1?



Let’s Learn About The Binary (Base 2) Number System,
But First, Lets Review The Decimal (Base 10) Number System

Base 10 Number System - Place Value

Which Number is bigger?

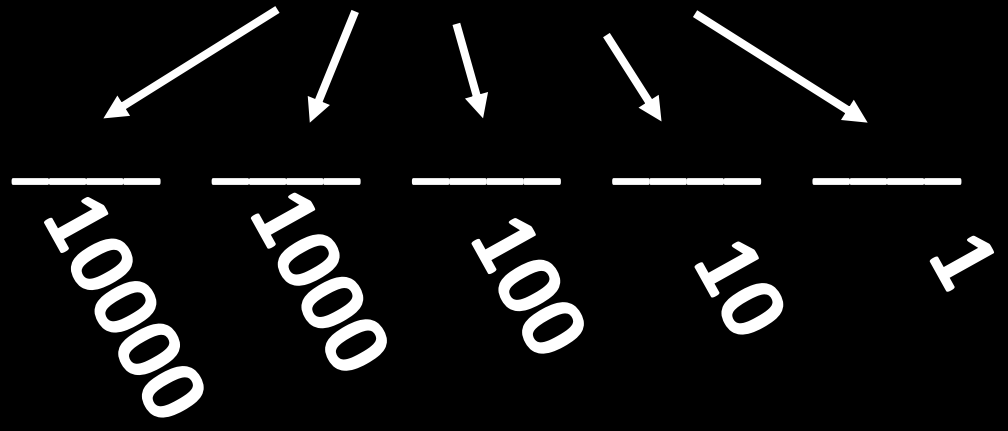
39 or 93

3	9		9	3
10	1		10	1

3x10 + 9x1 = 30 + 9

9x10 + 3x1 = 90 + 3

Place Value



5	6	3	9
1000	100	10	1

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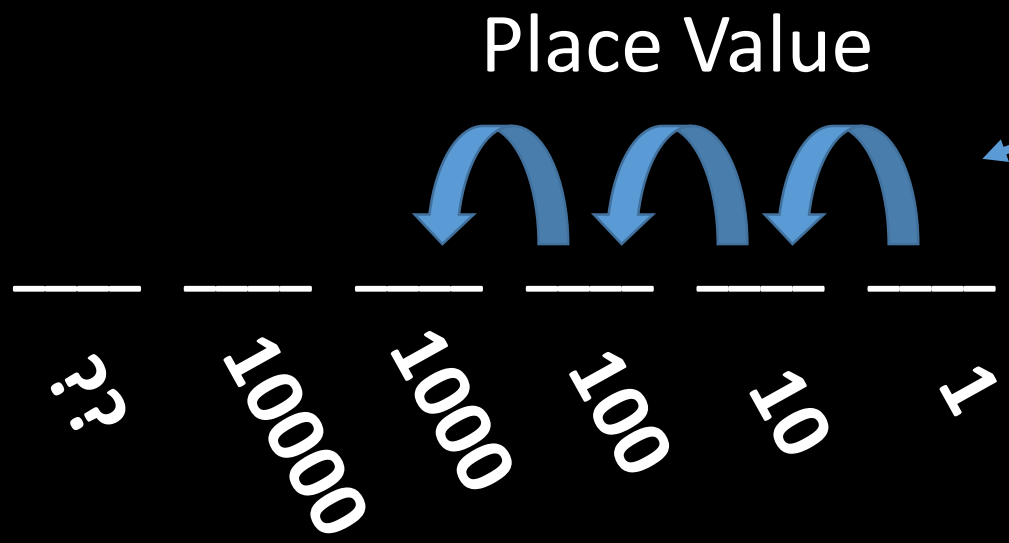
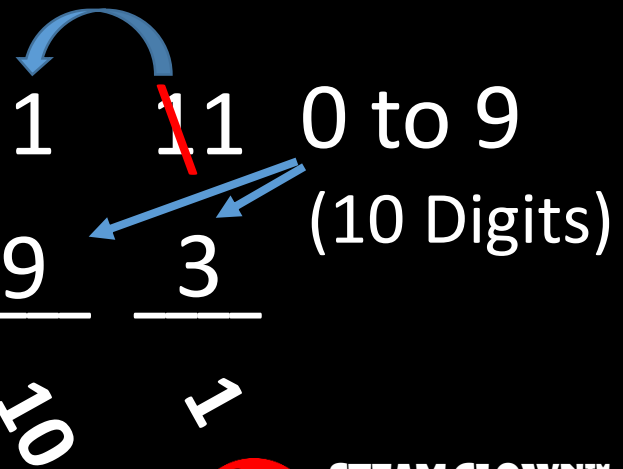
Base 10 Number System - Place Value

- How Do You move from one Place Value to the next?





- What Digits are allowed for each Place Value?

Only Allowed One Digit Per Place Value

FIGURING OUT OTHER BASE NUMBER SYSTEMS

- Base 16

Place Value

16 Digits = F,E,D,C,B,A,9,8,7,6,5,4,3,2,1,0

...	1048576	65536	4096	256	16	1

P.V.
x 16

- Base 2

Place Value

2 Digits = 1,0

256	128	64	32	16	8	4	2	1

P.V.
x 2

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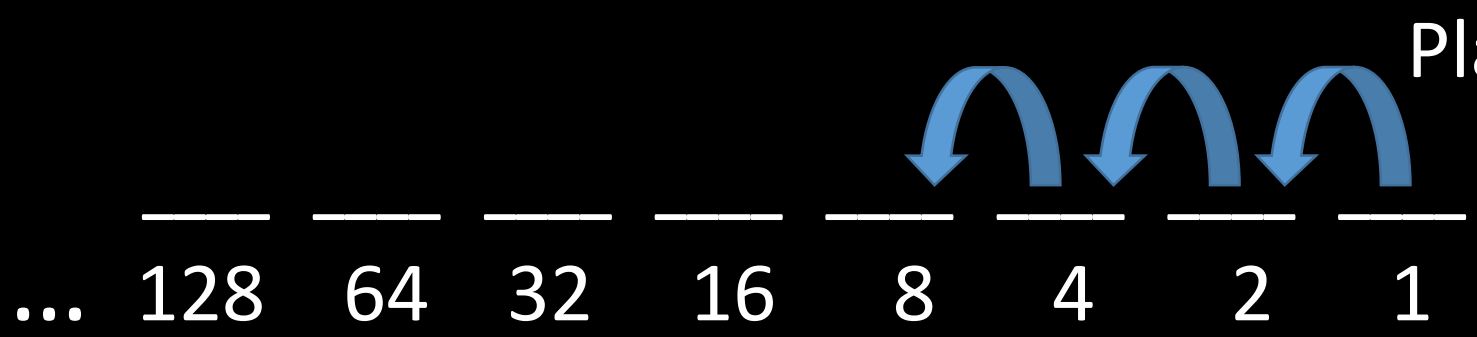
Base 2 Number System - Place Value

- How Do You move from one Place Value to the next?
- In Other Words, How Do You Count In Binary

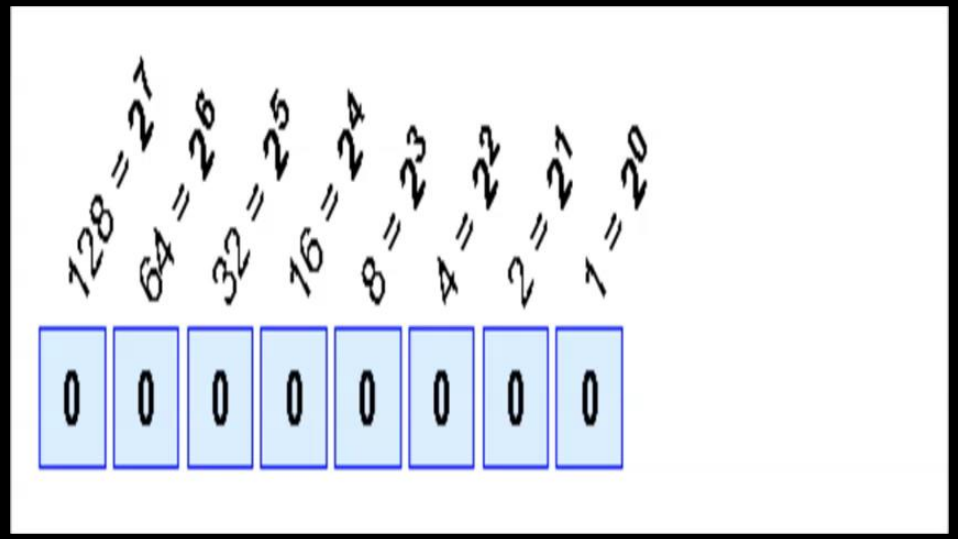


You Use The Same Rules As Decimal (Base 10)… Just In Binary (Base 2)

COUNTING IN BINARY

- Remember Binary Numbers are made of **0**s and **1**s
- Here Is An Example Of A Binary Number: **101011**
  - Binary Number can only be made from the Digits **0-1**
  - There is no **2,3,4,5,6,7,8** or **9** in Binary
- Lets Start Counting…

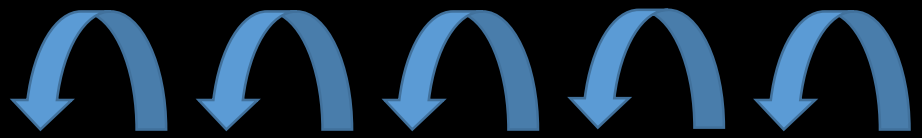
  - Start with 0
  - Then count to 1
  - Then ?? There is not symbol for 2



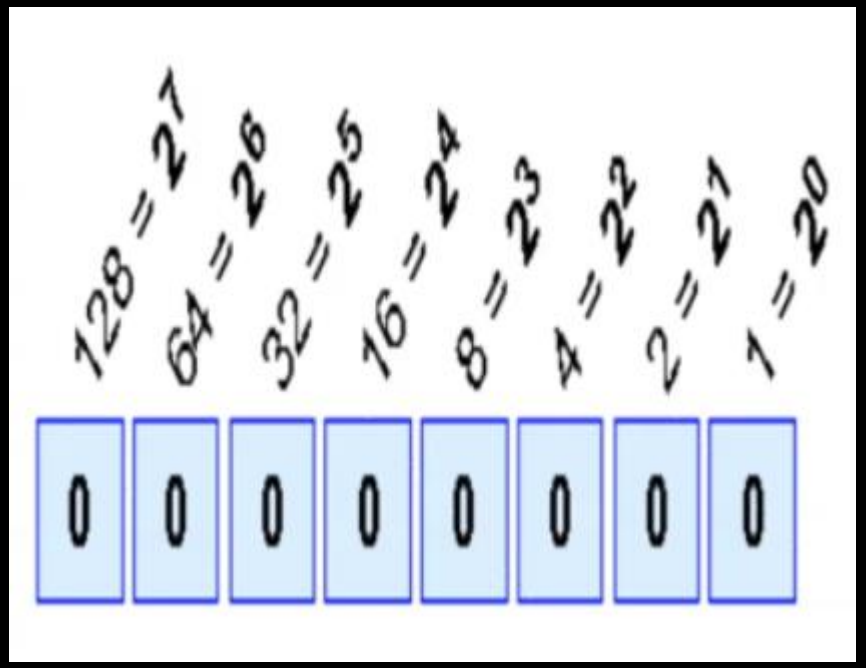
Play

Computer Humor

Binary is as easy as 01, 10, 11



...	128	64	32	16	8	4	2	1



Place Values

Convert the Following Binary Numbers:

0011 = 1x2 + 1x1 = 3

1011 = 1x8 + 0x4 + 1x2 + 1x1 = 11

10101 = 1x16 + 0x8 + 1x4 + 0x2 + 1x1 = 21

110011 = 1x32 + 1x16 + 0x8 + 0x4 + 1x2 + 1x1 = 51

Place Values

BITS AND BYTES?

- How does a computer count?
- It Uses The Binary (Base 2) number system?

You See the Number 3, The Computer Sees 0011

- Bits, Bytes, Words

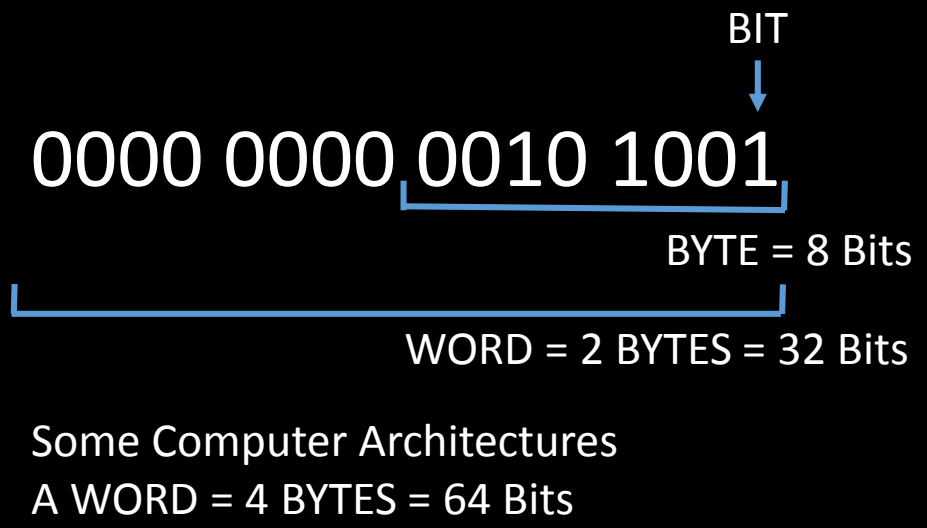
41_{10} = 0010 1001

254_{10} = 1111 1110

255_{10} = 1111 1111

256_{10} = 0001 0000 0000

1 BYTE



Some Computer Architectures
A WORD = 4 BYTES = 64 Bits

Decimal (Base 10)	Binary (Base 2)	Hex (Base 8)
0	0000 0000	0
1	0000 0001	1
2	0000 0010	2
3	0000 0011	3
4	0000 0100	4
5	0000 0101	5
6	0000 0110	6
7	0000 0111	7
8	0000 1000	8
9	0000 1001	9
10	0000 1010	A
11	0000 1011	B
12	0000 1100	C
13	0000 1101	D
14	0000 1110	E
15	0000 1111	F
16	0001 0000	10

ALL SIX CARDS

8	9	10	11	12	13	14	15
24	25	26	27	28	29	30	31
40	41	42	43	44	45	46	47
56	57	58	59	60	61	62	63

1	3	5	7	9	11	13	15
17	19	21	23	25	27	29	31
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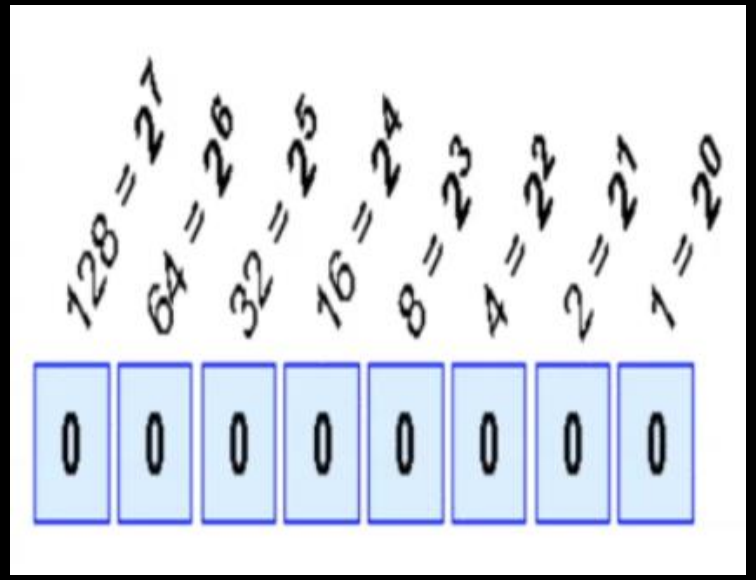

Decimal (Base 10)	Binary (Base 2)
0	0000 0000
1	0000 0001
2	0000 0010
3	0000 0011
4	0000 0100
5	0000 0101
6	0000 0110
7	0000 0111
8	0000 1000
9	0000 1001
10	0000 1010
11	0000 1011
12	0000 1100
13	0000 1101
14	0000 1110
15	0000 1111
16	0001 0000

ALL SIX CARDS

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

0 0 0 0 0 1 1 1

= 7

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ALL SIX CARDS

8	9	10	11	12	13	14	15
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0	0	0	0	1	1	0	1

= 13

ALL SIX CARDS

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0	0	0	1	0	0	0	0

= 16

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ALL SIX CARDS

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0	0	0	1	1	0	1	1

= 27

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ALL SIX CARDS

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0	0	1	0	1	0	0	1

= 41

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Ready for a Quiz?

- Web based Google Quiz
  - Decimal 2 Binary Quiz #1
  - Decimal 2 Binary Quiz #2
  - Binary 2 Decimal Quiz #3
  - Binary 2 Decimal Quiz #4
- Worksheet Hand Out

ADDING BINARY NUMBERS

Rule 1 → 0 + 0 = 0
Rule 2 → 0 + 1 = 1
Rule 3 → 1 + 0 = 1
} Just like decimal addition
Rule 4 → 1 + 1 = 10 ← Surprise!

```
  110
+ 101
-----
 1011
```

Since 1 + 1 = 10

Since 1 + 0 = 1

Since 0 + 1 =1

https://www.quickanddirtytips.com/education/math/how-to-add-binary-numbers?page=1

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MULTIPLYING BINARY NUMBERS

Rule 1 → 0 * 0 = 0
Rule 2 → 0 * 1 = 0
Rule 3 → 1 * 0 = 0
Rule 4 → 1 * 1 = 1

} Just like decimal multiplication

```
    110
*   101
-------
    110
  0000
 1100
-------
11110
```


https://www.quickanddirtytips.com/education/math/how-to-add-binary-numbers?page=1

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Adding and Multipying in Binary

- Adding Binary Numbers
  - Adding in binary | Applying mathematical reasoning
- Multiplying Binary Numbers
  - Multiplying in binary | Applying mathematical reasoning

REFERENCE SLIDES

Resources & Materials

- Lecture Slides (PDF)
- Student Worksheets (PDF) or Link to Google Quiz
- Student “Let’s Play A Game” Handout & Instructions

APPENDIX

Appendix A: License & Attribution

- This interpretation is primarily the Intellectual Property of Jim Burnham, Top STEAM Clown, at STEAMClown.org
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- My best attempt to properly attribute, or reference any other sources or work I have used are listed in Appendix B

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Appendix B: Attribution for Sources Used

- Decimal/Binary Conversion Quiz - http://acc6.its.brooklyn.cuny.edu/~gurwitz/core5/binquiz.html
- Online Magic - http://avimagic.com/tricks/number_cards.php
- Binary Trick - http://www.mathmaniacs.org/lessons/01-binary/Magic_Trick/
- Work sheet - http://www.cse4k12.org/binary/magic_trick.html
- Magic Binary Cards - http://www.northeastern.edu/seigen/11Magic/Binary/Magic_binary_cards.pdf
- Base 5 Number System – Basics - https://www.youtube.com/watch?v=qGi29E9q_f0
- Binary Number System - https://www.mathsisfun.com/binary-number-system.html
- Bits, bytes and words - http://www.plainenglish.info/Computer+Science/Computer+Architecture/Bits%2C+bytes+and+words