EE 340 : Communication Lab

Midsem Solution

Batch- A

Marking guidelines:

- Block diagrams don't carry marks. Only the final output matters.
- However, there may be multiple correct ways to obtain the results (please go through the block diagram carefully to make sure that the method used is not wrong even if the result is as expected). If wrong method is used, marks may not be awarded.

Question: 1

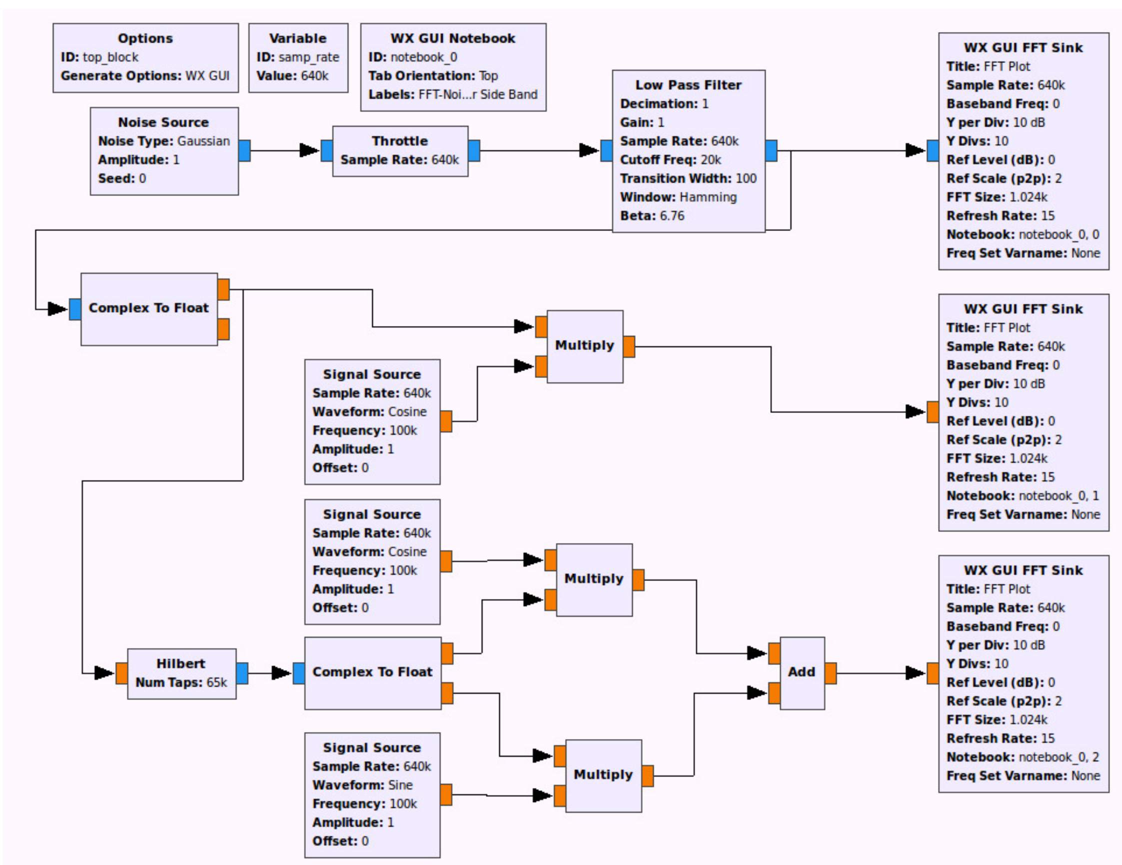


Figure 1 Flow Diagram for Question 1

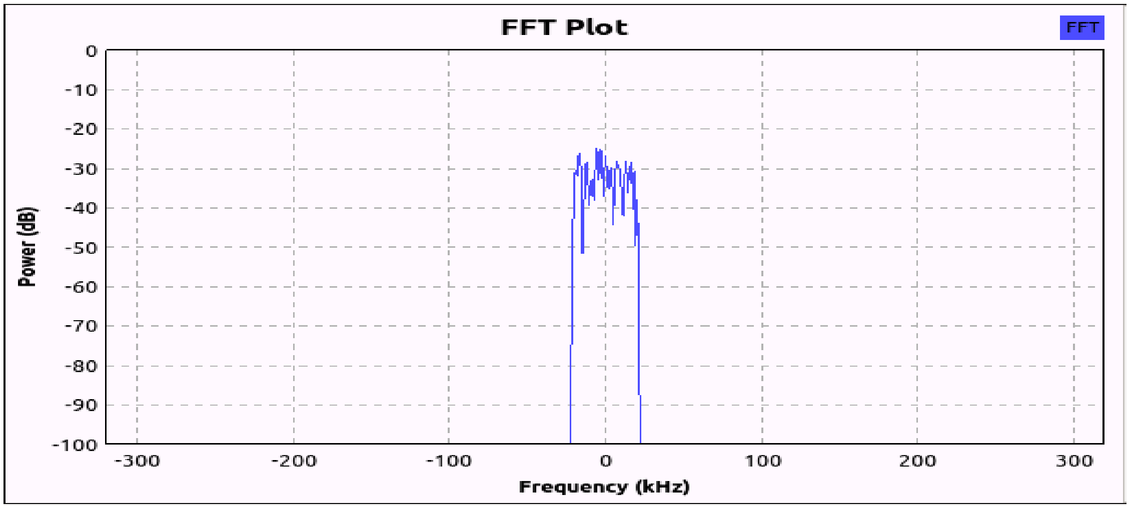


Figure 2 FFT for Question 1(a)

a) <u>2 marks for complex spectrum (i.e. both –ve and +ve frequencies)</u>
<u>1 mark if only one side or if the cut-off frequency is not correct.</u>

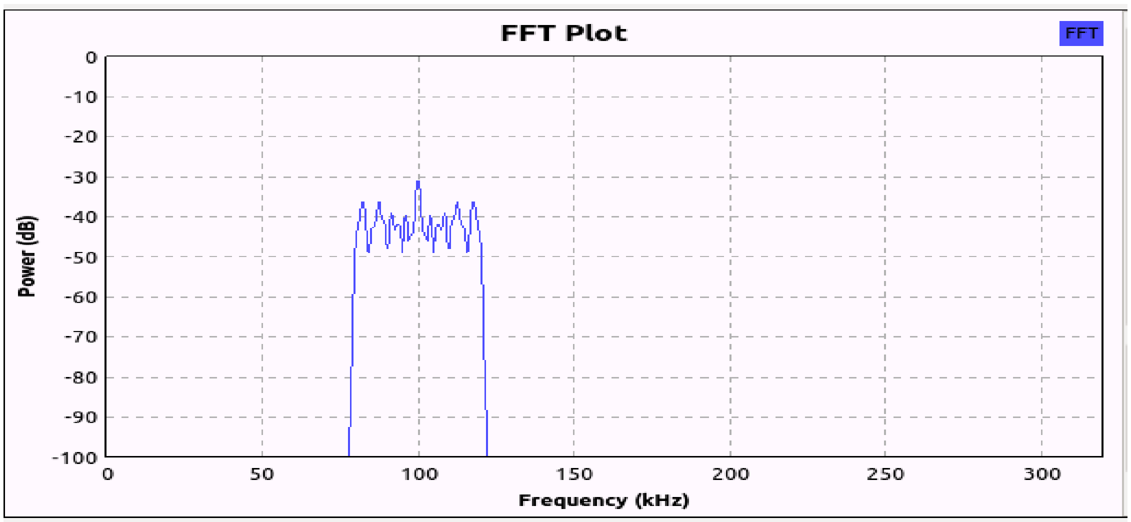


Figure 3 FFT for Question 1(b)

b) <u>2 marks for real spectrum (i.e. only +ve frequencies) shown and frequencies are also correct.</u>
<u>1 mark if complex spectrum is shown or frequencies are not correct.</u>

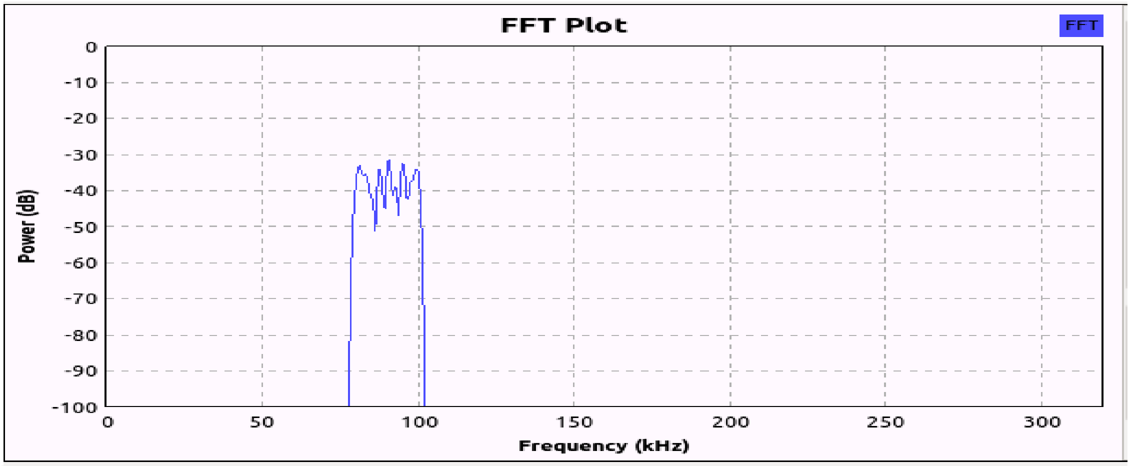


Figure 4 FFT for Question 1(c)

c) **First part:**

3 marks if the procedure (i.e. block diagram is correct) and the spectrum is also correct.
2 marks if they've shown upper sideband (instead of lower sideband) / or if a complex spectrum is shown.

Second part:

No, because the Hilbert transform block is implemented as a practical FIR filter and requires infinite number of taps to show ideal behaviour. (1 mark if both answer and explanation are correct).

Question: 2

The circuit can be emulated using a flow graph as shown in Fig. 5 :-

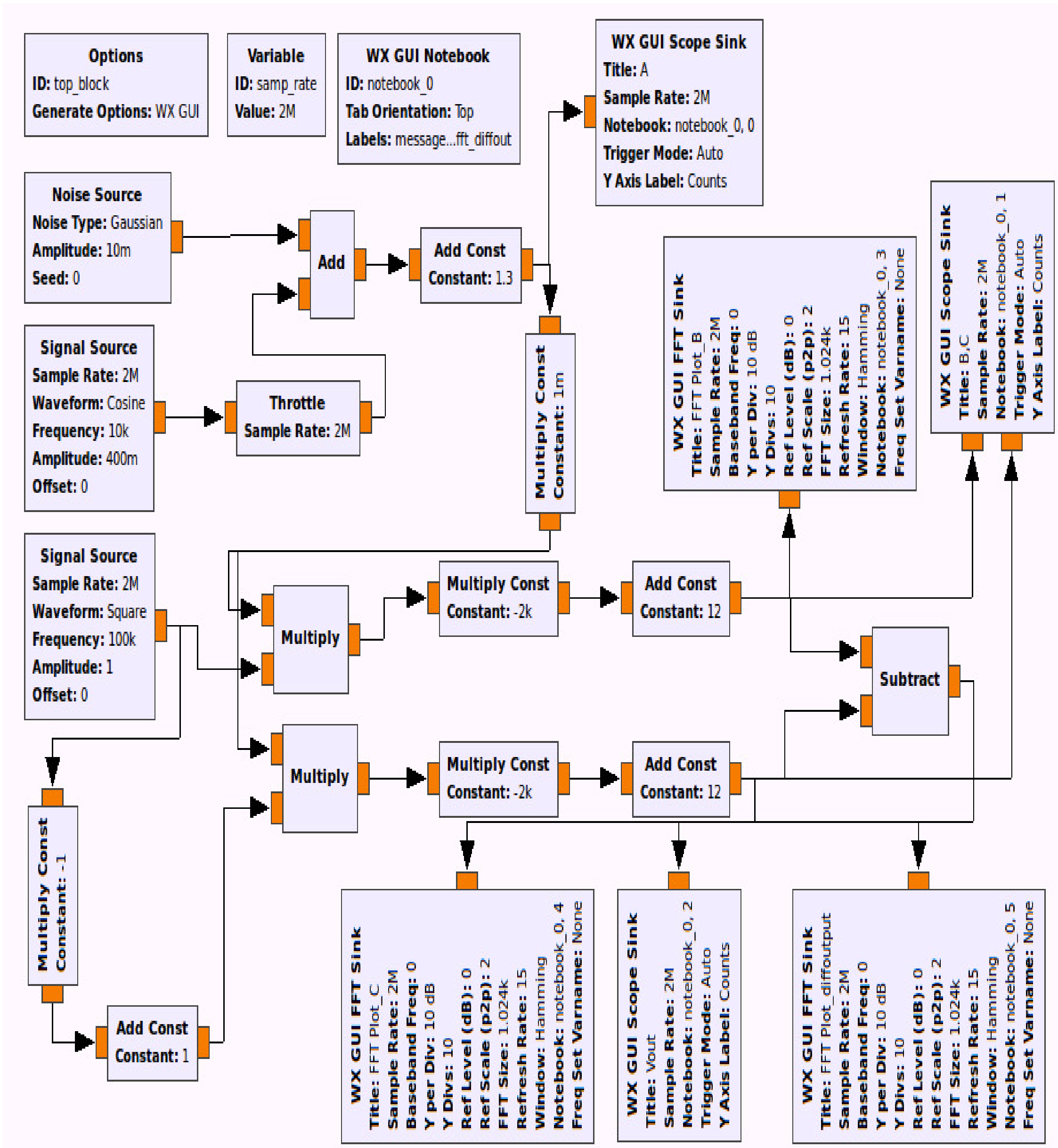


Figure 5:- Flow graph for Question 2

Question: 2 (a)

The time domain voltages at nodes A,B and C are as shown in Fig. 6 and Fig. 7 respectively.

At node A :-

$V(A) = 2 - (0.7) + v_{in}$ *Volts*

$V(A) = 1.3 + v_{in}$ And $v_{in} = 0.4\sin(2\pi 10\times 10^3 t)$ *Volts*

$V(A) = 1.3 + 0.4\sin(2\pi 10\times 10^3 t)$ *Volts*

$$I_b = \frac{1.3 + 0.4\sin(2\pi 10\times 10^3 t)}{R_E} \text{ A}$$

For $R_E = 1K$

$I_b = 1.3 + 0.4\sin(2\pi 10\times 10^3 t)$ mA

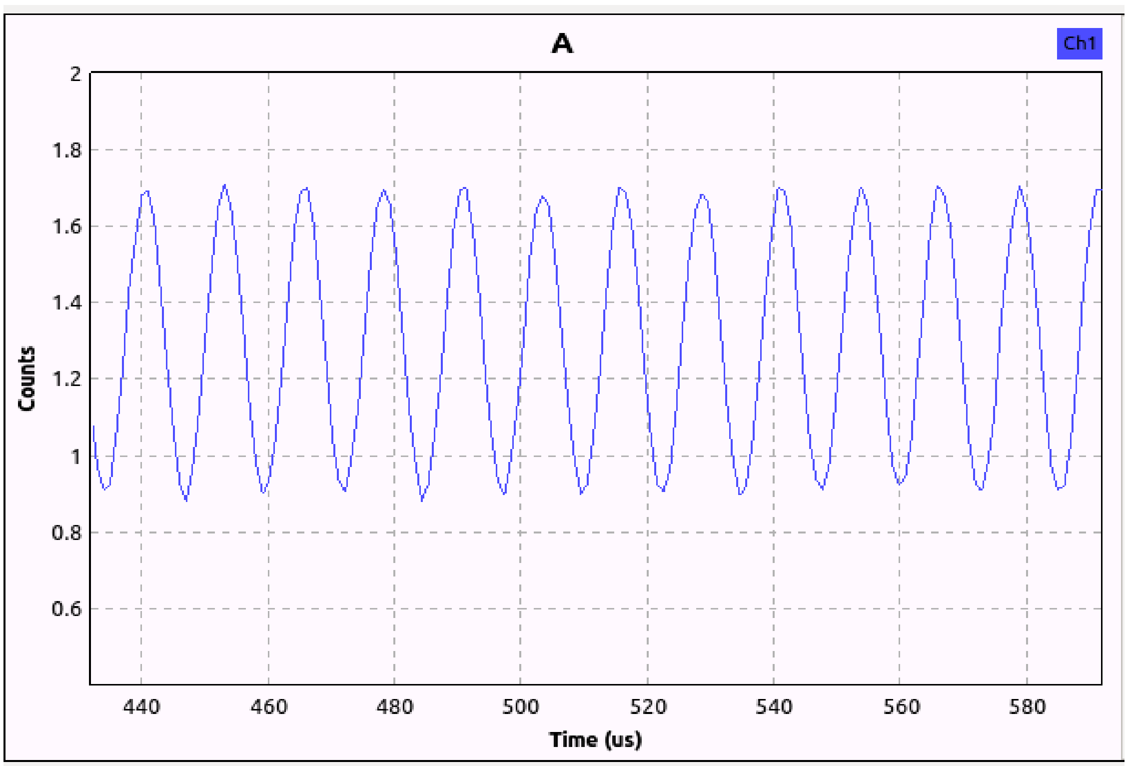
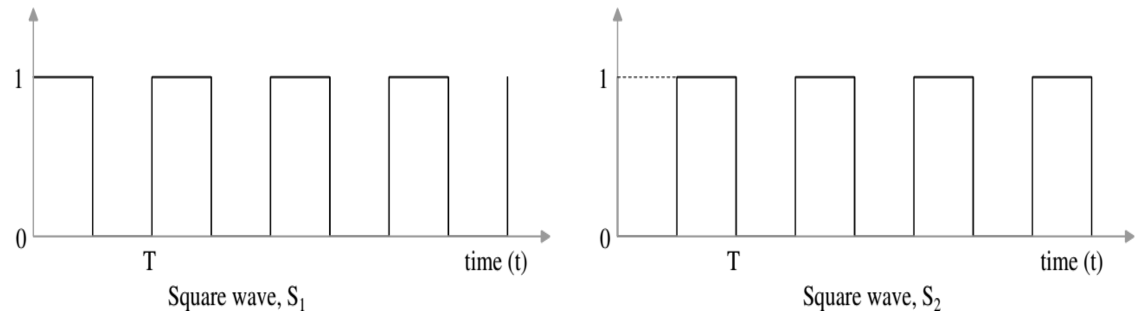


Figure 6 Voltage at node A (Current I_b flowing through R_E)

The switching action of the two transistors Q1 and Q2 is governed by the Square waves S_1 and S_2 respectively.



Using Fourier series integral for the above Square waves a_0, a_n and b_n can be determined. These coefficients give a Fourier series expansion as:-

$$S_1 = \frac{1}{2} + \frac{2}{\pi}\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]$$

Similarly

$$S_2 = \frac{1}{2} - \frac{2}{\pi}\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]$$

Voltage at node B and C is given as:-

$V(B) = 12 - (I_b R_C \times S_1)$ *Volts*

$V(B) = 12 - \dfrac{(1.3 + 0.4\sin(2\pi 10 \times 10^3 t))R_C}{R_E} \times S_1$ *Volts*

$V(B) = 12 - (2.6 + 0.8\sin(2\pi 10 \times 10^3 t)) \times S_1) = 12 - (2.6 + 0.8\sin(2\pi 10 \times 10^3 t)) \times S_1$

$V(C) = 12 - (I_b R_C \times S_2)$ *Volts*

$V(C) = 12 - \dfrac{(1.3 + 0.4\sin(2\pi 10 \times 10^3 t))R_C}{R_E} \times S_2$ *Volts*

$V(C) = 12 - (2.6 + 0.8\sin(2\pi 10 \times 10^3 t) \times S_2) = 12 - (2.6 + 0.8\sin(2\pi 10 \times 10^3 t)) \times S_2$

Where S_1 and S_2 are having 180^0 phase shift.

Therefore V(B) and V(C) are:-

$$V(B) = 12 - (2.6 + 0.8\sin(2\pi 10\times 10^{3}t))\left[\frac{1}{2} + \frac{2}{\pi}\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]\right]$$

$$V(C) = 12 - (2.6 + 0.8\sin(2\pi 10\times 10^{3}t))\left[\frac{1}{2} - \frac{2}{\pi}\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]\right]$$

Figure 7 Voltage at nodes B and C

Marking scheme:

a) <u>**For V(A):**</u>

<u>**1 mark if V(A) is a sinusoid with DC (average) voltage of 1.3V.**</u>

<u>**For V(B) and V(C):**</u>

<u>**3 marks if V(B) and V(C) are correct (with absolute voltages).**</u>

<u>**Deduct 1 out of 3 if any voltage is not correct.**</u>

<u>**Deduct 1 out of 3 if phase difference between them is not correct.**</u>

Question: 2 (b)

The differential Output voltage is obtained as:-

$$vout = \left[12-(2.6+0.8\sin(2\pi 10\times 10^{3}t))\left[\frac{1}{2}+\frac{2}{\pi}\left[\sin(w_0t)+\frac{\sin(3w_0t)}{3}+\frac{\sin(5w_0t)}{5}+\ldots\right]\right]\right]$$
$$-\left[12-(2.6+0.8\sin(2\pi 10\times 10^{3}t))\left[\frac{1}{2}-\frac{2}{\pi}\left[\sin(w_0t)+\frac{\sin(3w_0t)}{3}+\frac{\sin(5w_0t)}{5}+\ldots\right]\right]\right]$$

$$vout = \left[2\times(2.6+0.8\sin(2\pi 10\times 10^{3}t))\frac{4}{\pi}\left[\sin(w_0t)+\frac{\sin(3w_0t)}{3}+\frac{\sin(5w_0t)}{5}+\ldots\right]\right]$$

$$vout = (2.6+0.8\sin(2\pi 10\times 10^{3}t))\frac{4}{\pi}\left[\sin(w_0t)+\frac{\sin(3w_0t)}{3}+\frac{\sin(5w_0t)}{5}+\ldots\right]$$

$$vout = \frac{4}{\pi}(2.6+0.8\sin(2\pi 10\times 10^{3}t))\left[\sin(w_0t)+\frac{\sin(3w_0t)}{3}+\frac{\sin(5w_0t)}{5}+\ldots\right]$$

Figure 8 Differential output waveform

b) **<u>1 mark if V(OUT) is correct.</u>**

Question: 2 (c)

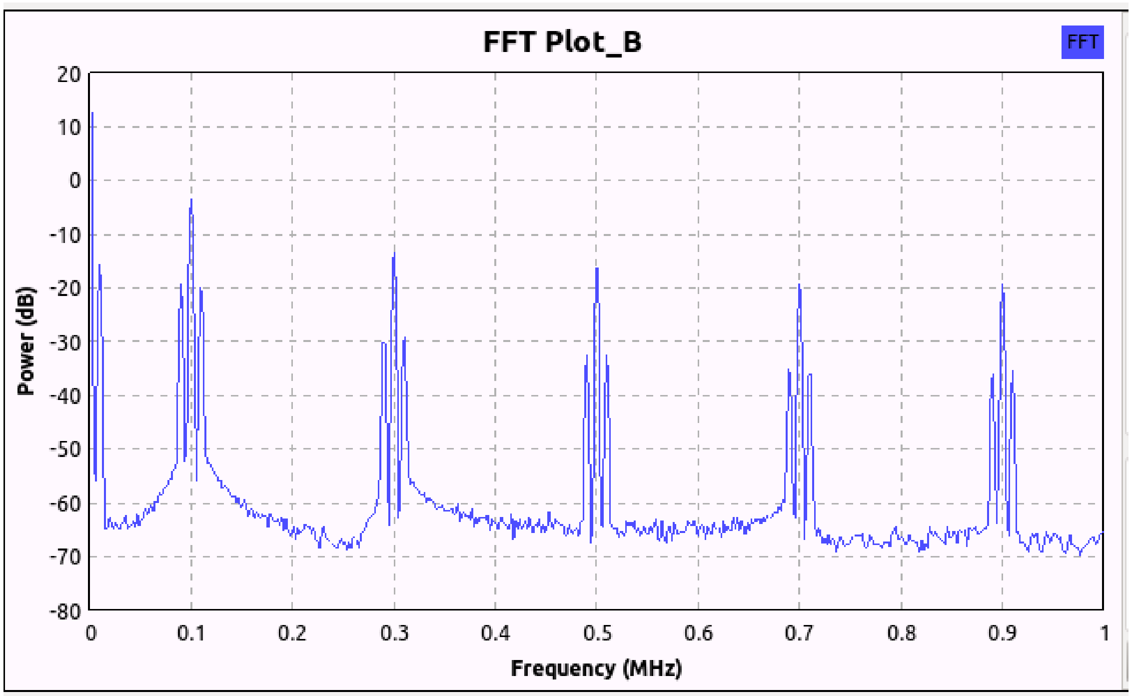


Figure 9 FFT for Question 2 at node B

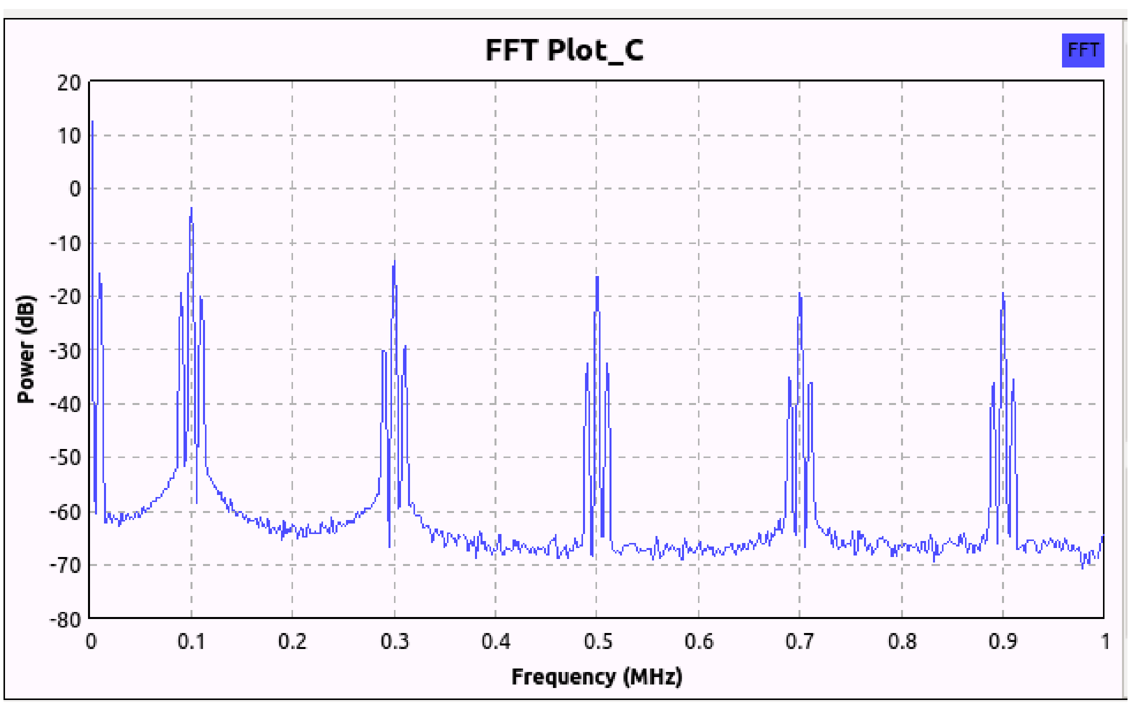


Figure 10 FFT for Question 2 at node C

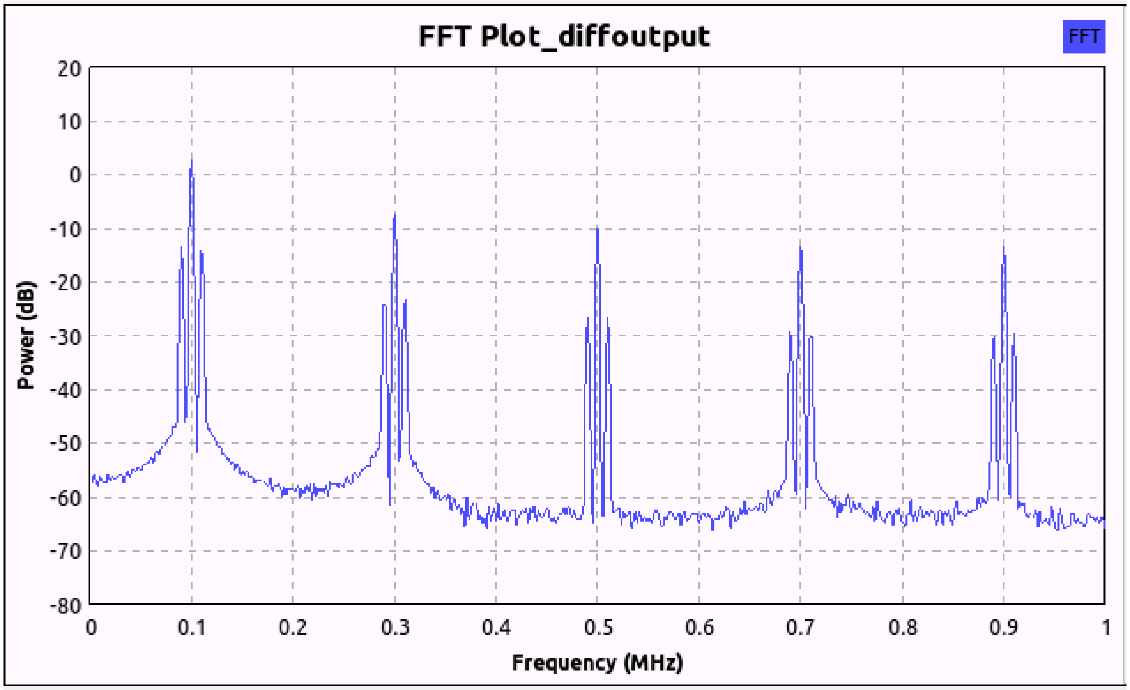


Figure 11 FFT for differential output

c) **If the spectra are correct, award 2 marks (if the FFT scale is NOT shown at least up to 1 MHz, deduct 1 out of 2 marks)**

Question: 2 (d)

Explanation:

Since the intividual square waves S1 and S2 have DC components (of 0.5) in each waveform, when they are multiplied with the message, the resultant has message component (i.e. 10 kHz) also in the output spectrum. However, when the difference is taken, this component gets cancelled.

Or if someone has given mathematical analysis, as below:

$$V(B) = 12 - 2.6\left[\frac{1}{2} + \frac{2}{\pi}\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]\right]$$

$$+0.8\sin(2\pi 10\times 10^3 t)\left[\frac{1}{2} + \frac{2}{\pi}\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]\right]$$

The last part gives rise to components at 10 kHz, which is same for V(C) also. Therefore, in the differential output, this term gets cancelled.

d) **1 Mark if the explanation is correct.**

Question: 2 (e)

Relative amplitudes for components at w_0, $3w_0$, $5w_0$ are 1, 1/3 , 1/5.

e) **<u>If the relative amplitudes have been derived using integration method for calculation of Fourier series coefficients, full 2 marks should be awarded (1 mark for only recalling the correct values).</u>**

Question: 2 (f)

For $V(A) = 1.3 + A\sin(2\pi 10\times 10^3 t)$ *Volts*

$$vout = \frac{8}{\pi}(1.3 + A\sin(2\pi 10\times 10^3 t))\left[\sin(w_0 t) + \frac{\sin(3w_0 t)}{3} + \frac{\sin(5w_0 t)}{5} + \ldots\right]$$

For m=0.5, A must be equal to 0.65 .

f) **<u>2 marks if the value of A is correct (only 1 mark if the student has written the general form for DSB-FC modulation in terms of modulation index, but got wrong final answer).</u>**