**Data Provided: None**

The University Of Sheffield.

**DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING**

**Spring Semester 2014-15 (3.0 hours)**

**EEE224 Communication Electronics**

Answer **FOUR** questions. **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.**

**1.** **a.** Describe what is meant by a causal system?

Describe what is meant by a system which is memoryless?

Which of the following, time varying, functions have memory? Also state if the functions are causal. **(5)**

i. $x(t) = sin(2t^2)$
ii. $x(t) = e^{t-1}\cos(t+2)$
iii. $x(t) = u(t-2)\tan(1/t)$

**b** Derive an analytical expression for the following convolution

$$y(t) = x(t) * f(t) * \mathrm{g(t)} \qquad \mathrm{t} \geq 0$$
$$\mathrm{y(t)} = 0 \qquad \mathrm{t} < 0$$

**(4)**

Given, $x(t) = t^3$, $f(t) = t$ and $g(t) = t$

**c** Figure Q1 shows a periodic time varying function. Derive an expression for the Fourier series of the function and plot the frequency spectrum for the first 4 frequency components. **(11)**

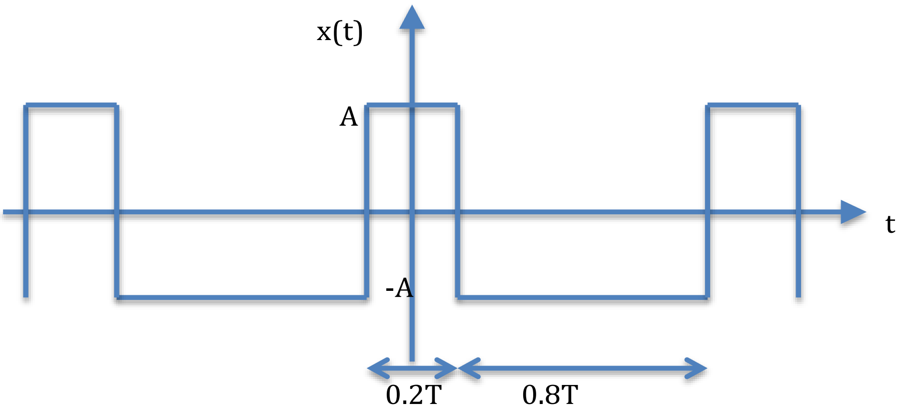



Figure Q1

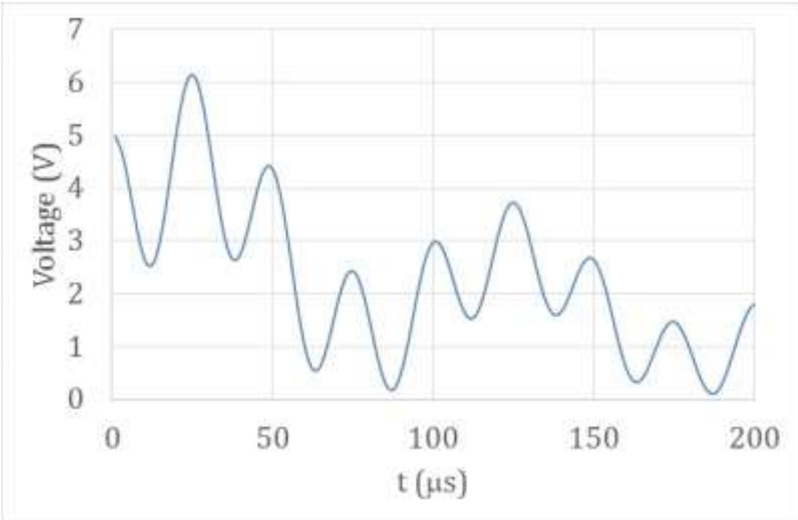
**2.** **a.** State four reasons why modulation is used in communications systems. **(4)**

**b** If a communication channel has a bandwidth of 20MHz and the signal to noise ratio at the receiver is 30dB, calculate the maximum capacity (bit/s) of the channel. **(6)**

If the bandwidth of the channel is doubled calculate the new maximum capacity.

**c** Figure Q2 shows a time continuous voltage waveform which is to be transmitted using Pulse Code Modulation (PCM). The following requirements for the PCM signal are given below.

- Maximum frequency of voltage waveform = 10kHz
- Signal sampling frequency = Nyquist frequency
- Number of quantization levels required = 8




**(10)**

Figure Q2

Calculate:-

i. The sampling frequency required.
ii. The number of bits to encode each quantized sample.
iii. The data rate of the PCM signal

Using Figure Q2 write down the binary form of the PCM signal (assume the first sample is at t=0).

**3.** **a.** Draw a system diagram of a dual conversion superhet receiver, including Automatic Gain Control (AGC) and explain the operation of each element of the system. **(7)**

**b** A dual frequency conversion superhet receiver is designed to receive Radio Frequency (RF) signals at a frequency of 420MHz. The 1st and 2nd stage Intermediate Frequencies (IF) are 60MHz and 455kHz respectively. The 1st stage Local Oscillator (LO) frequency is above the RF frequency and the 2nd stage LO frequency is below the 1st stage IF frequency. Calculate the following. **(6)**

i. The 1st stage LO frequency
ii. The 2nd stage LO frequency
iii. The image frequency associated with the 1st stage mixer
iv. The image frequency associated with the 2nd stage mixer
v. The frequencies of other possible signals that will cause 2nd stage mixer problems

**c** A single stage superhet receiver has a LO frequency of 100MHz and an IF of 455kHz, the RF is above the LO frequency. The input to the mixer has a bandpass filter to reduce the interference caused by possible signals at the image frequency of the mixer, the Q factor of the filter is 40. Calculate the following. **(4)**

i. The RF frequency that the receiver is tuned to.
ii. The Image Frequency Rejection Ratio (IFRR), in dB, of the bandpass filter.

**d** State two methods for increasing the IFRR. Which of the two methods is easiest to implement from a practical perspective? **(3)**

**4.** **a.** Find the standard-form transfer function, $v_o/v_i$, of the circuit in Figure Q4.a, and specify the corner frequency, the frequency independent gain, and the type of response that the circuit produces.

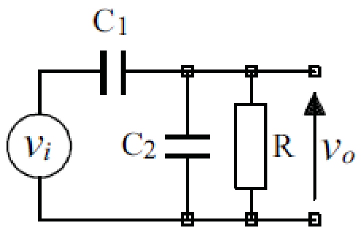



**Figure Q4.a** **(10)**

**b.** The circuit in Figure Q4.b has a high frequency gain of 10V/V, a pole frequency of 10Hz, and a zero frequency of 500Hz. Find the values of $R_2$, $R_3$ and $C$ for the circuit.

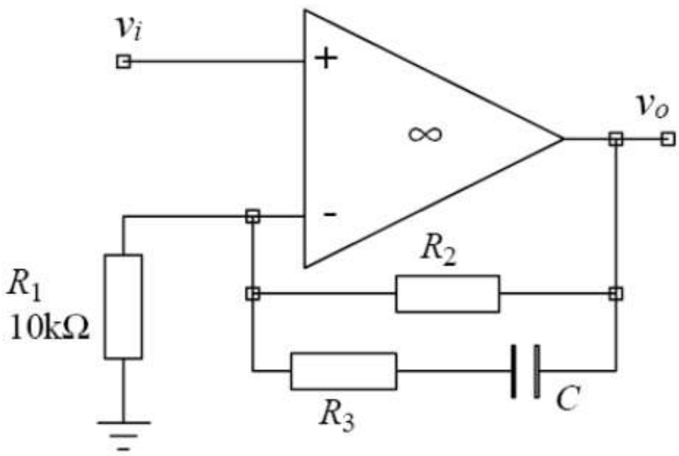



**Figure Q4.b** **(10)**

**5.** **a.** Compute the step response (for a unit step input) of a system with the following transfer function:

$$H(s) = \frac{s}{3s^2 + 9s + 6}.$$ **(8)**

**b.** **i)** Work out the standard-form transfer function of the circuit in Figure Q5.b, and identify its type of response. **(8)**

**ii)** If $C_1 = C_2$ and the quality factor $q = 3$, find the ratio between $R_1$ and $R_2$.

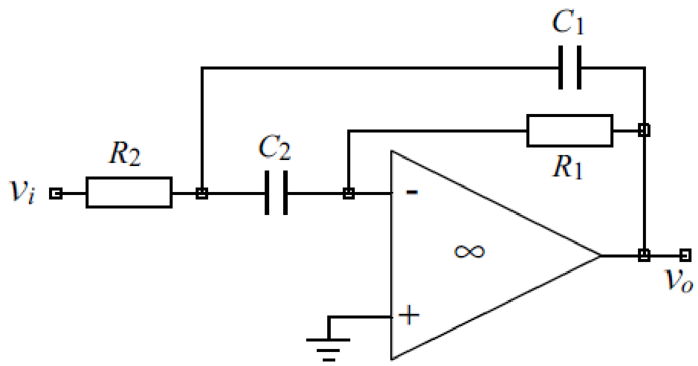



**Figure Q5.b** **(4)**

**6.** **a.** An oscilloscope is used to examine a circuit. The cable connecting the oscilloscope probe to the circuit is very long and has a characteristic impedance of 46Ω. What load does the oscilloscope probe add to the circuit?

**(3)**

**b.** In Figure Q6.b, the 144V voltage source has an internal resistance of 100Ω, the load resistance is also 100Ω, and the characteristic impedance of the line is 50Ω. It takes 1μs for a wave to travel down the line. If the switch is closed at $t$ = 0, plot the load voltage with time for 5μs.

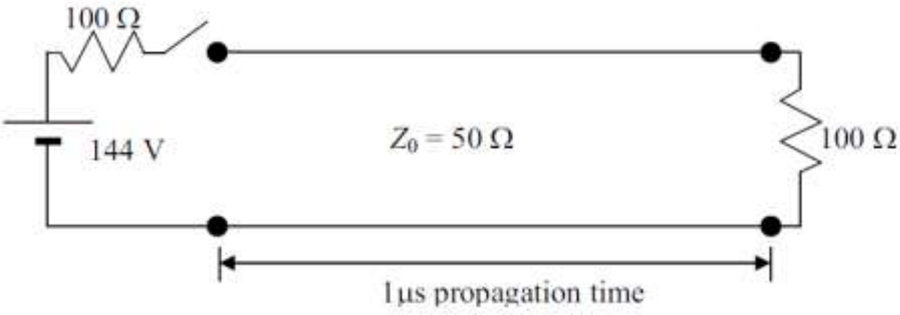



**Figure Q6.b**

**(9)**

**c.** In Figure Q6.c, the source has a voltage of 100V, and the transmission line has a characteristic impedance of 25Ω. It takes 1μs for a wave to travel down the line. Plot the current flowing through the short circuit for 5μs after the switch is closed at $t$ = 0.

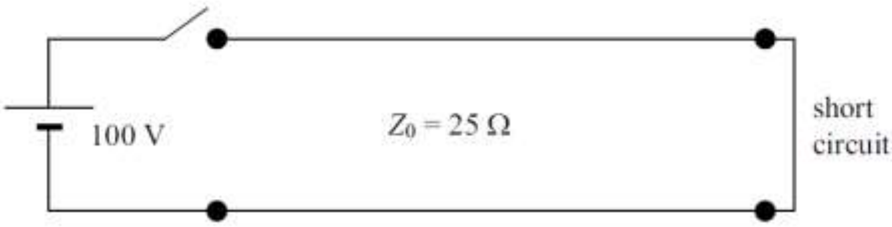



**Figure Q6.c**

**(8)**

## USEFUL INFORMATION

Convolution: $$x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$$

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

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

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

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

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

$$v_o = A_v(v^+ - v^-) \qquad A_v = \frac{A_0}{1 + j\frac{\omega}{\omega_0}} \qquad \zeta = \frac{1}{2q} \qquad \lambda = \frac{v}{f} \qquad k = \frac{2\pi}{\lambda}$$

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

$$Z_0 = \sqrt{\frac{L}{C}} \qquad v = \sqrt{\frac{1}{LC}} \qquad \rho_L = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \rho_g = \frac{Z_g - Z_0}{Z_g + Z_0}$$

Second-order standard forms:

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

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

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.

**LF/XC/MB**