Data Provided:

Useful information at end of paper

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2015-16 (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.** Briefly explain what is meant by a "stable" system. **(2)**

b. For the following time continuous functions, y(t), state if the function is "stable" or "not stable" assuming that the input signal, x(t), is a bounded signal.

i. $y(t)=tx(t)$
ii. $y(t)=\sin(tx(t))$
iii. $y(t)=e^{-tx(t)}$
iv. $y(t)= e^{tx(t)}$ **(4)**

c. Derive an expression for the output signal, y(t) of an Linear Time Invariant (LTI) system, with impulse response h(t), in response to the input signal x(t). Show all your workings. Both x(t) and h(t) are depicted in Figure Q.1 **(10)**

d. Sketch a graph of the output waveform, y(t), from part c. **(4)**

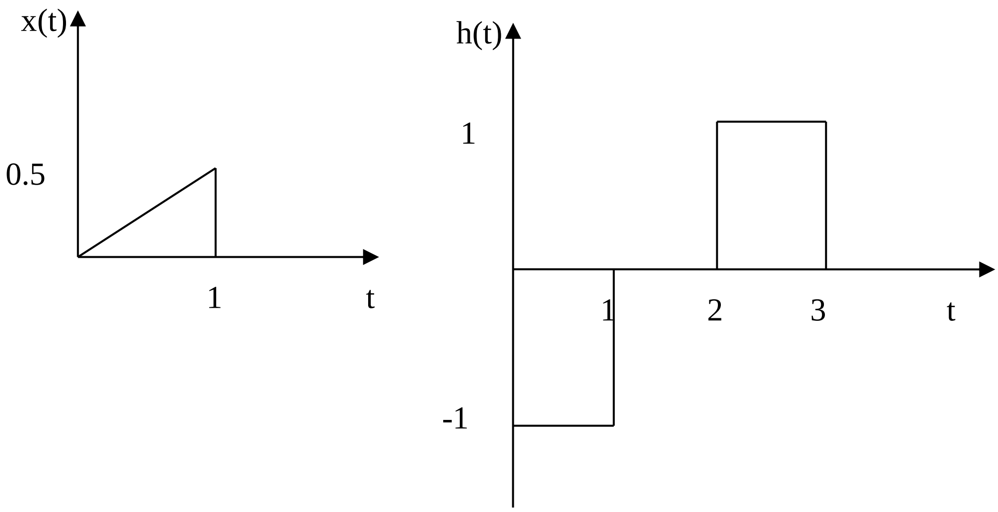

Figure Q1

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

b. The equation below describes an FM modulated signal where the terms have their usual definitions. The FM signal is input to an antenna which can be assumed to be equivalent to a 50Ω resistor.

$$V_{FM} = 5cos\left(\omega_c t + 4.4cos(\omega_m t)\right)$$

Where f_c=100MHz and f_m=2MHz

Calculate the following

i. The average power dissipated in the antenna.
ii. The modulation index of the FM signal.
iii. The maximum frequency deviation of the FM signal.
iv. The average power at the carrier frequency. **(8)**

c. i. Sketch the frequency spectrum of an FM signal whose maximum voltage is 1V, modulation index β=2.1, carrier frequency is 200MHz and baseband signal frequency is 1MHz. Plot up to the first five sidebands and label the amplitude and frequency of each sideband. **(6)**

ii. Calculate the bandwidth of the signal in part c(i) assuming any sideband with an amplitude less than 0.01 of the unmodulated carrier can be ignored. **(2)**

3. **a.** State the Hartley Shannon law and define the quantities within it. **(4)**

b. A signal has a bandwidth of 20kHz and the signal to noise ratio at the receiver is 30dB, calculate:

i. The maximum channel capacity
ii. The maximum capacity if the signal bandwidth is halved. **(6)**

c. Explain what is meant by the term "multiplexing".
Describe how a Frequency Division Multiplexing (FDM) system operates, including the transmitter and receiver elements. **(5)**

d. A coaxial cable passes frequencies in the range 0 to 45 MHz. Determine the maximum number of music channels, each 20 kHz wide, that can be transmitted down the cable via a frequency division multiplexed system using single sideband suppressed carrier techniques. Assume that guard bands of 4 kHz exist between adjacent channels. **(3)**

e. Comment on what you would expect if in part (d) a time division multiplexed PCM system was used. **(2)**

4. **a.** **i)** What are the conditions required for a circuit with a closed feedback loop to oscillate? **(4)**

ii) What type of input is required for an oscillator? **(2)**

b. In the circuit shown in Figure Q4.b, R = 1kΩ, R_2 = 100kΩ, and C = 0.015μF.

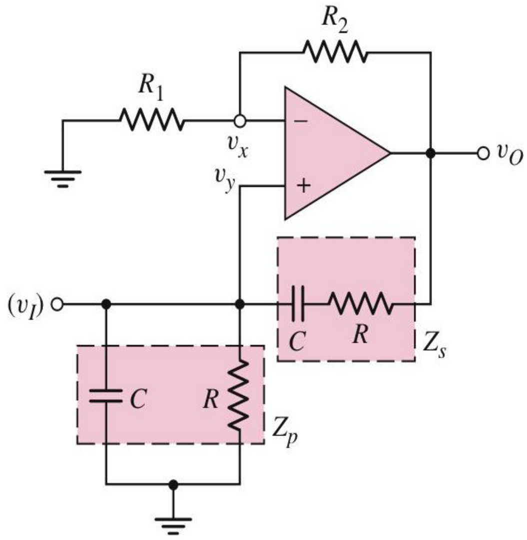

Figure Q4.b

i) Determine the necessary value of R_1 so that the circuit will oscillate. **(3)**

ii) What kind of oscillator will this circuit be? **(1)**

iii) Find the frequency of oscillation. **(3)**

c. In the circuit shown in Figure Q4.c, R = 4.7kΩ, and C = 0.02μF.

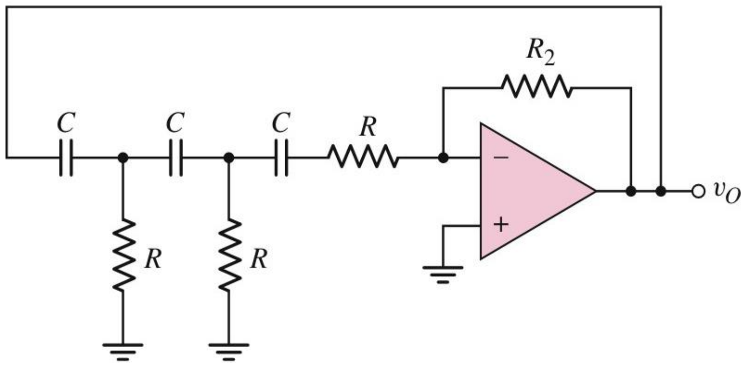

Figure Q4.c

i) Determine the value of R_2 necessary for the circuit to oscillate. **(3)**

ii) What kind of oscillator will this circuit be? **(1)**

iii) Find the frequency of oscillation. **(3)**

5. **a.** The input signal $x(t)$ and the output signal $y(t)$ of an RC circuit are related by the following equation. Under zero initial conditions, find the expressions of the system transfer function $H(s)$ and the impulse response $h(t)$.

$$\frac{dy(t)}{dt} + \frac{1}{RC}y(t) = \frac{1}{RC}x(t)$$ **(4)**

b. **i)** Define the voltage standing wave ratio (VSWR). **(2)**

ii) Give the conditions under which the propagation losses along a transmission line can be minimized. **(2)**

c. Figure Q5.c shows a transmission line circuit with a source resistance of 150Ω and a load resistance of 0Ω. The characteristic impedance of the transmission line is 50Ω and the transition time along the line is 2μs. A single 100V pulse of duration 6μs is applied to the transmission line. Sketch and label a graph of the voltage, V_{in}, at the line input for the first 15μs.

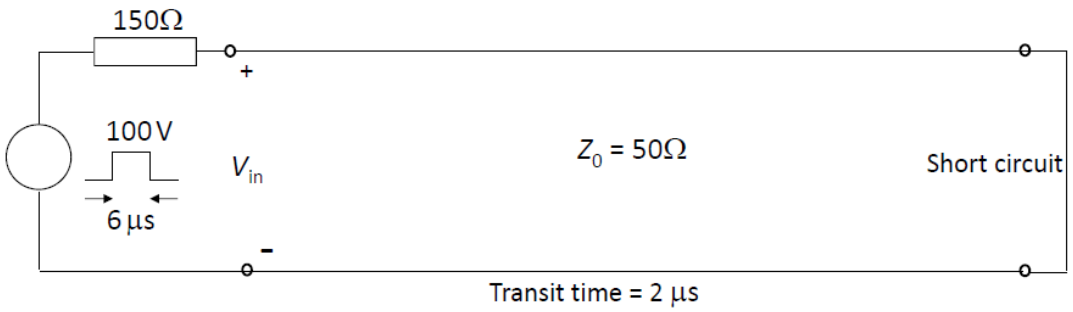

Figure Q5.c **(12)**

6. **a.** **i)** Find the high frequency gain and the low frequency gain of the circuit shown in Figure Q6.a in terms of the circuit components.

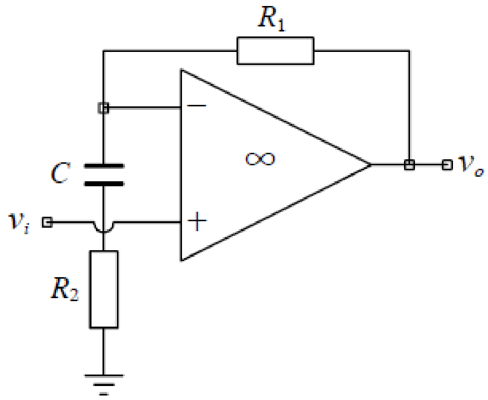

Figure Q6.a **(4)**

ii) Find the standard-form transfer function, v_o/v_i, of the circuit in Figure Q6.a. **(5)**

iii) Which four of the following terms can be applied correctly to the circuit in Figure Q6.a or its transfer function? (*Note that only the first four terms in your answer will be marked.*)

"First order"	"Digital"	"High pass"	"Band pass"	"Second order"
"Passive"	"Low pass"	"Active"	"Analogue"	"Pole zero"

(2)

b. **i)** The amplifier in Figure Q6.b has an infinite input resistance, zero output resistance, infinite bandwidth, and a well-defined gain $v_o/v_b = 2$. Find the standard-form transfer function, v_o/v_i, for the circuit of Figure Q6.b.

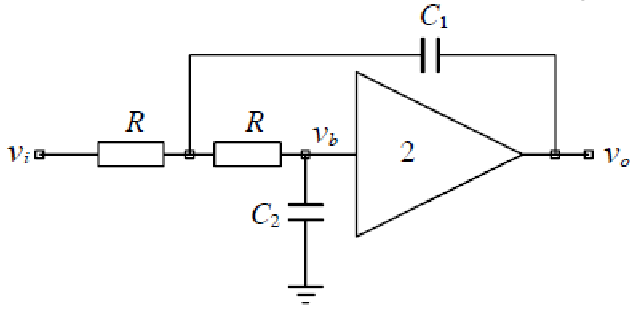

Figure Q6.b **(6)**

ii) From the transfer function of the circuit in Figure Q6.b, find the expressions of the frequency-independent constant k, the undamped natural frequency ω_0, and the quality factor q. **(3)**

USEFUL INFORMATION

Convolution

$$x[n] = \sum_{k=-\infty}^{\infty} x[k]\delta[n-k] \qquad\qquad x(t) = \int_{-\infty}^{\infty} x(\tau)\delta(t-\tau)d\tau$$

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

Bessel functions

β	$J_0(β)$	$J_1(β)$	$J_2(β)$	$J_3(β)$	$J_4(β)$	$J_5(β)$		β	$J_0(β)$	$J_1(β)$	$J_2(β)$	$J_3(β)$	$J_4(β)$	$J_5(β)$
0.0	1.000	0.000	0.000	0.000	0.000	0.000		3.0	-0.260	0.339	0.486	0.309	0.132	0.043
0.1	0.998	0.050	0.001	0.000	0.000	0.000		3.1	-0.292	0.301	0.486	0.326	0.146	0.049
0.2	0.990	0.100	0.005	0.000	0.000	0.000		3.2	-0.320	0.261	0.484	0.343	0.160	0.056
0.3	0.978	0.148	0.011	0.001	0.000	0.000		3.3	-0.344	0.221	0.478	0.359	0.174	0.064
0.4	0.960	0.196	0.020	0.001	0.000	0.000		3.4	-0.364	0.179	0.470	0.373	0.189	0.072
0.5	0.938	0.242	0.031	0.003	0.000	0.000		3.5	-0.380	0.137	0.459	0.387	0.204	0.080
0.6	0.912	0.287	0.044	0.004	0.000	0.000		3.6	-0.392	0.095	0.445	0.399	0.220	0.090
0.7	0.881	0.329	0.059	0.007	0.001	0.000		3.7	-0.399	0.054	0.428	0.409	0.235	0.099
0.8	0.846	0.369	0.076	0.010	0.001	0.000		3.8	-0.403	0.013	0.409	0.418	0.251	0.110
0.9	0.808	0.406	0.095	0.014	0.002	0.000		3.9	-0.402	-0.027	0.388	0.425	0.266	0.121
1.0	0.765	0.440	0.115	0.020	0.002	0.000		4.0	-0.397	-0.066	0.364	0.430	0.281	0.132
1.1	0.720	0.471	0.137	0.026	0.004	0.000		4.1	-0.389	-0.103	0.338	0.433	0.296	0.144
1.2	0.671	0.498	0.159	0.033	0.005	0.001		4.2	-0.377	-0.139	0.311	0.434	0.310	0.156
1.3	0.620	0.522	0.183	0.041	0.007	0.001		4.3	-0.361	-0.172	0.281	0.433	0.324	0.169
1.4	0.567	0.542	0.207	0.050	0.009	0.001		4.4	-0.342	-0.203	0.250	0.430	0.336	0.182
1.5	0.512	0.558	0.232	0.061	0.012	0.002		4.5	-0.321	-0.231	0.218	0.425	0.348	0.195
1.6	0.455	0.570	0.257	0.073	0.015	0.002		4.6	-0.296	-0.257	0.185	0.417	0.359	0.208
1.7	0.398	0.578	0.282	0.085	0.019	0.003		4.7	-0.269	-0.279	0.151	0.407	0.369	0.221
1.8	0.340	0.582	0.306	0.099	0.023	0.004		4.8	-0.240	-0.298	0.116	0.395	0.378	0.235
1.9	0.282	0.581	0.330	0.113	0.028	0.006		4.9	-0.210	-0.315	0.081	0.381	0.385	0.248
2.0	0.224	0.577	0.353	0.129	0.034	0.007		5.0	-0.178	-0.328	0.047	0.365	0.391	0.261
2.1	0.167	0.568	0.375	0.145	0.040	0.009		5.1	-0.144	-0.337	0.012	0.347	0.396	0.274
2.2	0.110	0.556	0.395	0.162	0.048	0.011		5.2	-0.110	-0.343	-0.022	0.327	0.398	0.287
2.3	0.056	0.540	0.414	0.180	0.056	0.013		5.3	-0.076	-0.346	-0.055	0.305	0.400	0.299
2.4	0.003	0.520	0.431	0.198	0.064	0.016		5.4	-0.041	-0.345	-0.087	0.281	0.399	0.310
2.5	-0.048	0.497	0.446	0.217	0.074	0.020		5.5	-0.007	-0.341	-0.117	0.256	0.397	0.321
2.6	-0.097	0.471	0.459	0.235	0.084	0.023		5.6	0.027	-0.334	-0.146	0.230	0.393	0.331
2.7	-0.142	0.442	0.470	0.254	0.095	0.027		5.7	0.060	-0.324	-0.174	0.202	0.387	0.340
2.8	-0.185	0.410	0.478	0.273	0.107	0.032		5.8	0.092	-0.311	-0.199	0.174	0.379	0.349
2.9	-0.224	0.375	0.483	0.291	0.119	0.037		5.9	0.122	-0.295	-0.222	0.145	0.369	0.356

USEFUL INFORMATION

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

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

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

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

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

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