[ESS019]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) ELECTRICAL & ELECTRONICS ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

ANALOGUE SIGNAL PROCESSING & COMMUNICATIONS

MODULE NO: EEE5015

Date: Friday 24th May 2019 **Time: 2:00pm – 4:30pm**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached).**

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Question 1.

(a) Using one single equation, define the characteristics of a linear system.

[2 marks]

(b) Estimate the period of signal g(t) given by

$$g(t) = 10\sin(12\pi t) + 4\cos(18\pi t)$$

[5 marks]

(c) Considering the signal shown below in Fig.Q1.1, calculate and draw the value of a new signal described by x(2(t-1)).

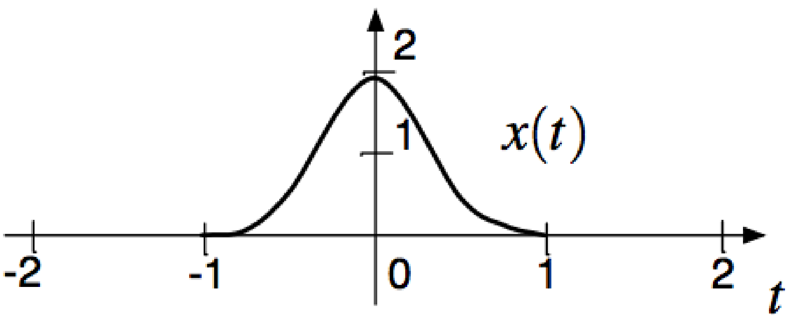

Fig. Q1.1: A signal plot

[8 marks]

(d) Determine if the system described by the equation $y(n)=x(n)\cos(2\pi n)$ is

(i) linear,

(ii) time invariant.

[10 marks]

Total 25 marks

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Question 2

(a) Given x(t) = u(t)-u(t-3) and h(t) = u(t)-u(t-2),

(i) Draw the two signals,

[5 marks]

(ii) Evaluate the convolution y(t)=x(t)*h(t) either by analytical or graphical method.

Hint: y(t)=x(t)*h(t) = $\int_0^t x(\tau)h(t-\tau)d\tau$

[10 marks]

(b) Find the signal power of x(t) = Acos(2πft+θ), where f is the frequency of the signal and θ is the phase shift.

Hints: The average power Px is given by

$$Px = \lim_{T\to\infty} \frac{1}{T} \int_{-T}^{T} |x(t)|^2 dt$$

$$\cos(x)\cos(y) = \frac{1}{2}[\cos(x-y) + \cos(x+y)]$$

[10 marks]

Total 25 marks

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Question 3

(a) An active first order, low-pass filter can be constructed using a combination of op-amp, resistors and capacitors as shown in Fig.Q3.1. For this circuit:

(i) Derive the equations for transfer function and cutoff-frequency, f_0 **[10 marks]**

(ii) Now, design a first-order low-pass filter to give a high cutoff frequency of f_o= 1 kHz with a pass-band gain of 4. What is the expected roll-off rate for such filters? Choose C ≤ 1 µF.

[5 marks]

(iii) For the filter constructed in part (ii) above, if the desired frequency is now changed to f_n = 1.5 kHz, calculate the new value of Rn. **[3 marks]**

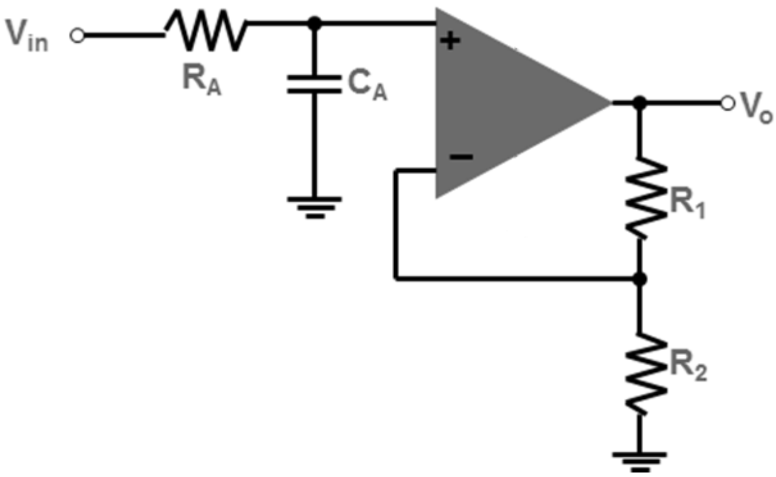

Fig.Q3.1: An operational amplifier circuit

Q3 continues over the page…

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Q3 continued…

(b) A generic Sallen-Key filter topology can be depicted by circuit shown in Fig.Q3.2.

(i) For this circuit assuming the op-amp to be an ideal one, determine the critical frequency of the filter shown in Fig Q3.2 with values of R=10 kΩ, C=0.2 μF and R2=1 kΩ.

[4 marks]

(ii) What should be the value of R1 for an approximate Butterworth response? What is the expected roll-off rate for such a filter? **[3 marks]**

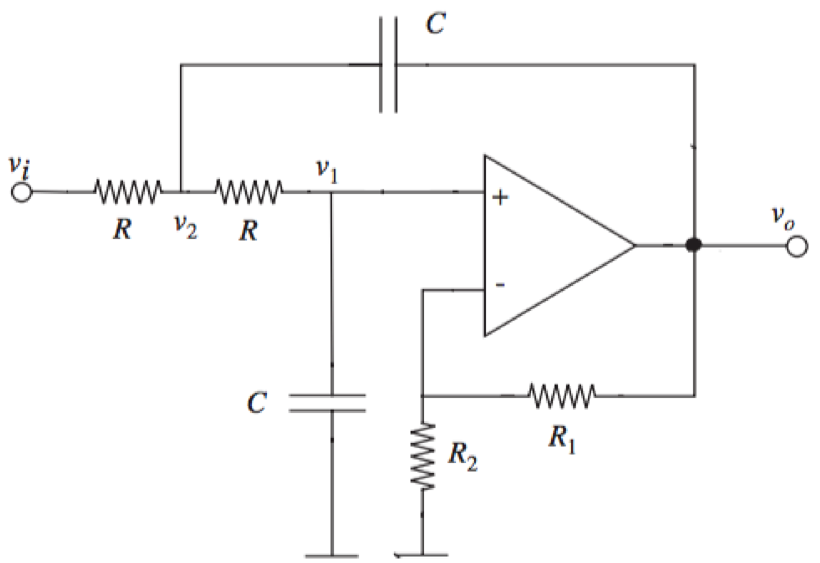

Fig.Q3.2: A Generic Sallen-Key filter

Total 25 marks

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Question 4:

a) A Linear Time Invariant (LTI) system is specified by the following equation

$$(D^2 + 4D + 4)y(t) = Df(t)$$

(i) Find the characteristic polynomial, characteristic equation, characteristic roots and characteristic modes of this system.

[5 marks]

(ii) Find $y_0(t)$, the zero-input component of the response y(t) for t≥0, subject to the initial conditions y(0)= 3 and y'(0)= -4.

[5 marks]

b) Find out the unit impulse response of the system specified by the following equation, subject to initial conditions y(0)=0 and y\`(0)=1:

$$\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 3y(t) = \frac{dx}{dt} + 5x(t)$$

[10 marks]

Q4 continues over the page…

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Q4 continued…

c) The circuit shown below (Fig.Q4c) has a centre frequency of 1 rad/s, bandwidth of 1 rad/s and a Q value of 1. Using scaling laws, compute the values of R and L that yield a circuit with the same Q factor but with a centre frequency of 5 kHz. Assume that a scaled capacitance value of 120 μF is being used in the revised circuit.

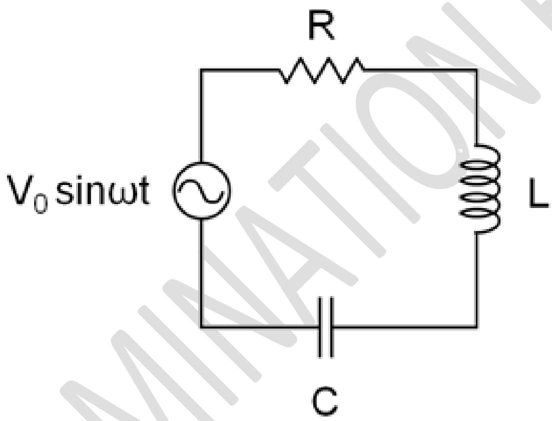

Fig.Q4c: A RLC circuit

[5 marks]

Total 25 marks

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Question 5.

a) Consider the system shown in Fig.Q5.1 with the values of transfer functions being $H_1(s) = \frac{s}{(s+1)(s+a)}$ and $H_2(s) = \frac{b}{s}$

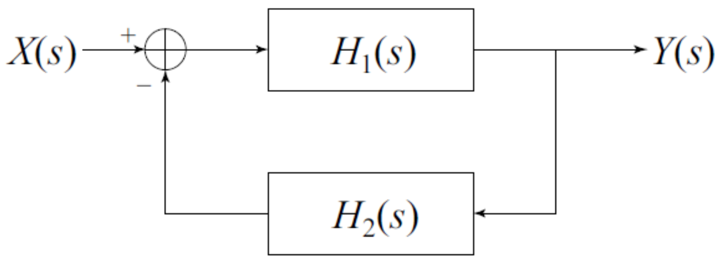

Fig.Q5.1: A close loop block diagram

(i) Determine the values of a and b such that the overall transfer function is given by:

$$H(s) = \frac{s}{(s+4)(s+5)}$$

[10 marks]

(ii) Determine the output y(t) of the system with the above transfer function to the unit step input x(t)=u(t)

[10 marks]

b) A signal has a bandwidth of 10 MHz. This signal is sampled and quantized with an analogue-to-digital converter (ADC).

(i) Determine the sampling rate if the signal is to be sampled at a rate 20% above the Nyquist rate.

[2.5 marks]

Q5 continues over the page…
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(ii) If the samples are quantized into 1024 levels, determine the number of binary pulses required to encode each sample.

[2.5 marks]

Total 25 marks

Question 6:

(a) What is the role of an anti-aliasing filter? For a signal described by the equation $x(t) = 3\cos(100\pi t)$, find out the minimum sampling rate required to avoid aliasing

[5 marks]

(b) Describe the term multiplexing and illustrate two methods that can be used to achieve this.

[7 marks]

(c) Describe the term modulation and explain how it is useful for broadcasting of signals.

[8 marks]

(d) Describe the three basic types of modulation.

[5 marks]

Total 25 marks

END OF QUESTIONS

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FORMULA SHEET

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

$$E_f = \frac{1}{2\pi}\int_{-\infty}^{\infty} |F(\omega)|^2 \, d\omega$$

Butterworth Response Table

ORDER	ROLL-OFF DB/DECADE	1ST STAGE POLES	1ST STAGE DF	1ST STAGE R_1/R_2	2ND STAGE POLES	2ND STAGE DF	2ND STAGE R_3/R_4	3RD STAGE POLES	3RD STAGE DF	3RD STAGE R_5/R_6
1	−20	1	Optional							
2	−40	2	1.414	0.586						
3	−60	2	1.00	1	1	1.00	1			
4	−80	2	1.848	0.152	2	0.765	1.235			
5	−100	2	1.00	1	2	1.618	0.382	1	0.618	1.382
6	−120	2	1.932	0.068	2	1.414	0.586	2	0.518	1.482

Form of the natural response

Root of characteristic equation	**Form of natural response**
Real and distinct root, s_k	$C_k\exp(s_k t)$
Complex conjugate $\beta \pm j\omega$	$[C_1 \cos(\omega t) + C_2 \sin(\omega t)]\exp(\beta t)$
Real repeated root, $(s_k)^p$	$(K1+K_1t+K_2t^2+\ldots..+K_pt^p)\exp(s_kt)$
Complex repeated roots $(\beta \pm j\omega)^p$	$(C_0+C_1t+C_2t^2+\ldots.+C_pt^p)\text{cost}(\omega t)\exp(\beta t)+$ $(D_0+D_1t+D_2t^2+\ldots\ldots+D_pt^p)\sin(\omega t)\exp(\beta t)$

Form of the forced response

Forcing Function	**Form of forced response**
C (constant)	C_1 (constant)
exp(-αt), α≠root of characteristic equation	Kexp(-αt)
t	K_0+K_1t
t^p	$K_0+K_1t+K_2t^2+\ldots..+K_pt^p$
texp(-αt)	$(K_0+K_1t)\exp(-\alpha t)$
$t^p\exp(-\alpha t)$	$(K_0+K_1t+K_2t^2+\ldots..+K_pt^p)\exp(-\alpha t)$

END OF FORMULA SHEET

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