MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
EE101: INTRODUCTION TO ELECTRICAL& ELECTRONICS ENGINEERING

Project 4 Report
Arduino-Based Visible Light Communication

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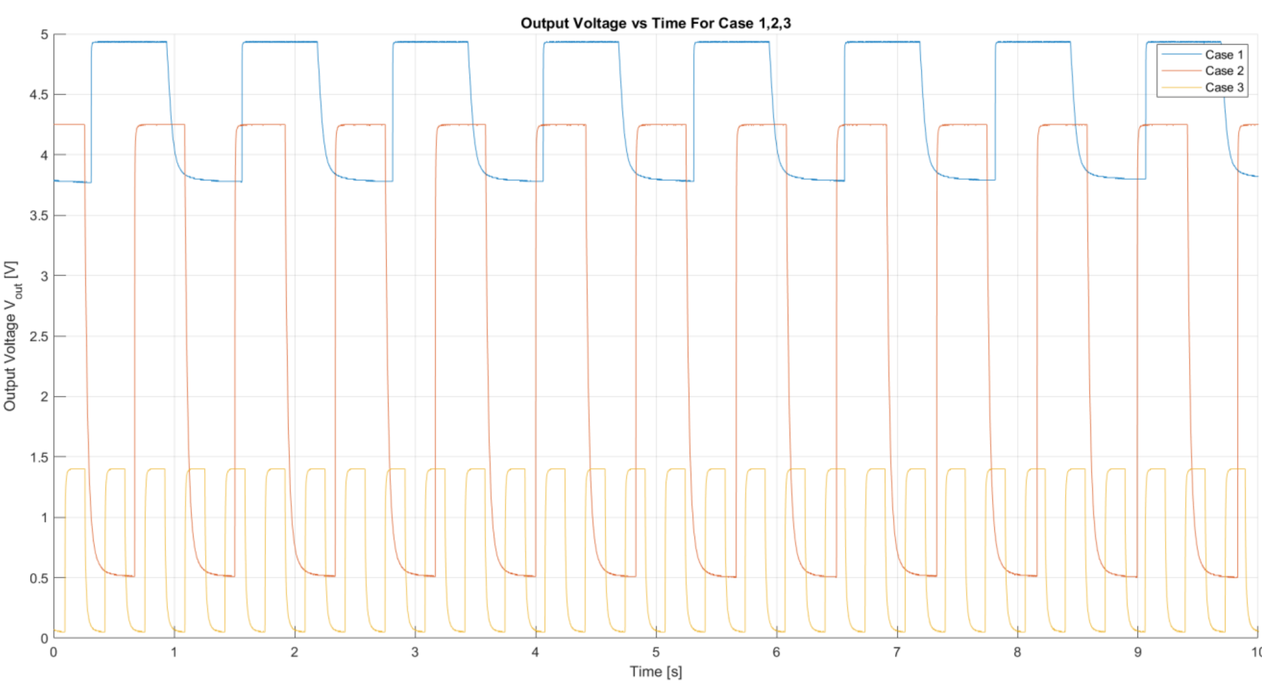
P1.1. Plot the corresponding $V_{out}(t)$ for each case on the same plot. Which case is optimum for the VLC system considering the range of the output voltage signal, i.e., output voltage change? Justify your choice.

In your plots, use time in proper units for the x-axis, label your axes, include a legend. You may use `'hold on'` *in MATLAB to plot multiple lines in the same graph.*



Case 2 is optimum for the VLC system considering the range of he output voltage signal, since the max(c2)-min(c2) is closest to 5 as we can see from the graph.

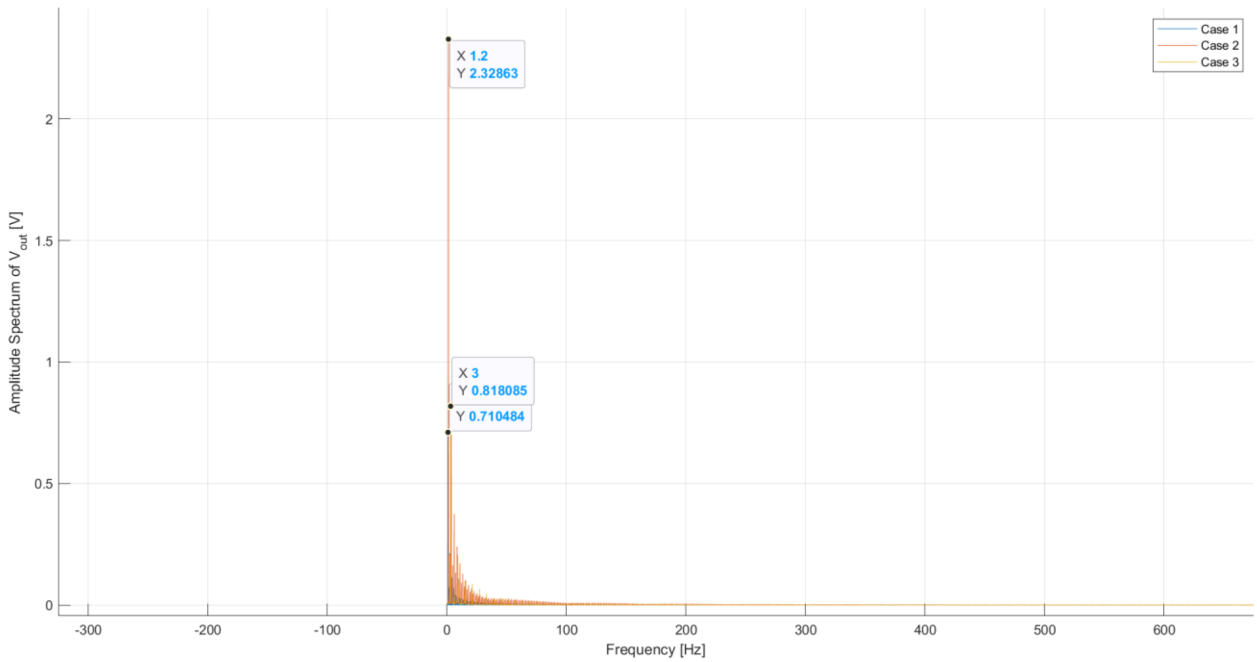
P1.2. For case #2, determine the maximum resistance value of LDR (i.e. dark case corresponding to V_{DATA} = 0 V) and minimum resistance value of LDR (i.e. bright light case corresponding to V_{DATA} = 5 V).

*Show your calculations, refer to Figure 1 and Equation 1—the receiver schematic and voltage division equation in your manual. Note that fixed resistor for this case is R_S = 8.2 k*Ω.

$V_{OUT} = R_S / (R_{S+}R) *V_{BIAS}$ V_{OUT} = 0.5 V for maximum resistance. V_{BIAS} = 5 V And R_S=8200 Ω So, V_{OUT} * (8200+R) = 8200*5 R is equal to 73800 Ω	$V_{OUT} = R_S / (R_{S+}R) *V_{BIAS}$ V_{OUT} = 4.25 V for minimum resistance. V_{BIAS} = 5 V And R_S=8200 Ω So, V_{OUT} * (8200+R) = 8200*5 R is equal to 1447 Ω
Max. Resistance of LDR [kΩ] = 73.8 kΩ	Min. Resistance of LDR [kΩ] = 1.447 kΩ

P1.3. Plot the amplitude spectrum (i.e. magnitude of the Fourier transform obtained using `fft` in MATLAB) for each case on the same plot. Determine and show the fundamental (dominant) frequency for each case. Why is the frequency at which FFT takes its maximum value considered so as to determine the frequency of the signal?

For this part, subtract the mean value of entire data from itself since we are interested in the alternating (ac) part of the signal. You can use mean function in MATLAB as of form `x - mean(x)`*. In your plots, use frequency in proper units for the x-axis, label your axes, include a legend. Use data tips to indicate dominant frequencies. Use* `semilogx` *function (instead of* `plot`*) to show frequency in logarithmic scale to be able to see a large range of frequencies.*



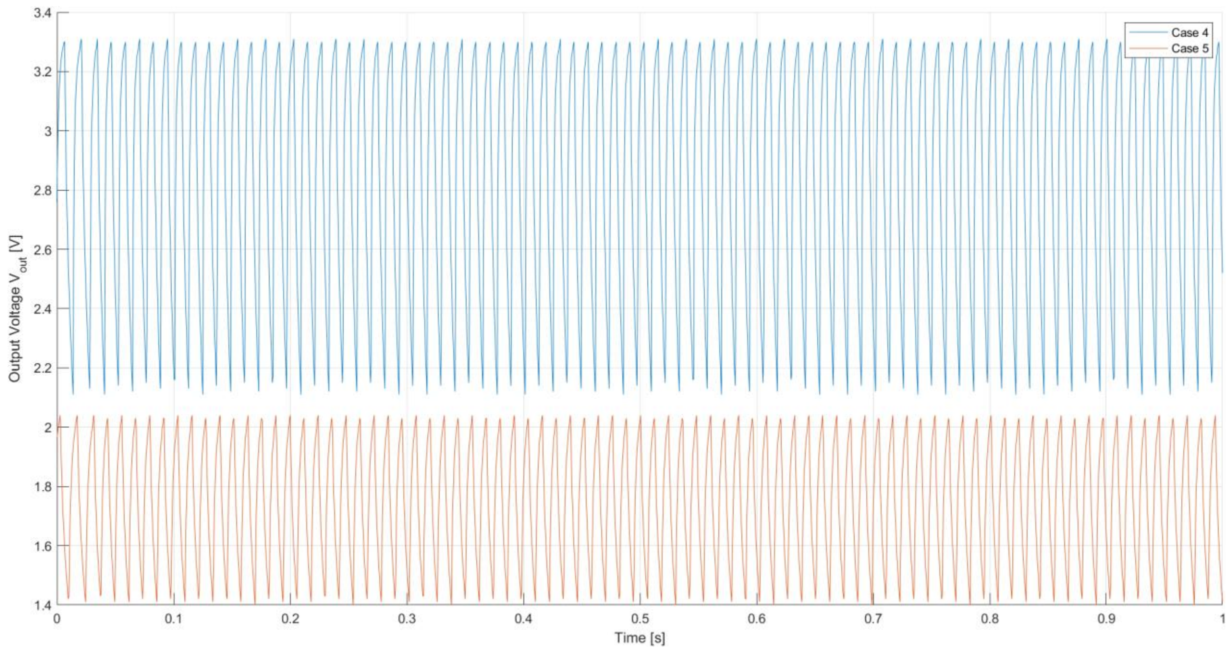
It can not be seen clearly but 0.8 Hz is the dominant frequency of Case 1, 1.2 Hz is the dominant frequency of Case 2 , and 3 Hz is the dominant frequency of Case 3. The frequency at which FFT takes its maximum value is considered to determine the frequency of the signal because fourier transform shows the frequencies of a signal, and at its maximum value it gives the dominant frequency of the signal.

P2.1. Plot the corresponding $V_{out}(t)$ for the case #4 and #5 on the same graph, which correspond to cases with different receiver to transmitter distance (x). Calculate the voltage change ΔV for each case (i.e. the maximum voltage value minus the minimum voltage value). Suppose that we can model the relation between the voltage change ΔV and the distance x between the transmitter and the receiver as follows by assuming that ΔV is inversely proportional to the squared distance x^2:

$$\Delta V = \frac{c}{(x + x_0)^2} \qquad (2)$$

Using this model, determine the parameters x_0 and c for the case #4 and #5. Assuming that the minimum detection limit for our system is $\Delta V \geq 25$ mV, determine the maximum distance x for a reliable operation using the found parameters x_0 and c.

In your plots, use time in proper units for the x-axis, label your axes, include a legend. Show your calculations.



ΔV_4= 1.2 V, ΔV_4= 0.64 V

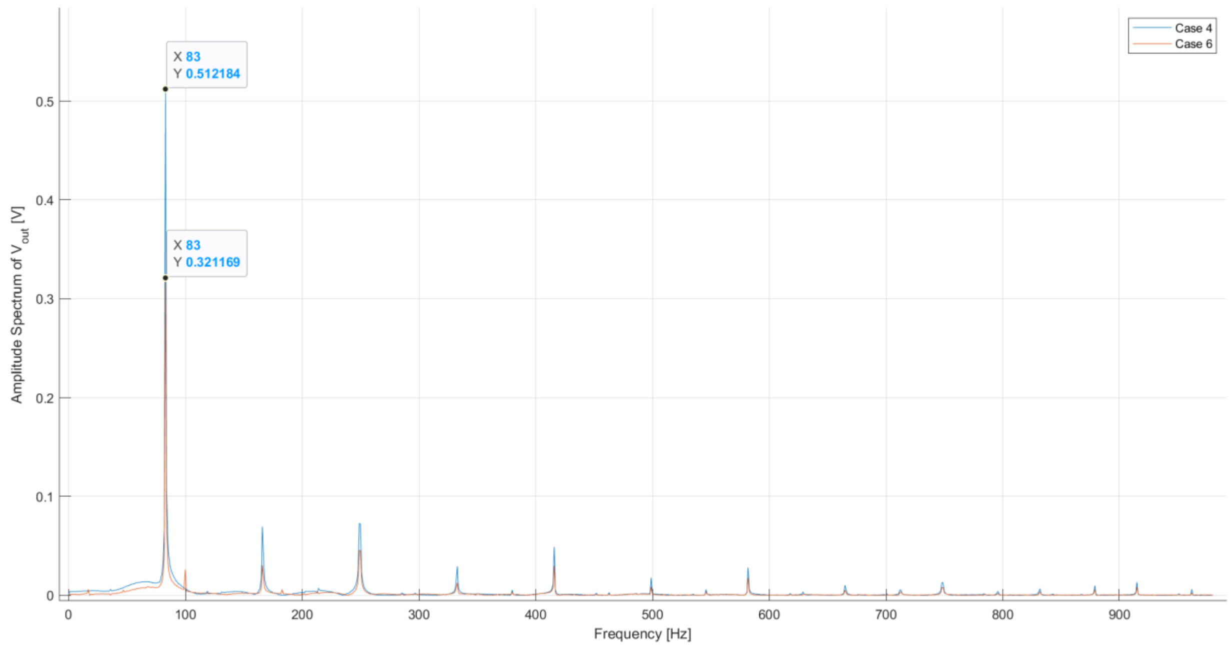
X_4 = 4 cm , X_5 = 7 cm , Since c is constant, we can equalize $\Delta V_4 * ((4 + x_0)^2) = \Delta V_5 * ((7 + x_0)^2)$ and from that equation, we can find that $x_0 = 2/7(3\sqrt{30} - 2)$ cm. By using this, we can substitute x_0 in any equation and can find that c = 79.1863 V.cm^2. Since we have found both constants, we can determine the maximum distance x by assuming that ΔV=25 mV.

From the equation $25 * (10)^{-3} = \frac{79.1863}{\left(x+2/7(3\sqrt{30}-2)\right)^2}$, maximum distance x is approximately 52.157 cm.

x_0 [cm] = 4.123 cm	c [V.cm^2] = 79.1863 V.cm^2	x_{max} [cm] = 52.157 cm

P2.2. To analyze the interference effect of a conventional fluorescent lighting on the VLC system, plot the frequency content (by subtracting the mean like P1.3) for the case #4 and case #6 on the same graph. Can you see anything unexpected in this spectrum? If it is so, what can be the origin of this change? When fluorescent lighting is present in the environment, what limitation does it impose on the selection of the operating frequency of our VLC system?

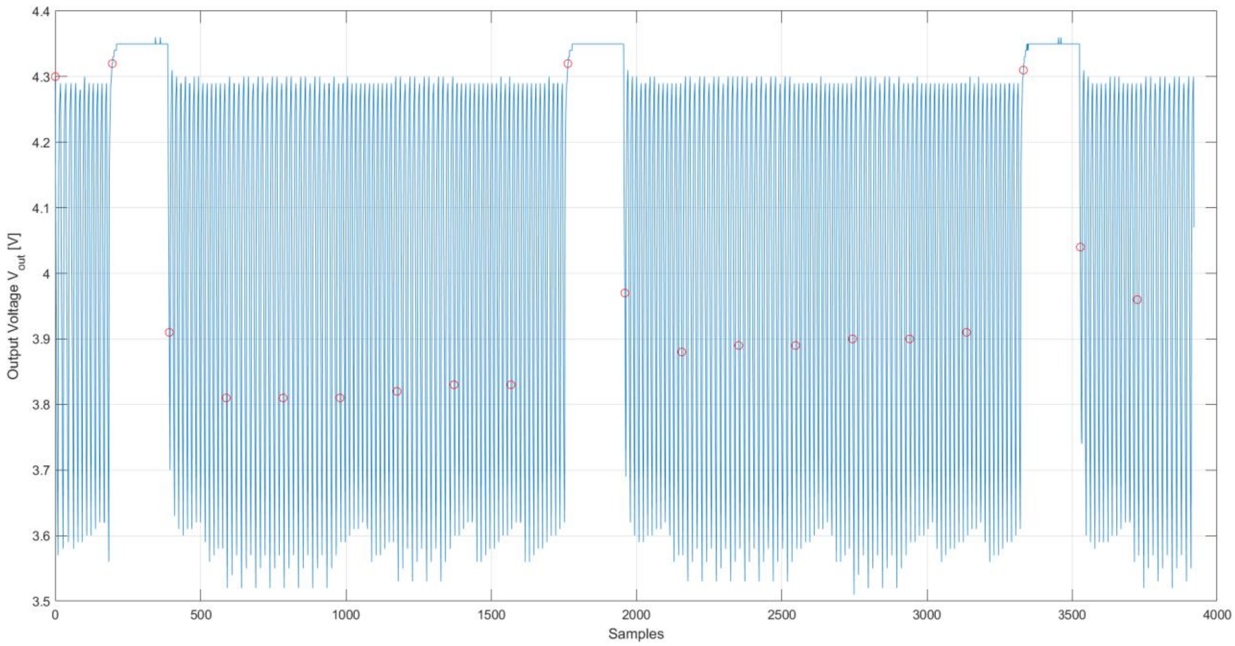
Similar to P1.3, subtract the mean value of entire data from. In your plots, use frequency in proper units for the x-axis, label your axes, include a legend. Use data tips to indicate any anomaly if present. Use `semilogx` *function (instead of* `plot`*) to show frequency in logarithmic scale to be able to see a large range of frequencies.*



Since there is an extra fluorescent in the environment, Amplitude of V_{OUT} has decreased. As we have observed from the graph, it doesn't impose limitation on the selection of the operating frequency, however it decreases the amplitude of V_{OUT} at the same frequencies.

P3.1. Plot $V_{out}(t)$ for this message and show the starting point of each bit on the plot. Write down the start and end indices of each bit. Note that the sampling frequency of the Arduino is f_S = 1.96 kHz. Hence, each transmitted bit corresponds to 196 samples since each bit is transmitted for a duration of 100 ms. What is the bitrate of our VLC system? Is this simple VLC system capable of transmitting data at high speeds? Comment. (Complicated modulation schemes are used in practice to enable fast communication speeds. You can learn such modulation techniques in the communication courses of our department.)

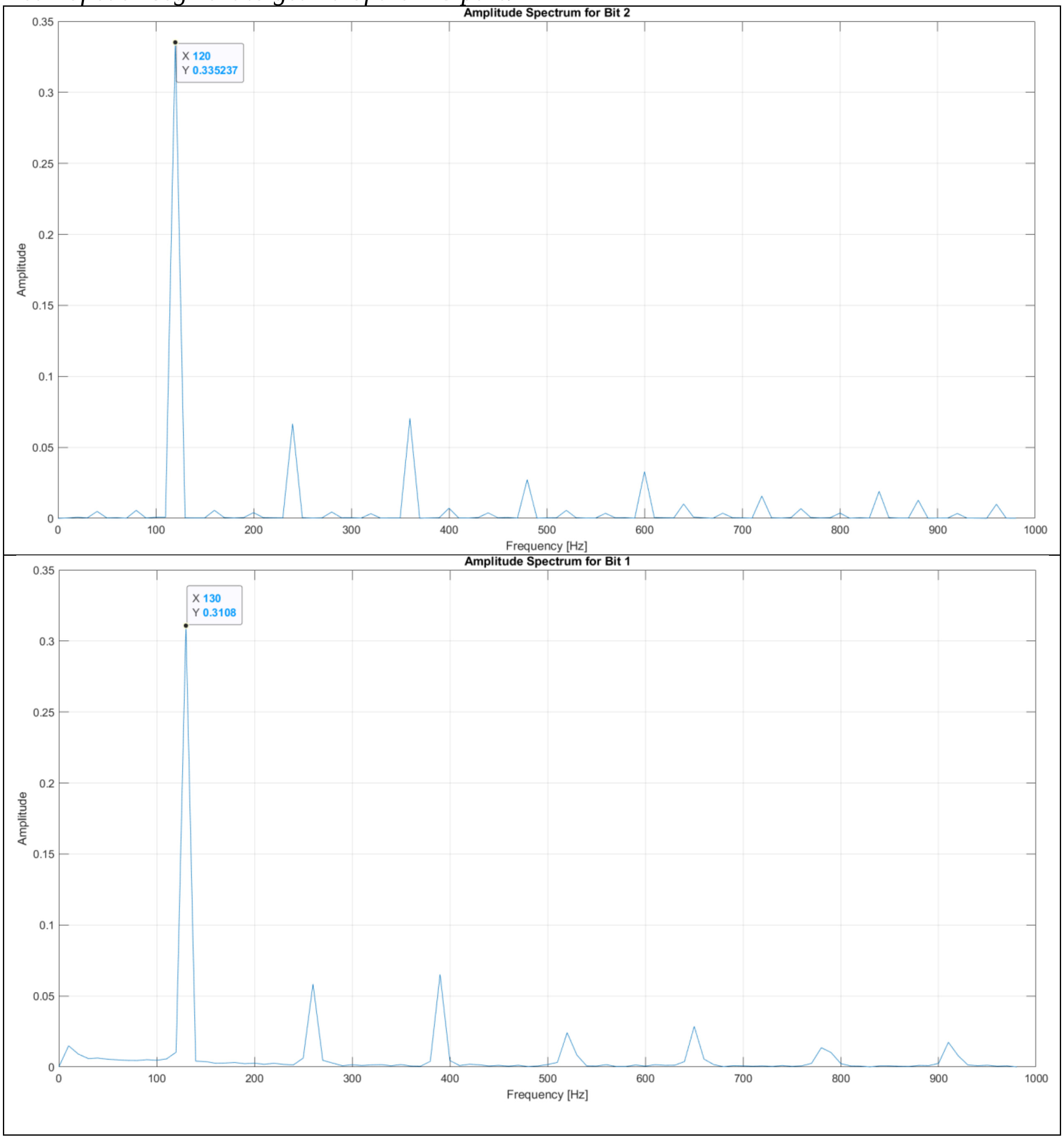
In your plots, use time in proper units for the x-axis, label your axes. Use data tips for indicating the starting point of each bit.



Indices for Bit 1: <393,589> Bit 2: <589,785> Bit 3: <785,981> Bit 4: <981,1177> Bit 5: <1177,1373> Bit 6: <1373,1569> Bit 7: <1569,1765>	Since each bit is transmitted for a duration of 100ms, bitrate of our VLC system is 10 bits/s. Thus, our system is not capable of transmitting data at high speeds. Its bitrate is much lower than an average VLC system.
Bitrate [bits/s] = 10 bits/s	

P3.2. Determine the switching frequencies of the LED corresponding to bits 0 and 1. Plot the amplitude spectrum of each bit segment and use data tips to find the dominant frequency for each bit. Write down the transmitted message in binary form. Then convert this binary message into decimal, and determine the corresponding character using an ASCII chart (note that it is casesensitive). In your report include the plots of the two amplitude spectrum corresponding to bits 0 and 1 (you may use any portion of the received signal that corresponds to bit 0 and 1).

You need to segment your data (see Array Indexing in MATLAB support), and take successive Fourier transform of each segment to determine the frequency. Like P1.3 and P2.2, subtract the mean of each segment to get rid of the DC part.



Frequency for 0 [Hz] = 120 Hz
Frequency for 1 [Hz] = 130 Hz

Message in binary = 1001011
Message in decimal = 75

Corresponding ASCII character = K