Overflow in Addition

- **Unsigned:** When there is a carry out of the MSB

1000 (8)
+1001 (9)
1 0001 (1)

Overflow in Addition

- **2's complement:** When the signs of the addends are the same, but the sign of the result is different
- Adding 2 numbers of opposite signs never overflows.


```
  0011 (3)
+ 0110 (6)
------
  1001 (-7)
```

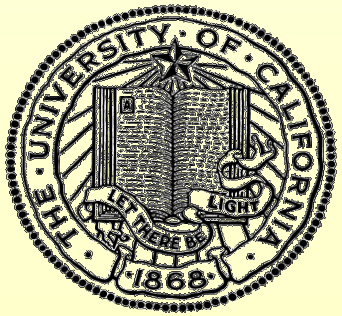
- End of Midterm Coverage!

- **Quiz2 on 2/11/21 (10-15 mins)**
- **Same format as Quiz1**
- **Will cover till Midterm**

- Will not provide solutions for sample midterms
- May discuss possible solutions amongst yourselves

- Please attend more TA Office hours!
- TAs have reported a sharp decline in attendance

Floating Point, FP Addition, FP Multiplication



(Unsigned) Fixed Point Numbers

- With binary integers, we assume each position is a power of the base 2
  - … 8's, 4's, 2's, 1's
  - This is actually … 2^3, 2^2, 2^1, 2^0
- What if we extend this with a negative power?
  - 2^{-1}, 2^{-2}, 2^{-3}, etc.
    - Negative exponent means it is denominator
    - ½, ¼, ⅛, etc.
  - 0.5's, 0.25's, 0.125's, etc.

Fixed Point Example 1

- Convert to a 4+4 bit fixed point number
  - 12.75

Fixed Point Example 1

- Convert to a 4+4 bit fixed point number
  - ? ? ? ?. ? ? ? ?
  - 3 2 1 0. -1 -2 -3 -4
  - 0.75 = ¾ = ½ + ¼
    = .11

Fixed Point Example 1

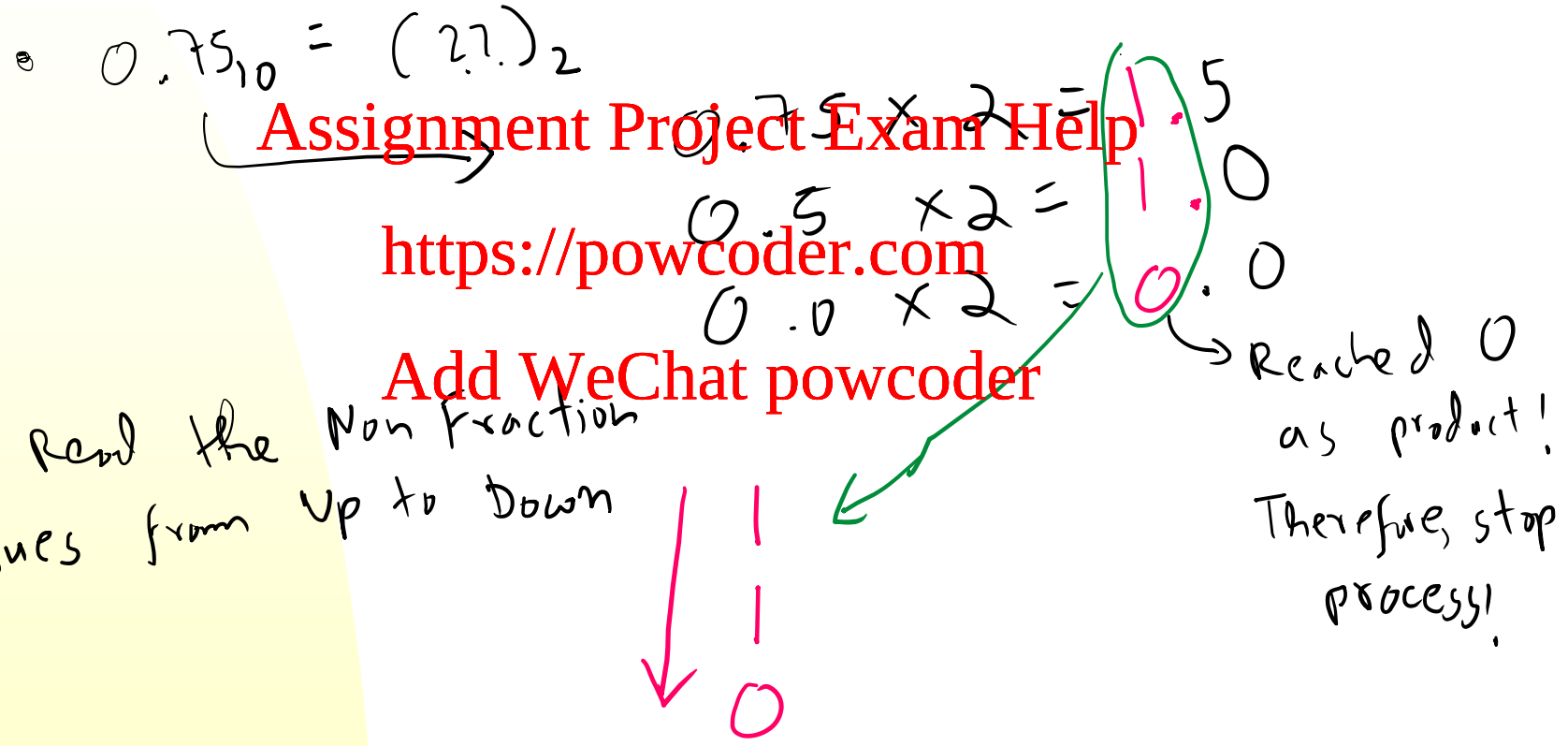
- Convert to a 4+4 bit fixed point number
  - 12 = 8 + 4
    = 1100

Alternative way for finding out Binary of Fractions from a given Decimal value

- ***Split*** the **value** into **2 parts**: Integer part + Fractional part
- Find the **binary representation** of the ***integral*** **part** by **repeatedly *divide* the value** by **2** (to obtain the **powers of 2^n**) (Already discussed in previous lectures)
- Find the **binary representation** of the ***fractional*** **part** by **repeatedly *multiply* the value** by **2** (to obtain the **powers of 2^{-n}**)

Fixed Point Example 1:Alternative solution

- Convert to a 4+4 bit fixed point number
  - $12 = 8+4 = 1100_2$



Fixed Point Example 2

- Given 4+4 bit fixed point number, what is the decimal value?
  - 0110.1010

Fixed Point Example 2

- Given 4+4 bit fixed point number, what is the decimal value?
  - 0110.1010 = 4 + 2 + ½ +⅛

Fixed Point Example 2

- Given 4+4 bit fixed point number, what is the decimal value?
  - 0110.1010 = 4 + 2 + ½ +⅛
    = 6.625

(Unsigned) Fixed Point Precision

- This assumes that the fraction point begins at a fixed bit location
  - Example, 32-bit number, 8-bits decimal
    - 24 bits are used for the integer part
    - 8 bits are used for the decimal part
  - You can think of each number as multiplied by a scale (2^8), and it is 8 bits
- What is the most accurate you can represent this fixed-point number(precision)?
  - Example, 2^{-8} = 1/256 = 0.00390625

Repeating Fractions

- Convert to a 4+4 bit fixed point number
  - 5.2

Repeating Fractions

- Convert to a 4+4 bit fixed point number
  - 5 = 101

Repeating Fractions

- Convert to a 4+4 bit fixed point number
  - .2 = ????

½ = 0.5

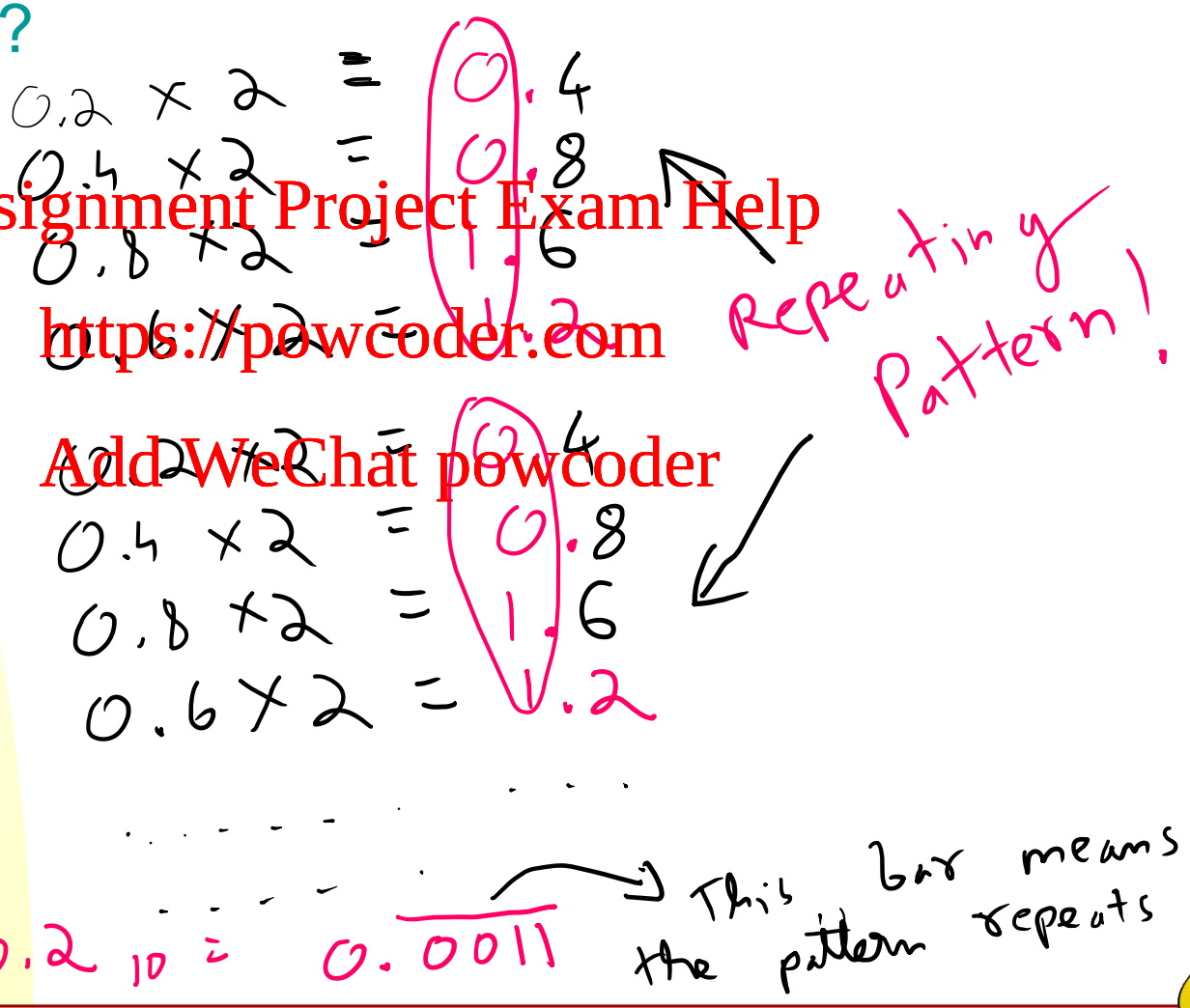
¼ = 0.25

⅛ = 0.125

1/16 = 0.0625

Repeating Fractions

- Convert to a 4+4 bit fixed point number
  - .2 = ???



Repeating Fractions

- We saw that 0.2_{10} cannot be exactly expressed in 4+4 fixed point since we will lose precision
- So what is the most accurate we can represent it then in binary 4+4?
- We know for certain $0011_2 = 0.1875_{10} < 0.2_{10}$
- Next largest possible binary number in 4+4 is .0011+ .0001 =0.0100= 0.25_{10}
- But **0.2**-0.1875 < 0.25 – **0.2**
- Thus 0.0011 is the closest we can accurately convey 0.2_{10} in binary 4+4
- Therefore, 5.2_{10}= 0101.0011 in 4+4

Repeating Fractions

- Convert to a 4+4 bit fixed point number
  - 5.2 ≈ 0101.0011

(Unsigned) Fixed Point Range

- Consider again this 24 + 8 bit fixed point number.
- What is the maximum value?
  - All 1's for integer, all 1's for fraction
  - 2^{23} <– >2^{-8}
- What is the minimum value?
  - 0