Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2012-13 (3.0 hours)

EEE224 Communication Electronics 2

Answer **TWO** questions from **SECTION A** and **TWO** questions from **SECTION B**. **No marks will be awarded for solutions to a fifth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

SECTION A

1. **a.** Describe the two properties of a linear system. **(2)**

Are the two functions below linear? Show your working.

$$y(t) = K\frac{dx(t)}{dt}, \quad \text{where } K \text{ is a constant.}$$

$$y(t) = 4x(t) + 7$$ **(4)**

b. Figure Q1 shows a periodically repeating “saw tooth” waveform.

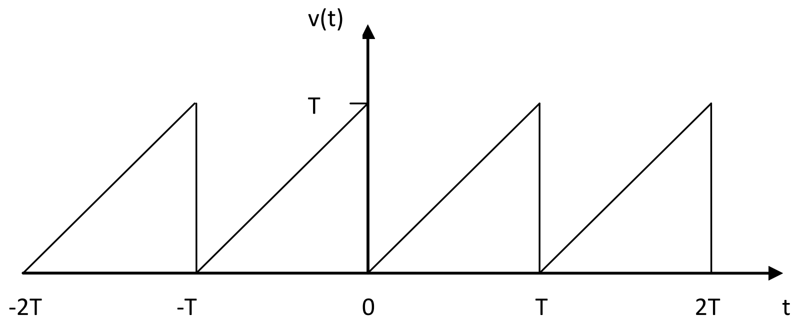

Figure Q1

Derive equations for the trigonometric Fourier series coefficients for the signal v(t) in Figure Q1.

Write down an expression for the Fourier series representation of v(t). **(10)**

c. Sketch and label the amplitude spectrum, up to the 4^{th} harmonic, for the signal v(t) in Figure Q1. **(4)**

2. **a.** With the aid of diagrams, describe the Nyquist sampling theorem, and show that the Nyquist sampling rate is given as

$$T_s \leq \frac{1}{2f_m}$$

where T_s is the maximum sampling time period needed to accurately reconstitute an input signal, which has a maximum frequency of f_m. **(8)**

Explain the term “aliasing”. **(2)**

b. Several audio signals are to be simultaneously transmitted over a radio link using time division Pulse Width Modulation (PWM). Using the information given below, calculate the maximum number of audio signals that can be transmitted simultaneously.

- When the audio signals are applied to the PWM circuitry, the pulse width varies at a rate of 0.1μs/V.
- Audio signal voltage range = 0-10V
- Audio signal maximum frequency = 20kHz
- Minimum pulse width = 0.4μs
- Minimum adjacent channel pulse separation = 0.2μs

(8)

Approximate the maximum bandwidth of the PWM signal described above. **(2)**

3. **a.** Explain why modulation is used in communication systems. **(4)**

b. Using a block diagram, explain how stereo audio signals with independent left and right channels are transmitted in FM broadcast systems without losing compatibility with mono systems. Include a sketch of the spectrum of the composite broadcast signal.

(8)

c. Figure Q3 shows a block diagram of an FM Armstrong modulator.

Calculate the values of n_1 and n_2 for the frequency multiplier circuits, given the information below.

- Carrier frequency of the "FM signal" output = 100MHz
- Minimum frequency deviation of the "FM signal" output = 75kHz
- Baseband signal frequency range =100 Hz to 15kHz
- Modulation index of the "Narrowband phase modulator" = 0.2 radians

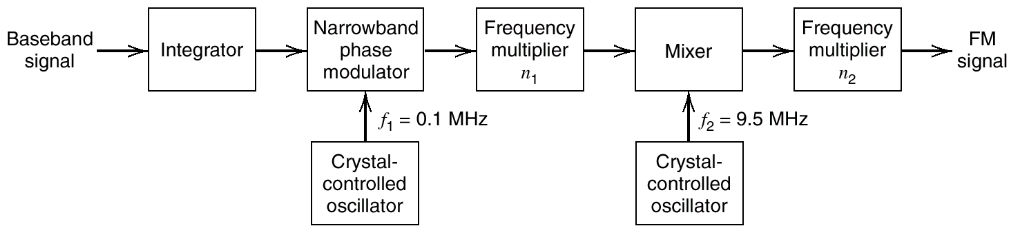

Figure Q3 **(8)**

SECTION B

4. **a.** Write down the high-frequency and low-frequency gains of the circuit in Figure Q4-a in terms of the relevant circuit components.

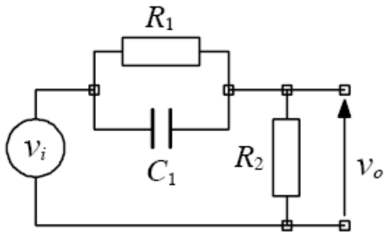

Figure Q4-a **(2)**

b. Write down the standard-form transfer function of the circuit in Figure Q4-a. **(5)**

c. Using a decibel (dB) scale for gain and a logarithmic scale for frequency, sketch the amplitude response of the circuit in Figure Q4-a. Label the high and low frequency gains, the corner frequencies, and the slope of any gradient. **(5)**

d. For the circuit in Figure Q4-d, if R_1 = 2kΩ, R_2 = 10kΩ, C = 100nF, and v_i is a step input changing from −2V to +2V at t = 0, sketch the shape of v_o in response to the step input. Label the values of v_o at $t = 0^-$, $t = 0^+$ and $t \Rightarrow \infty$, and give the value of the response time constant.

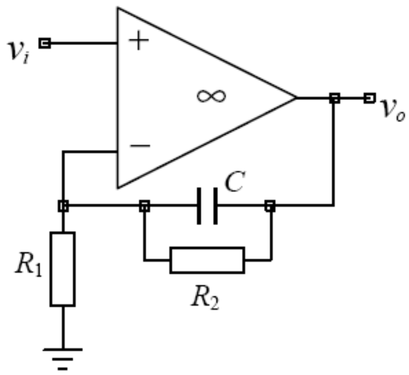

Figure Q4-d **(8)**

5. **a.** For the circuit in Figure Q5, show that

$$v_o = \frac{2v_i}{sRC}.$$

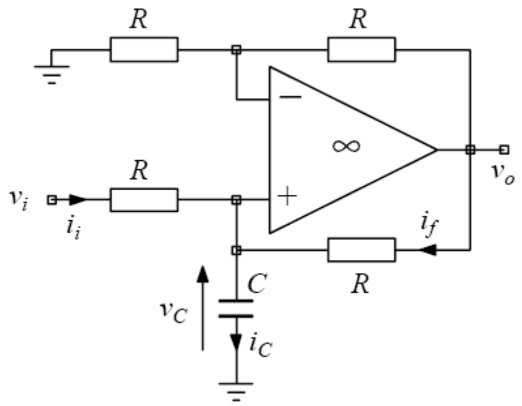

Figure Q5 **(6)**

b. A system has the following transfer function:

$$H(s) = \frac{1}{s^2 + 6s + 13}.$$

Determine the poles, the natural frequency and the damping factor of this system, and state the nature of the system response. **(5)**

c. Determine the Laplace transform of the following signal, and sketch the pole-zero plot and region of convergence (if it exists).

$$x(t) = e^{-3|t|}$$ **(7)**

d. Define the concept of gain-bandwidth product (GBP) of an operational amplifier. **(2)**

6. **a.** Work out the standard-form transfer function of the circuit in Figure Q6, and identify the type of response that the circuit produces.

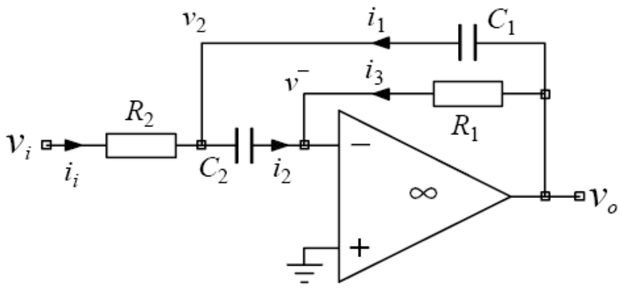

Figure Q6

(7)

b. In Figure Q6, if $C_1 = C_2$ and $R_1 = 4R_2$, compute the value of the quality factor q and the circuit gain at the undamped natural frequency. **(6)**

c. Compute the impulse response and the step response (for a unit step input) of a system with its transfer function given by

$$H(s) = \frac{s}{2s^2 + 10s + 12}.$$

(7)

USEFUL INFORMATION

Fourier series:

$$f(t) = a_0 + \sum_{n=1}^{N}\left[a_n \cos\left(\frac{2n\pi t}{T}\right) + b_n \sin\left(\frac{2n\pi t}{T}\right)\right]$$

$$a_0 = \frac{1}{T}\int_{-T/2}^{T/2} f(t)dt$$

$$a_n = \frac{2}{T}\int_{-T/2}^{T/2} f(t)\cos\left(\frac{2\pi nt}{T}\right)dt$$

$$b_n = \frac{2}{T}\int_{-T/2}^{T/2} f(t)\sin\left(\frac{2\pi nt}{T}\right)dt$$

Trigonometric identities:

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

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

$$\sin(x+y) = \sin(x)\cos(y) + \cos(x)\sin(y)$$

Integration by parts:

$$\int_b^a u\frac{dv}{dx}dx = \left[uv\right]_b^a - \int_b^a v\frac{du}{dx}dx$$

USEFUL INFORMATION

$i(t) = C\dfrac{dv(t)}{dt}$ $\quad v(t) = L\dfrac{di(t)}{dt}$ $\quad v(t) = i(t)R$ $\quad V(t) = (V_{start} - V_{finish})e^{-t/\tau} + V_{fini}$

$v_o = A_v(v^+ - v^-)$ $\quad A_v = \dfrac{A_0}{1 + j\dfrac{\omega}{\omega_0}}$ $\quad \zeta = \dfrac{1}{2q}$

$\omega = 2\pi f$ $\quad s = j\omega$ $\quad X(s) = \int_{-\infty}^{\infty} x(t)e^{-st}dt$ $\quad x(t) = \dfrac{1}{j2\pi}\int_{c-j\infty}^{c+j\infty} X(s)e^{st}dt$

Second-order standard forms:

$$\frac{v_o}{v_i} = k\frac{1}{1 + \dfrac{s}{\omega_0 q} + \dfrac{s^2}{\omega_0^2}} \qquad \frac{v_o}{v_i} = k\frac{\dfrac{s}{\omega_0 q}}{1 + \dfrac{s}{\omega_0 q} + \dfrac{s^2}{\omega_0^2}} \qquad \frac{v_o}{v_i} = k\frac{\dfrac{s^2}{\omega_0^2}}{1 + \dfrac{s}{\omega_0 q} + \dfrac{s^2}{\omega_0^2}}$$

Laplace Transform Pairs		Laplace Transform Properties
Signal	Transform	
$\delta(t)$	1	$x(t)e^{s_o t} \leftrightarrow X(s - s_o)$
$u(t)$	$\dfrac{1}{s}$	$\dfrac{dx(t)}{dt} \leftrightarrow sX(s) - x(0)$
$tu(t)$	$\dfrac{1}{s^2}$	$\int_{-\infty}^{t} x(\tau)d\tau \leftrightarrow \dfrac{1}{s}X(s)$
$e^{-at}u(t)$	$\dfrac{1}{s+a}$	$x(t - t_o)u(t - t_o) \leftrightarrow X(s)e^{-st_o}$, $t_o > 0$

Unit multipliers:

p = $\times 10^{-12}$, n = $\times 10^{-9}$, μ = $\times 10^{-6}$, m = $\times 10^{-3}$, k = $\times 10^{3}$, M = $\times 10^{6}$, G = $\times 10^{9}$

All the symbols have their usual meanings.

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