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The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2013-14 (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. i) Describe the two characteristics of a linear system.

ii) Describe the characteristic of a time invariant system. **(3)**

b. The output of a linear time invariant (LTI) system, y(t), when subjected to an input signal, x(t), is shown in Figure 1.1.

Sketch a graph of the output signal versus time when the LTI system has an input signal, $x_1(t)$, as shown in Figure 1.2.

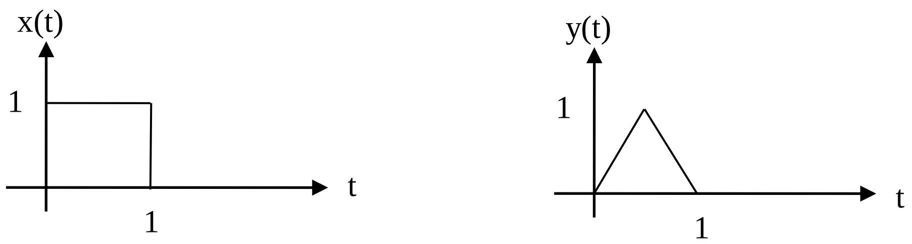


Figure 1.1 **(5)**

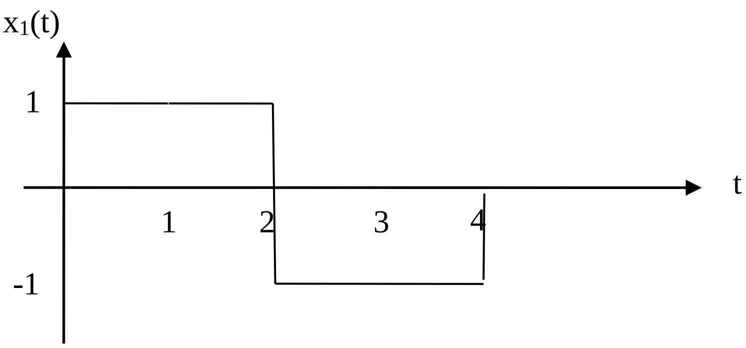


Figure 1.2

c. A linear time invariant (LTI) system has an impulse response, h(t), shown in Figure 1.3.

Using a graphical method sketch and label a graph of the output of the system, y(t), versus time when an input signal, x(t), shown in Figure 1.3, is applied to the LTI system.

Show all your working.

(12)

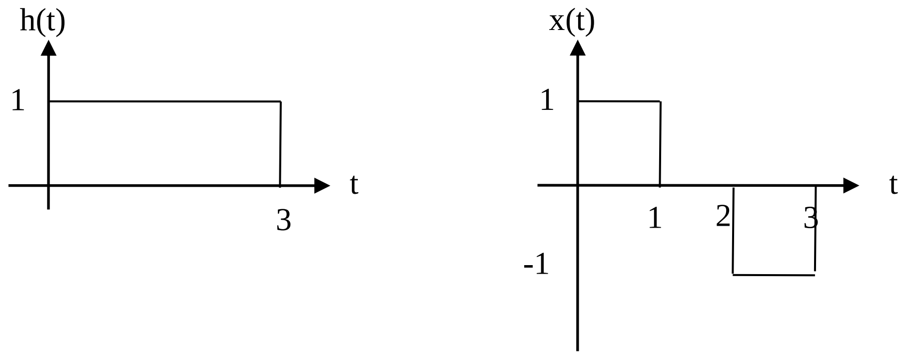


Figure 1.3

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

b. The equation below gives the standard form of an AM DSB CP modulated signal.

$$V_{AM} = V_c\left(1 + m\sin(\omega_m t)\right)\sin(\omega_c t) \text{ Volts}$$

where the symbols have their usual meanings. **(4)**

Sketch, and label, a graph of the frequency spectrum of the AM DSB CP signal.

c. An AM DSB CP signal given below is to be demodulated using a *square law detector*. Figure 2.1 shows a diagram of the demodulator.

The baseband message frequency is 1kHz and the carrier frequency is 1MHz.

$$V_{AM}(t) = 0.2\left(1 + 0.5\sin\left(2\pi * 1 * 10^3 t\right)\right)\sin\left(2\pi * 1 * 10^6 t\right) \text{ Volts}$$

The current flowing in the circuit, i(t), is given below as a function of the input voltage, $V_{AM}(t)$.

$$i(t) = 0.1V_{AM}(t) + 0.05V_{AM}^2(t) \text{ Amps}$$

i) Calculate the peak current for the 1kHz frequency component. i.e the baseband message

ii) Calculate the peak current for the 2kHz frequency component. i.e. the second harmonic of the message frequency. **(10)**

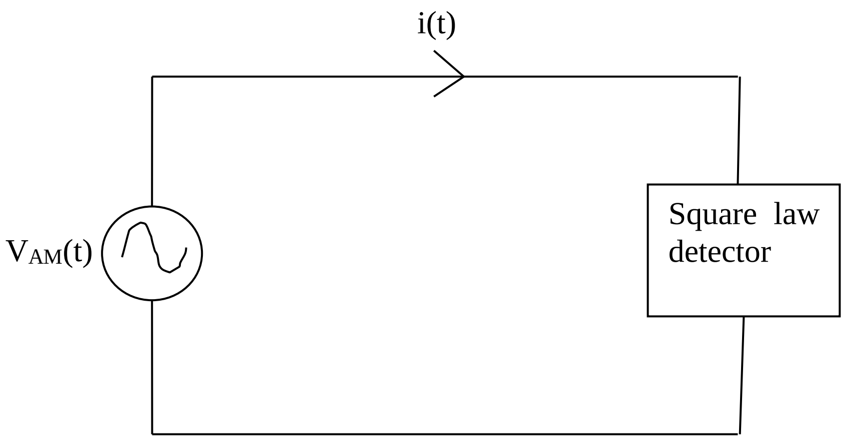


Figure 2.1

d. What type of circuit would need to be included in the demodulator to retrieve the baseband signal? **(2)**

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

b. A signal has a bandwidth of 40kHz and the signal to noise ratio at the receiver is 20dB. **(6)**

i) Calculate the maximum channel capacity.
ii) Calculate the maximum channel capacity if the bandwidth of the signal is doubled whilst the signal power remains constant.

c. A four level Frequency Shift Keying (FSK) system is used to modulate binary information. The FSK system has four sub-carrier frequencies for transmitting pairs of bits as shown in Table 3.1.

The symbol rate of the system is 100 symbols/s (baud)

Binary data pairs	00	01	10	11
Sub-carrier frequency (kHz)	1.0	1.5	2.0	2.5

(8)

Table 3.1

i) Calculate the information transfer rate.
ii) Sketch and label the frequency spectrum of the signal.
iii) Estimate the bandwidth of the signal.

d. Estimate what the maximum symbol rate could be before significant interference would occur between the sub-carriers. **(2)**

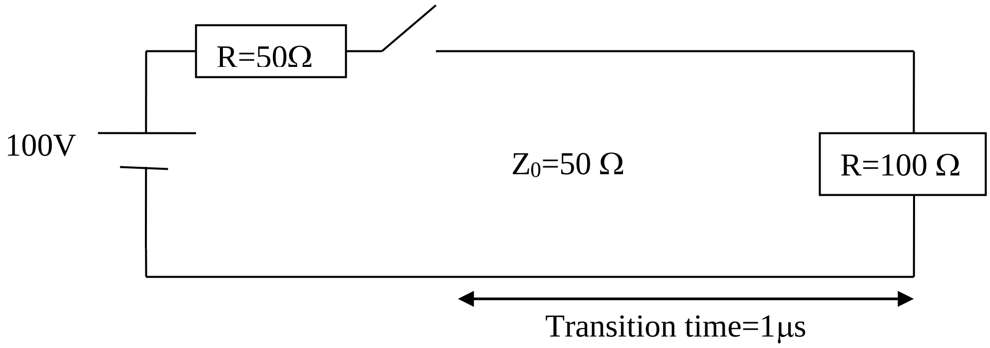
4. **a.** Calculate the reflection coefficient for the following transmission line terminations.

i) Short circuit.
ii) Open circuit.
iii) Matched load.

(3)

b. Figure 4.1 shows a transmission line with a source resistance of 50Ω and a load resistance of 100Ω. The transmission line has a characteristic impedance of 50Ω and the transition time is 1μs.

The switch is closed at time, t=0s.

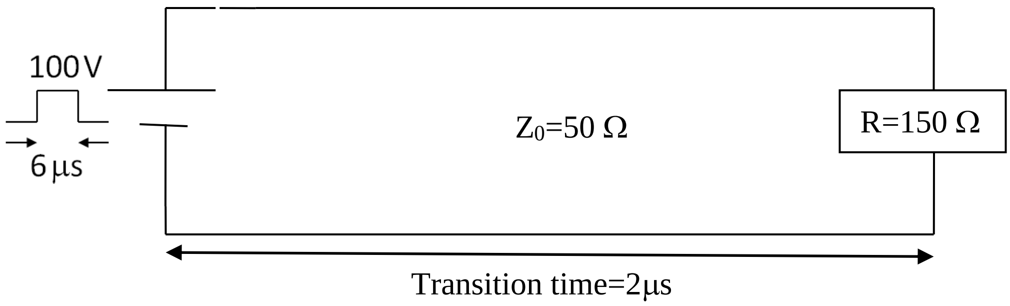


(7)

Figure 4.1

Sketch and label a graph of the voltage across the 100 Ω resistor versus time for 4 μs after the switch is closed.

c Figure 4.2 shows a transmission line with a load resistance of 150 Ω. The characteristic impedance of the line is 50Ω and the transition time is 2 μs. A 100V pulse of duration 6μs is applied to the transmission line.



(10)

Figure 4.2

Sketch and label a graph of the voltage across the 150Ω resistor for the first 10μs.

5. a. Briefly describe the conditions that have to be met for a closed loop system to act as a linear oscillator. **(2)**

b. In the circuit of figure 5.1, v_1 is a driving voltage applied as shown and v_2 is the measured output voltage. Show that v_2 and v_1 are in phase when

$$f = \frac{1}{2pCR}$$

and that at that frequency, $\frac{v_2}{v_1} = \frac{1}{3}$. **(5)**

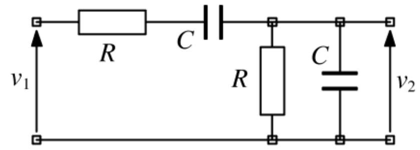


Figure 5.1

c. Draw a circuit diagram to show how the network of figure 5.1 can be used with a suitably configured operational amplifier circuit to form a Wein Bridge oscillator. Suggest suitable values for all the components in your circuit if *f* is required to be 100 kHz. **(6)**

d. How could you "tune" the output of your oscillator? (that is, how could you vary the output frequency of your design.) **(2)**

e. Why is a non-linear element necessary somewhere in the circuit of part **c.** if the amplitude of the oscillator output signal must not change significantly with output frequency, time and temperature?

Show how such a non-linear element could be included in your circuit and explain briefly how it stabilizes the amplitude of the output sinusoid. **(5)**

6. **a.** Show that the Sallen and Key circuit of figure 6.1 has a transfer function

$$\frac{v_o}{v_i} = \frac{A}{1 + sCR\left(\frac{2}{x} + x(1 - A)\right) + s^2C^2R^2}$$

where x is a constant and A is a well defined non-inverting gain. **(6)**

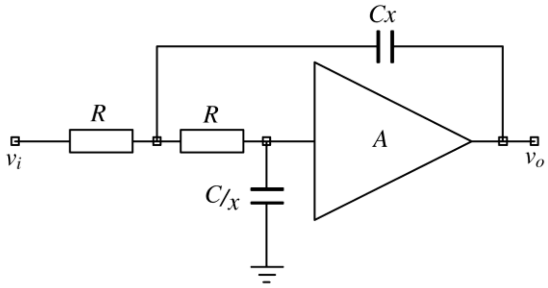


Figure 6.1

b. For the transfer function of part **a.**

(i) find a relationship between A and x that must be satisfied if the circuit is to be stable. **(4)**

(ii) Find expressions for the q factor and undamped natural frequency. **(3)**

c. The circuit is to be used to realise part of a third order Butterworth low-pass filter with a cut off frequency of 10 kHz. All the resistors in the circuit are to be 10 kΩ and the gain A is to be unity. Find the values of C and x needed in the second order section and the value of capacitance needed in the first order section of the filter. **(5)**

A normalised third order Butterworth filter polynomial is $(s+1)(s^2+s+1)$.

d. Sketch a circuit diagram of the whole filter. **(2)**

The standard form of a second order low-pass transfer function is

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

, where ω_n is the undamped natural frequency and k is a dimensionless constant.

USEFUL INFORMATION

Convolution:

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

Trigonometric identities:

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

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

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

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

$$\cos^2(x)=\frac{1}{2}\left[1+\cos(2x)\right]$$

LF/RCT/XC /RJL