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Section 1

(1)

(1)-(a) ***How could you best make use of the 24 bits available? (10 marks)***

Since humans are 1.5 times more sensitive to Red and Green than to Blue, we could assign more bits to Red and Green than to Blue, instead of using the same number of bits for each color channel.

Red: 9 bits, Green: 9 bits, Blue: 6 bits.

Therefor, in total, 24 bits are used to represent a color, and Red and Green are assigned 1.5 times more bits than Blue.

(1)-(b) ***Give your new strategy, convert the existing 2 × 2 image to a new image. Write down the new decimal integers in Figure 2. (10 marks)***

Original, 8 bits range from 0 to 255
Current, 9 bits range from 0 to 511, 6 bits range from 0 to 63

Therefore,

Red and Green, from 8 bits to 9 bits: $Y_9 = \lfloor X_8 \times \frac{511}{255} + 0.5 \rfloor$
Blue, from 8 bits to 6 bits: $Y_6 = \lfloor X_8 \times \frac{63}{255} + 0.5 \rfloor$

Applying the formulas to the original image:

Pixel (0,0): R:32, G:128, B:245 $\rightarrow 32 \times \frac{511}{255}, 128 \times \frac{511}{255}, 245 \times \frac{63}{255}$ $\rightarrow$ R:64, G:257, B:61

Pixel (0,1): R:100, G:201, B:15 $\rightarrow 100 \times \frac{511}{255}, 201 \times \frac{511}{255}, 15 \times \frac{63}{255}$ $\rightarrow$ R:200, G:403, B:4

Pixel (1,0): R:231, G:16, B:80 $\rightarrow 231 \times \frac{511}{255}, 16 \times \frac{511}{255}, 80 \times \frac{63}{255}$ $\rightarrow$ R:463, G:32, B:20

Pixel (1,1): R:176, G:143, B:196 $\rightarrow 176 \times \frac{511}{255}, 143 \times \frac{511}{255}, 196 \times \frac{63}{255}$ $\rightarrow$ R:353, G:287, B:48

R: 64 G: 257 B: 61	R: 200 G: 403 B: 4
R: 463 G: 32 B: 20	R: 353 G: 287 B: 48

Figure 2

(1)-(c) ***Write down the 9th bit plane of two images.***

Assumption: The 24 bits forms the RGB channels in the order of Red, Green, Blue from left (MSB) to right (LSB), and the MSB of the 24 bits is the MSB of the Red channel. Therefore, the 9th bit of the 24 bits is counted from left to right as indicated in the following yellow marks.

Figure 1 (8-bit, 8-bit, 8-bit):

- Pixel (0,0): R:32, G:128, B:245 $\rightarrow$ 0010 0000, 1000 0000, 1111 0101
- Pixel (0,1): R:100, G:201, B:15 $\rightarrow$ 0110 0100, 1100 1001, 0000 1111
- Pixel (1,0): R:231, G:16, B:80 $\rightarrow$ 1110 0111, 0001 0000, 0101 0000
- Pixel (1,1): R:176, G:143, B:196 $\rightarrow$ 1011 0000, 1000 1111, 1100 0100

Figure 2 (10-bit, 10-bit, 4-bit):

- Pixel (0,0): R:64, G:257, B:61 $\longrightarrow$ 0 0100 0000, 1 0000 0001, 0 0011 1101
- Pixel (0,1): R:200, G:403, B:4 $\longrightarrow$ 0 1100 1000, 1 1001 0011, 0 0000 0100
- Pixel (1,0): R:463, G:32, B:20 $\longrightarrow$ 1 1100 1111, 0 0010 0000, 0 0001 0100
- Pixel (1,1): R:353, G:287, B:48 $\longrightarrow$ 1 0110 0001, 1 0001 1111, 0 0011 0000

0	**1**
0	**0**

The 9th bit plane of Figure 1

1	**1**
0	**1**

The 9th bit plane of Figure 2

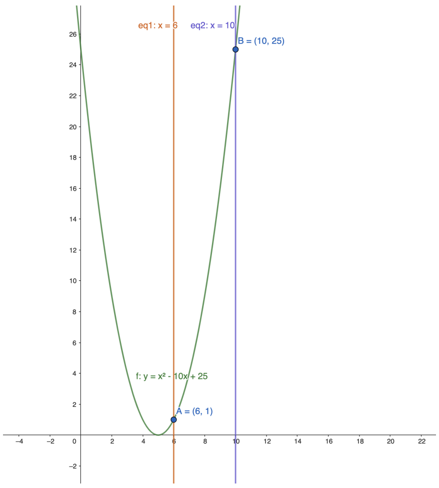
---

(2) For audio signal

$$x(t) = 5 + \sum_{k=6}^{10} k * \sin(2\pi(k-5)^2 * t + \pi/2)$$

(2)-(a) ***What is the highest frequency in the signal?***

The frequency of the signal $x(t)$ is $f = \frac{2\pi(k-5)^2}{2\pi} = (k-5)^2, k \in [6, 10]$



According to the frequency function, the highest frequency in the signal is $f_{max} = (10-5)^2 = 25$, when $k = 10$.

(2)-(b) ***What is the lowest frequency in the signal?***

According to the frequency function, the lowest frequency in the signal is $f_{min} = (6-5)^2 = 1$, when $k = 6$.

(2)-(c) ***What is the Nyquist rate of the signal?***

According to the Nyquist Theorem, the sampling frequency should be at least twice the highest frequency contained in the signal.

$$f_S \geq 2f_{max}$$

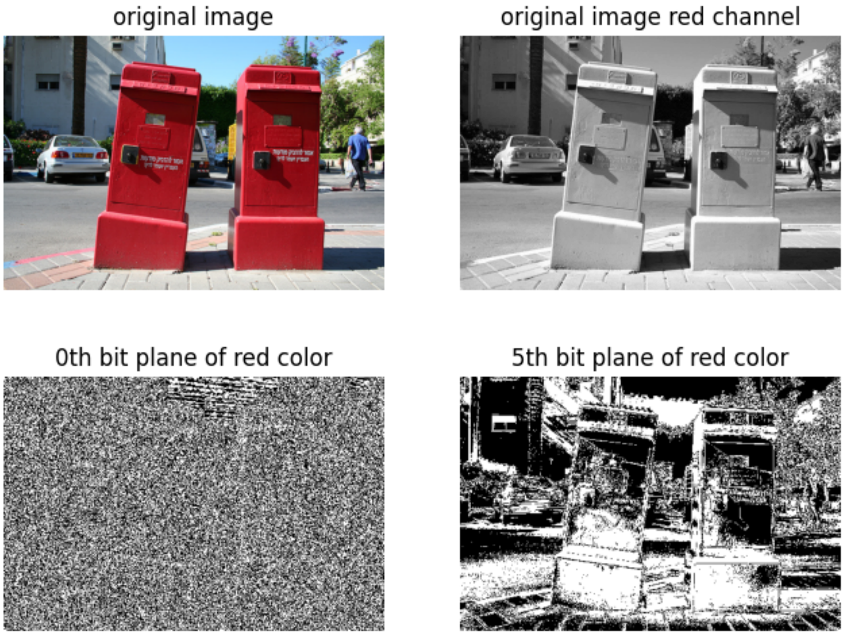
Therefore, for the $x(t)$, the $f_S \geq 2f_{max} = 2 \times 25 = 50Hz$

Thus, the Nyquist rate is the minimum required sampling rate $f_S = 50Hz$

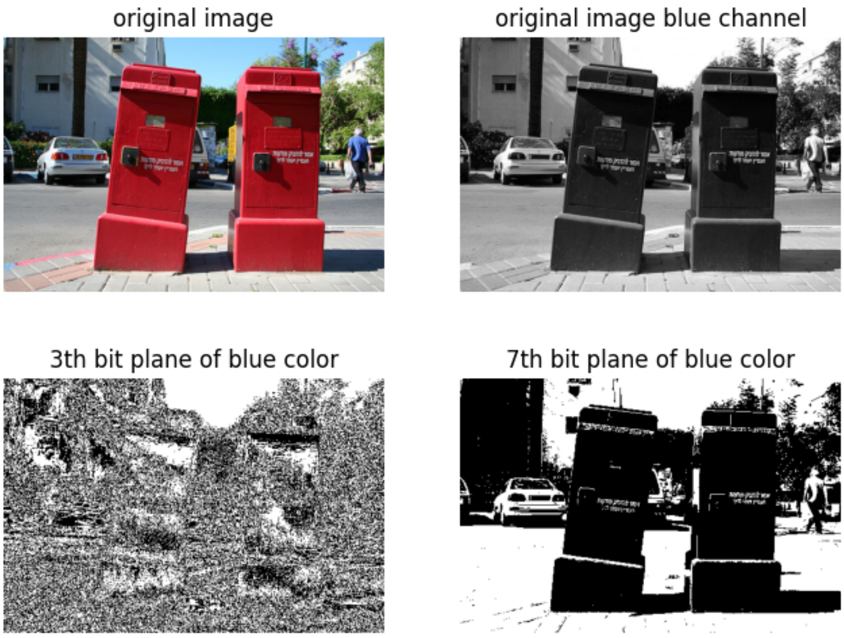
Section 2

(3)

(3)-(a) **0th and 5th bit planes of red color**



(3)-(b) **3rd and 7th bit planes of blue color**



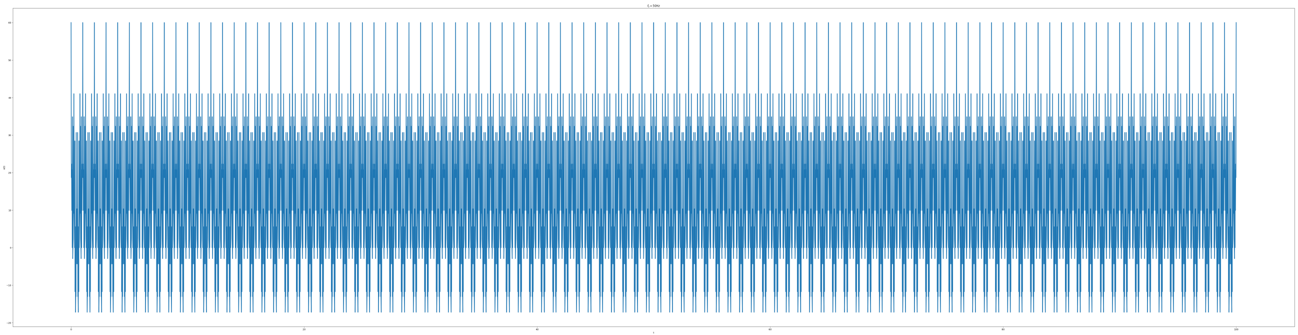
(4) **Plot the audio single**

$$x(t) = 5 + \sum_{k=1}^{10} k * \sin(2\pi(k-5)^2 * t + \pi/2), t \in [0, 100]$$

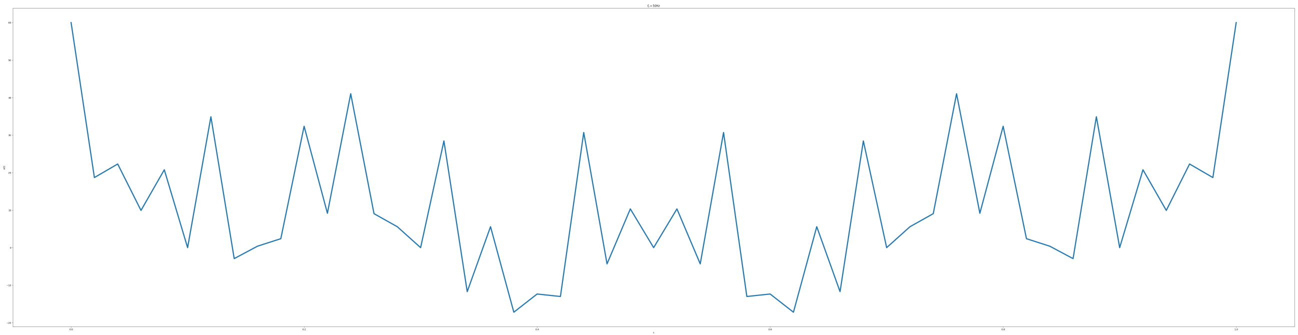
According to the question (2), the the Nyquist rate is $f_S = 50Hz$, therefore, I try to sample the audio signal at $f_S = 50Hz, 100Hz, \text{and } 500Hz$ respectively.

1. $f_S = 50Hz$

- For $t \in [0, 100]$, $f_S = 50Hz$:

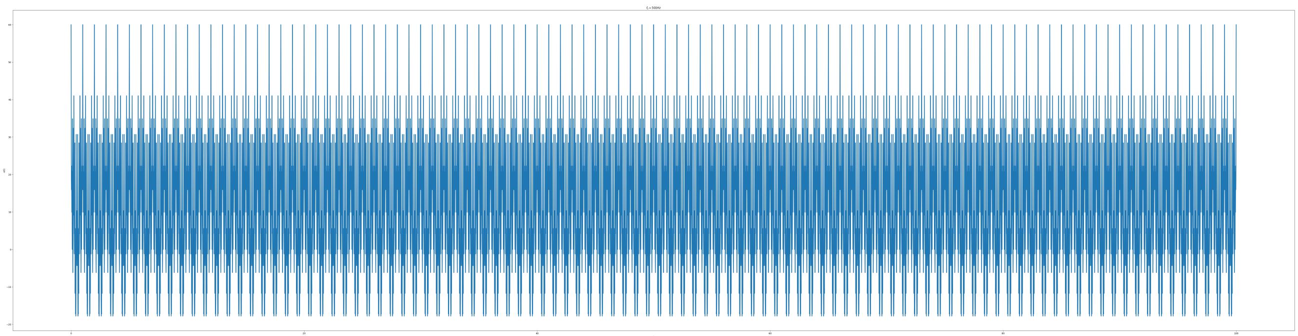


- A close-up view for $t \in [0, 1]$, $f_S = 50Hz$:

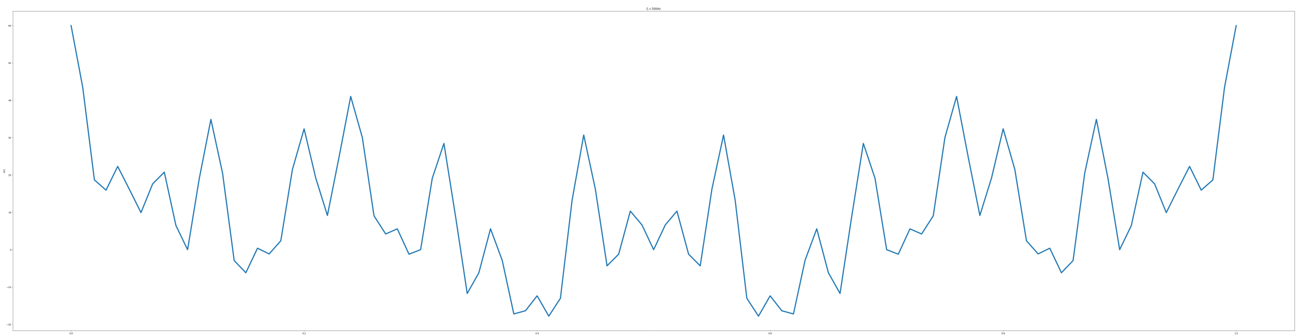


2. $f_S = 100Hz$

- For $t \in [0, 100]$, $f_S = 100Hz$:

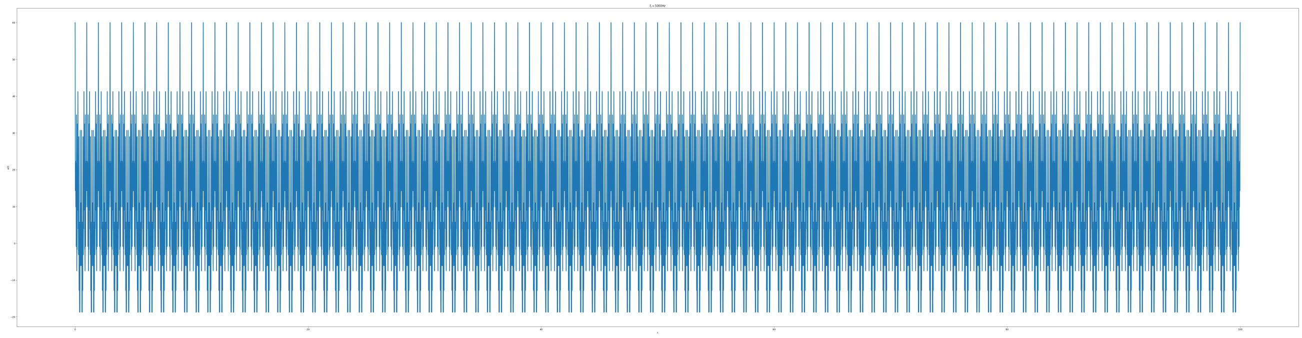


- A close-up view for $t \in [0, 1]$, $f_S = 100Hz$:



3. $f_S = 500Hz$

- For $t \in [0, 100], f_S = 500Hz$:



- A close-up view for $t \in [0, 1], f_S = 500Hz$: