NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR
(Semester II: 2018/2019)

Names of examiners: J W Zhang, Sangit Sasidhar and C S Ng

CG2023 – SIGNALS AND SYSTEMS

Apr/May 2019 – Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This paper contains **SIX (6)** questions and comprises **EIGHTEEN (18)** printed pages.
2. Answer **ALL** questions in both Sections A and B.
3. The maximum mark for this paper is 80.
4. This is a **CLOSED BOOK** examination. You are allowed to bring **ONE (1)** A4 size crib sheet to the examination.
5. Programmable and/or graphic calculators are not allowed.
6. Tables of formulas are provided on a separate sheet.
7. Write your **answers** in the spaces indicated in this question paper and hand it in at the end of the examination. Attachment will not be graded.
8. Write only your **matric number** in the spaces indicated below. Do not write your name.

MATRICULATION NUMBER:

	QUESTION NUMBER	MARKS
For examiners' use only:	**Q.1**	
	Q.2	
	Q.3	
	Q.4	
	Q.5	
	Q.6	
	TOTAL	

SECTION A
Answer ALL questions in this section (Each question carries 10 marks)

Q.1 Given the signal $x(t) = 2 \times \mathrm{rect}(t) \ast \left[\delta(t-0.5) + \delta(t+0.5)\right]$ where '$\ast$' denotes the convolution operation.

(a) Find the Fourier transform, $X(f)$, of $x(t)$. (3 marks)

(b) Find the energy of $x(t)$. (3 marks)

(c) Find the 1st-null bandwidth of $x(t)$. (4 marks)

Q.1 ANSWER

Q.1 ANSWER ~ continued

Q.2 The signal $x(t)$ is a half cosine pulse as shown in Figure Q2. The spectrum of another signal $y(t)$ is $Y(f) = X(f) \times \sum_{k=-\infty}^{\infty} \delta(f - 0.25k)$ where k is an integer index.

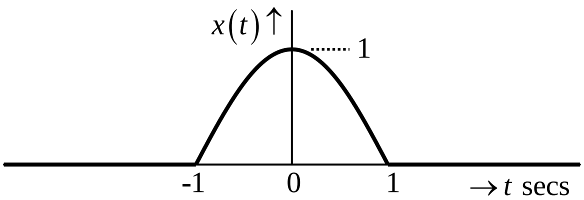


Figure Q2

(a) Find the Fourier transform, $X(f)$, of $x(t)$. (4 marks)

(b) Find the energy of $x(t)$. (3 marks)

(c) Determine if $y(t)$ is a power signal or an energy signal. Find its average power if it is a power signal or find its energy if it is an energy signal. (3 marks)

Q.2 ANSWER

Q.2 ANSWER ~ continued

Q.3 The transfer function of a 2nd-order system is given by $\tilde{H}(s) = \dfrac{20(1-s)}{5s^2 + 11s + 2}$.

(a) What are the system poles and zeros? (3 marks)

(b) Is the system BIBO stable, and why? (2 marks)

(c) Is the system underdamped, and why? (2 marks)

(d) Describe the high-frequency asymptotic behavior of $\tilde{H}(s)$. (3 marks)

Q.3 ANSWER

Q.3 ANSWER ~ continued

Q.4 A signal $x(t)$ is sampled, stored and later reconstructed from the stored samples using a reconstruction filter. The spectrum of $x(t)$ and the frequency response of the reconstruction filter are shown in the Figure Q4.

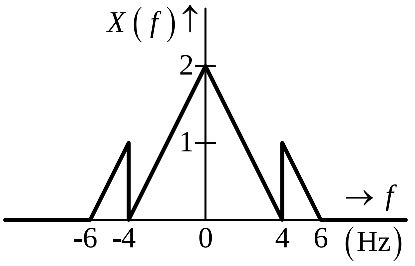


Figure Q4(a): Spectrum of $x(t)$

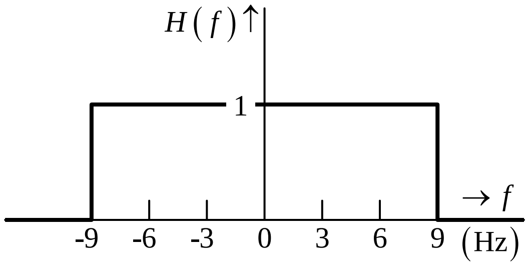


Figure Q4(b): Frequency response of reconstruction filter

(a) Based on Figure Q4(a), what is the Nyquist sampling frequency for $x(t)$ (2 marks)

(b) Sketch the spectrum of the reconstruction filter output if $x(t)$ is sampled at Nyquist sampling frequency. Is the reconstructed spectrum identical to $X(f)$? (4 marks)

(c) Recommend a sampling frequency so that $x(t)$ can be reconstructed from its samples without distortion. (4 marks)

Q.4 ANSWER

Q.4 ANSWER ~ continued

SECTION B

Answer ALL questions in this section (Each question carries 20 marks)

Q.5 An audiophile set out to design a speech enhancement system. His initial design, $\tilde{H}_1(s)$, was found to severely distort the original speech. During troubleshooting, he realized that the problem could be corrected by a filter $\tilde{H}_2(s)$. In his prototype design, $\tilde{H}_2(s) = \dfrac{1-s}{1+s}$ and the straight-line Bode magnitude plot of the corrected system $\tilde{H}(s) = \tilde{H}_1(s)\tilde{H}_2(s)$ is shown in Figure Q5.

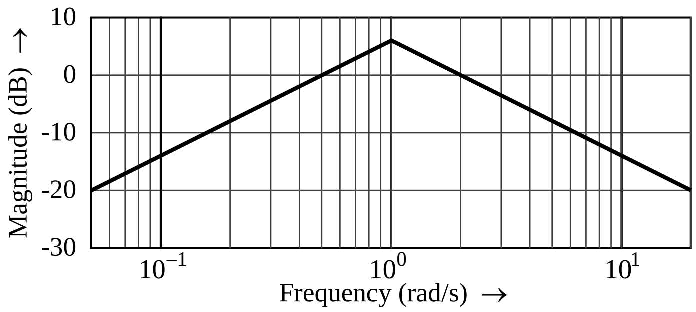


Figure Q5: Bode magnitude plot of $\tilde{H}(s)$

(a) Identify $\tilde{H}(s)$, of which all the poles and zeros are real. (6 marks)

(b) A signal $x(t) = 5\sin(t + 30°)u(t)$ is applied at the input of $\tilde{H}(s)$. Determine the corresponding steady-state output $y_{ss}(t)$. (5 marks)

(c) Determine $\tilde{H}_1(s)$. (3 marks)

(d) Using the semilog-x grids provided in the answer space on Page 13, draw and label the straight-line Bode magnitude and phase plots of $\tilde{H}_2(s)$. State specifically how did $\tilde{H}_2(s)$ correct the initial design problem. (6 marks)

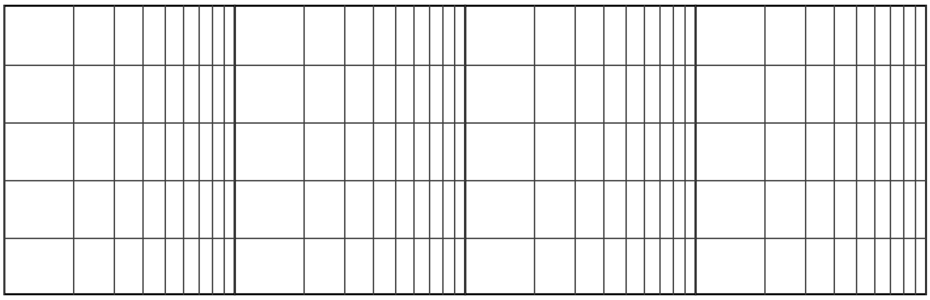
Q.5 ANSWER

Q.5 ANSWER ~ continued

Q.5 ANSWER ~ continued

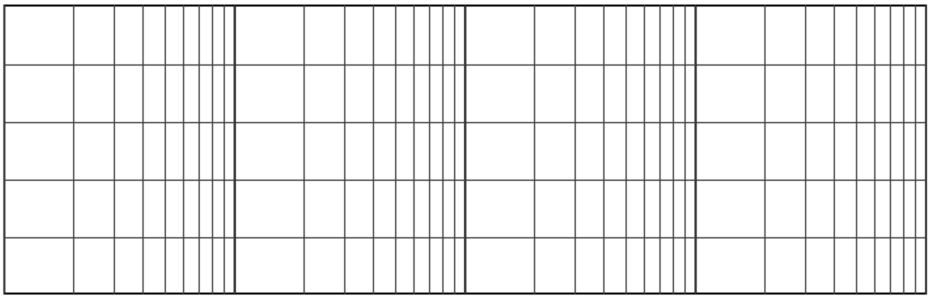
Q.5 ANSWER ~ continued

$\left|\tilde{H}_2(j\omega)\right|_{dB} \uparrow$



$\rightarrow \omega$

$\angle \tilde{H}_2(j\omega)^{\circ} \uparrow$



$\rightarrow \omega$

Q.6 Two friends want to transmit two different messages simultaneously without interference. They decide to use frequency division multiplexing (FDM). The transmitter and receiver of the FDM is shown in Figure Q6, where $x_1(t) = 4sinc(t)$ and $x_2(t) = 8sinc^2(4t)$ are the message signals, B_1 and B_2 are the bandwidths of $x_1(t)$ and $x_2(t)$ respectively.

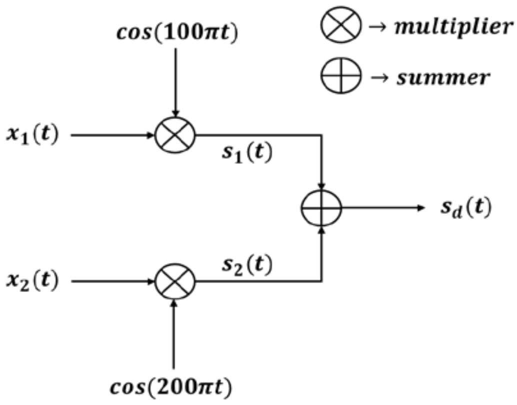


Figure Q6(a): Transmitter

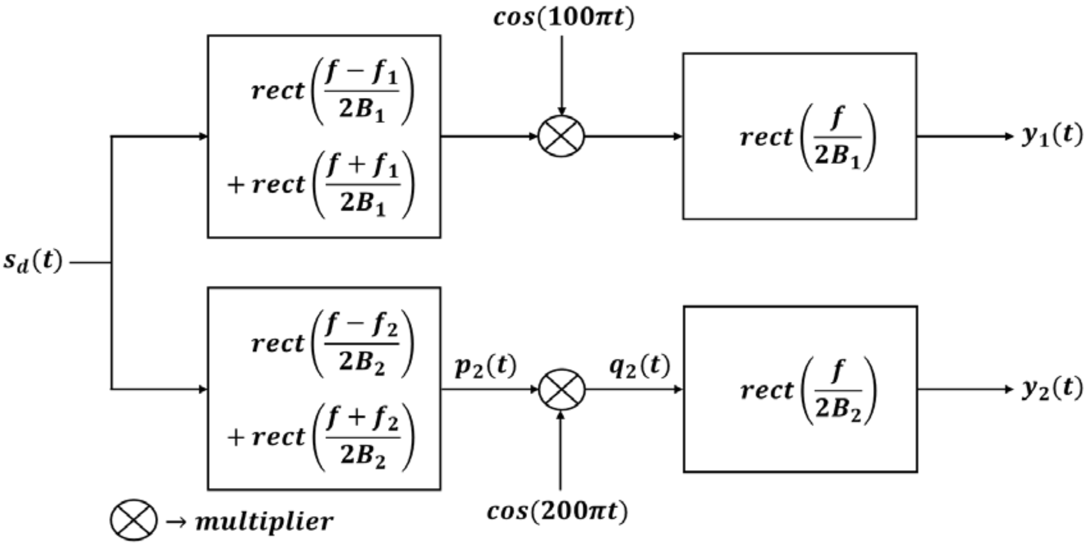


Figure Q6(b): Receiver

(a) Find the spectrum, $S_d(f)$, of the FDM signal $s_d(t)$. (8 marks)

(b) Find the values of B_1 and B_2. What are the centre frequencies, f_1 and f_2 of signals $s_1(t)$ and $s_2(t)$ respectively? (4 marks)

(c) Trace the signal flow through the lower branch of the Figure Q6(b) by sketching the magnitude spectra of $s_d(t)$, $p_2(t)$, $q_2(t)$ and $y_2(t)$. (8 marks)

Q.6 ANSWER

Q.6 ANSWER ~ continued

Q.6 ANSWER ~ continued

Q.6 ANSWER ~ continued

END OF PAPER