1+1 = 2
… in hardware!

CS 3410: Computer System Organization and Programming

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Computer Science

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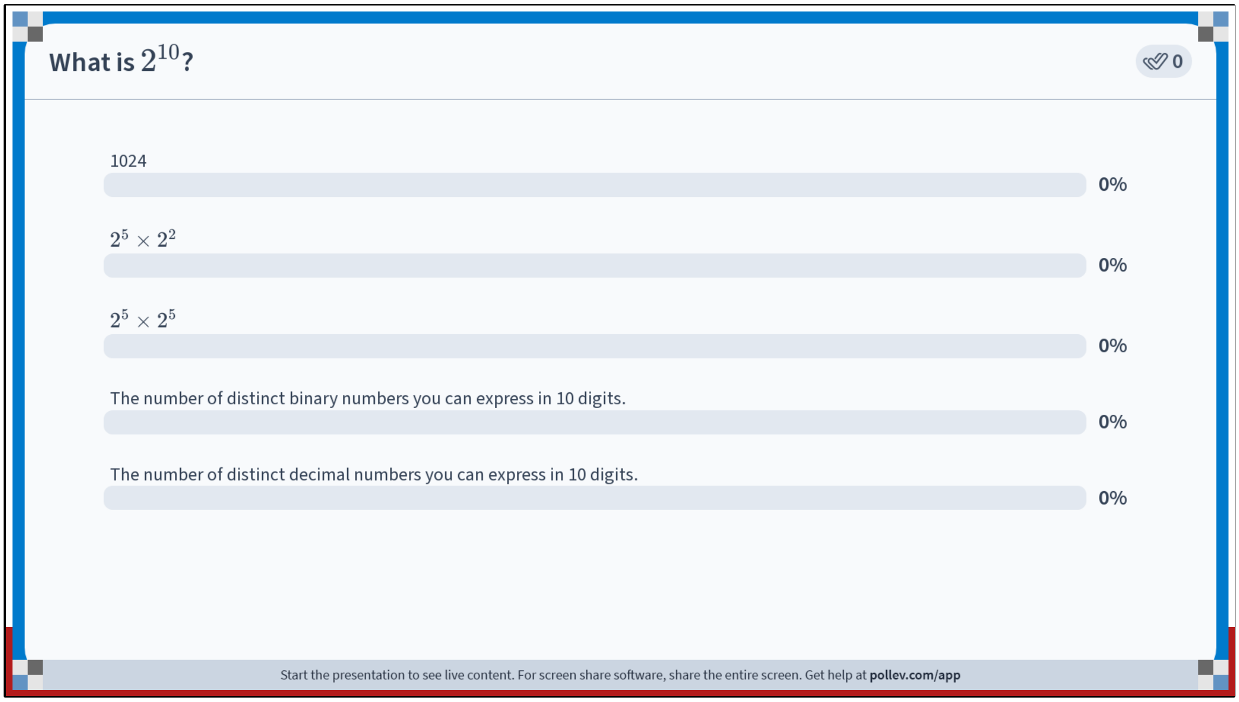

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What is $$2^{10}$$?
https://www.polleverywhere.com/multiple_choice_polls/NFsS8idj7KZQeYGoidpJZ?state=opened&flow=Default&onscreen=persist

Goals for Today

- Number representations
  - How to translate between different **bases**
- Addition
  - How to construct simple **binary** adders

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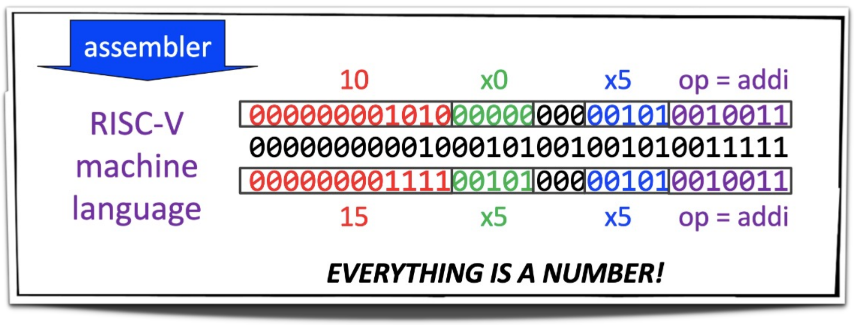
Number Representations

Most computers represent exactly 2 symbols:

- "high voltage" = 1 = true; ”low voltage" = 0 = false

Recall:



Number Representations

Most computers represent exactly 2 symbols:

- "high voltage" = 1 = true; ”low voltage" = 0 = false

How do we represent numbers in Binary? (base 2)

How do we do it for decimal? (base 10)

Base 10

hundreds tens ones

$637_{10} = 6 \cdot 10^2 + 3 \cdot 10^1 + 7 \cdot 10^0 = 637$

Base 2

fours twos ones

$101_2 = 1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 = 5$

Counting in Different Bases

DEC (Base 10)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIN (Base 2)	0	1	10	11	100	101	110	111	1000	1001	1010	1011	1100	1101	1110	1111	10000	10001	10010
OCT (Base 8)	0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17	20	21	22
HEX (Base 16)	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	10	11	12

Counting in Different Bases

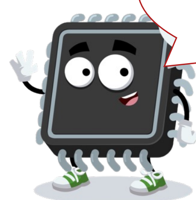
DEC (Base 10)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIN (Base 2)	0	1	10	11	100	101	110	111	1000	1001	1010	1011	1100	1101	1110	1111	10000	10001	10010
OCT (Base 8)	0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17	20	21	22
HEX (Base 16)	0	1	2	3	4	5	6	7	8	9	A	B	C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12

```
0b   1111 1111 =255      0o  77 = 63
0b 1 0000 0000 =256      0o 100 = 64

        0x  ff = 255
        0x 100 = 256
```

PRO TIP!

4 binary digits = 1 hex digit
3 binary digits = 1 octal digit



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Converting between bases: $637_{10} \rightarrow$ octal

Approach #1: Left to Right

637 – 1 x 512 = 125
125 – 1 x 64 = 61
61 – 7 x 8 = 5

8^3	8^2	8^1	8^0
512	64	8	1
1	1	7	5

Approach #2: Right to Left (repetitive division)

637 / 8 = 79 remainder 5
79 / 8 = 9 remainder 7
9 / 8 = 1 remainder 1
1 / 8 = 0 remainder 1

lsb (least significant bit*)

msb (most significant bit*)

637 = 0o1175

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Try $637_{10} \rightarrow$ binary! (using both methods)

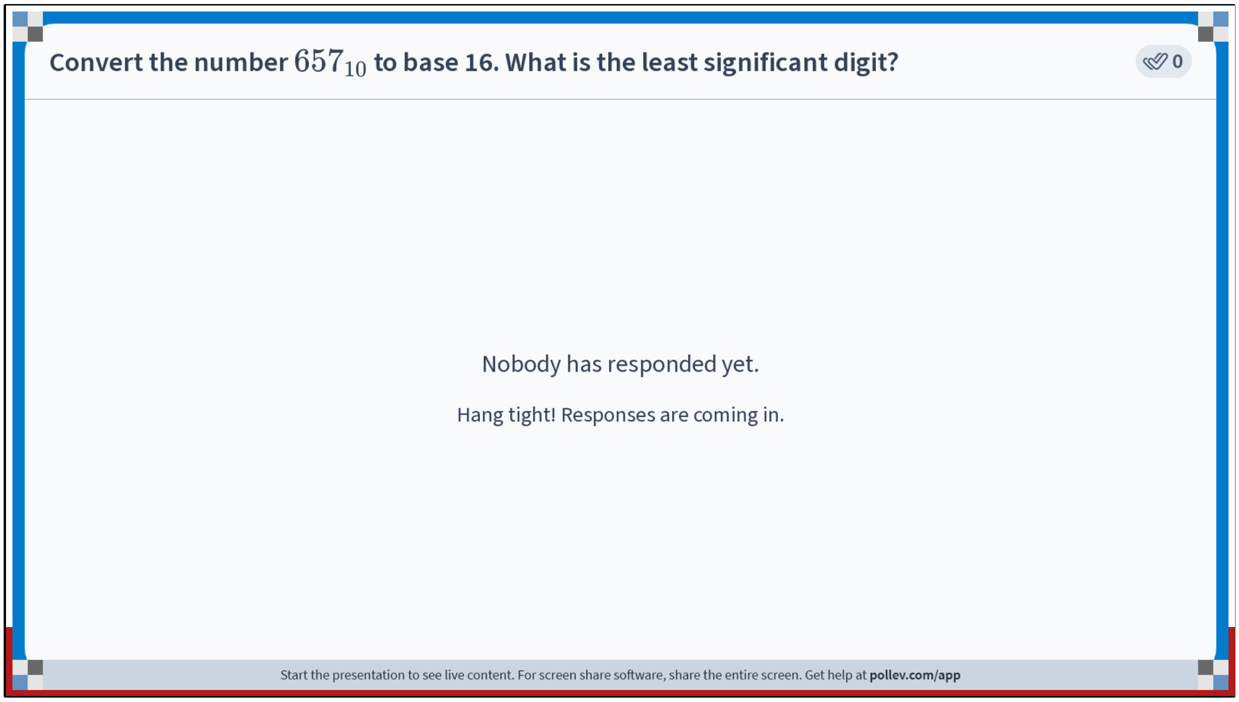
Poll Everywhere Question #2:

Convert the number 657_{10} to base 16
What is the least significant digit of this number?

a) D
b) F
c) 0
d) 1
e) 11

657 = 0x291

Answer is D: 1



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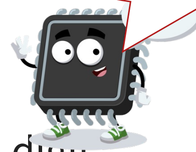
Convert the number $$657_{10}$$ to base 16. What is the least significant digit?
https://www.polleverywhere.com/free_text_polls/x9CIvT5ndcQas5SAuWVxs

Convert from Binary to other powers of 2



- Binary to Octal
  - 3 bits (000—111) have values 0…7 = 1 octal digit

    example: `0b 1 001 111 101`

    `1 1 7 5` → `0o1175`

- Binary to Hexadecimal
  - **Nibble** (0000—1111) has values 0…15 = 1 hex digit

    example: `0b 10 0111 1101`

    `2 7 d` → `0x27d`

Ask class to convert from binary to octal

637 = 0o1175 = 0b10 0111 1101 = 0x27D
oct: 637 : 79 : 9 : 1 : 0
bin: 637 : 318 : 159 : 79 : 39 : 19 : 9 : 4 : 2 : 1 : 0
hex: 637 : 39 : 2 : 0

Achievement Unlocked!

There are 10 types of people in the world:

- Those who understand binary
- And those who do not
- *And* those who know this joke is in base 3

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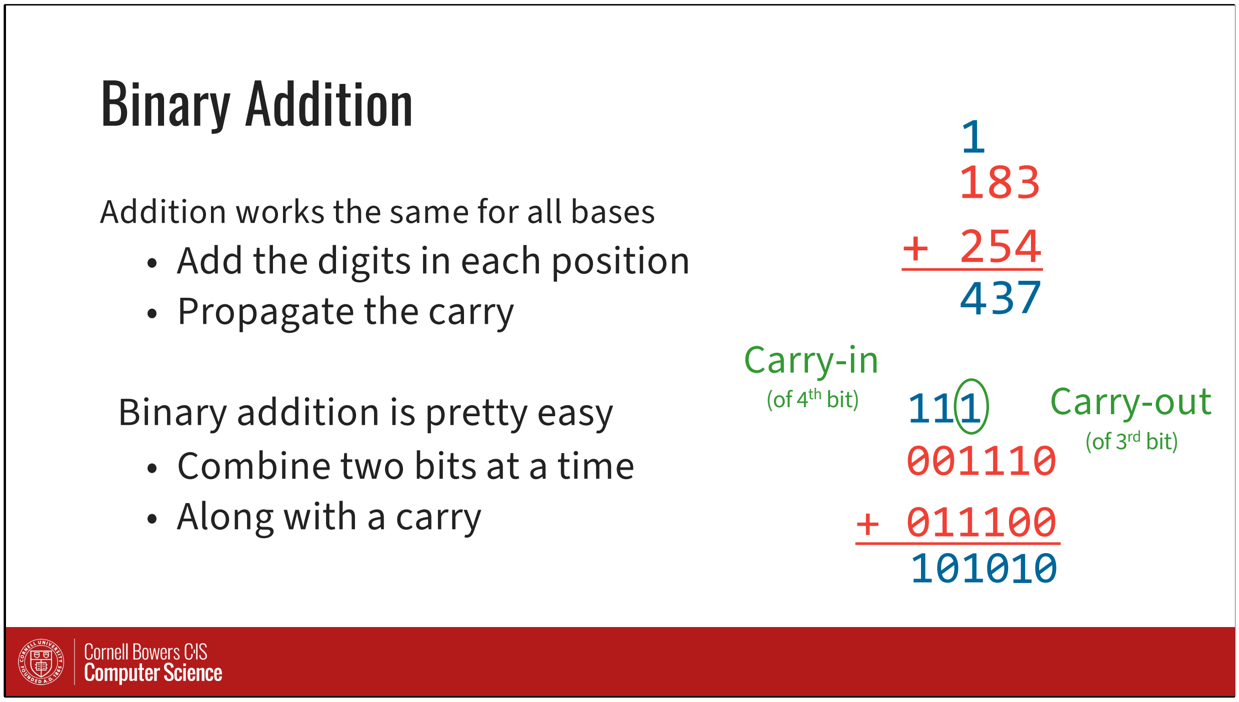

Talk about Cin (carry in) and Cout (carry out)
Animate this better
Add another slide
So we need two numbers, the sum, carry in, and carry out

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