

EXAMINATION INTERNAL VERIFICATION FORM (2017-2018)

MODULE :	PSDE 5014 – Signals and Digital Comms			LEVEL:	5
PROGRAMME :	BSc Electrical and Electronic Engineering			TERM OF EXAM: (SPRING OR SUMMER)	Summer
LEARNING OUTCOME(S) BEING ASSESSED:	All	EXAM PAPER:	Main	EXAMINATION AUTHOR :	M Hall

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2.			

INTERNAL VERIFIER PLEASE TICK TO INDICATE THAT THE EXAMINATION:	
☒	Conforms to the assessment pattern described in the module syllabus
☒	Tests the module learning outcome(s) appropriately

SIGNATURES OF FINAL APPROVAL:	SIGNATURE	DATE
INTERNAL VERIFIER: I confirm that this version of the exam paper is ready to be sent to the external examiner		16/03/2018
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LOCATION: COLEG SIR GAR

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LEVEL 5

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EXAMINATION PERIOD

MAY 2018

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MAI 2018

MODULE CODE: PSDE 5014

Signals and Digital Comms

TIME: 2 HOURS

THIS PAPER IS IN 2 PARTS:

ANSWER ALL QUESTIONS IN PART A

ANSWER TWO QUESTIONS OUT OF THREE IN PART B

Equipment or materials required – Calculator

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MAIN

Formulae

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = \frac{V_{modulation}}{V_{carrier}}$$

$$V_{min} = E_c - mE_c, \quad V_{max} = E_c + mE_c$$

$$E_c = \frac{V_{max} + V_{min}}{2}, \quad E_s = \frac{V_{max} - V_{min}}{2}$$

$$v = [E_c + v_s] \cos(\omega_c t)$$

$$V = \frac{mE_c}{2}$$

$$P_{sideband} = \frac{1}{2} m^2 P_{carrier}, \quad P = \sum \frac{E^2}{2R}$$

$$f_c = \frac{f_{max} + f_{min}}{2}$$

$$\Delta f_c = f_{max} - f_c$$

$$\beta = \frac{\Delta f_c}{f_s}$$

$$e = E_c \cos(\varpi_c t + m_f \sin \varpi_s t)$$

$$\overline{\rho_v} = \frac{\overline{v_r}}{\overline{v_i}}, \quad \overline{\rho_v} = \frac{\overline{Z_L} - Z_0}{\overline{Z_L} + Z_0}$$

$$VSWR = \frac{1 + |\overline{p_v}|}{1 - |\overline{p_v}|} = \frac{|\overline{V_I}| + |\overline{V_R}|}{|\overline{V_I}| - |\overline{V_R}|}$$

$$\overline{V_L} = \overline{V_I} + \overline{V_R}$$

$$\overline{Z_{in}} = \frac{Z_0^2}{\overline{Z_L}}$$

$$Z_0 = \frac{138}{\sqrt{k}} \log \frac{D}{d}$$

$$DR = 20 \log_{10}(N)$$

$$q = \text{Voltage Range} / N$$

$$V_{QN} = q / \sqrt{12}$$

$$SQNR = \text{rms Signal Voltage} / V_{QN}$$

PART A – Answer ALL questions.

A1. The final stage of a 465kHz AM transmitter feeds into a 50Ω load and the waveform shown in Figure A1 is observed on an oscilloscope. If the maximum and minimum observed amplitudes of this waveform are 18V and 4V respectively then:

- Calculate the modulation index for this waveform.
- Calculate the amplitude of the carrier and the sideband frequencies
- If the message signal has a frequency of 5kHz, sketch and label the amplitude spectrum of this AM wave, showing the amplitude and frequency of each component and explaining how they were obtained.

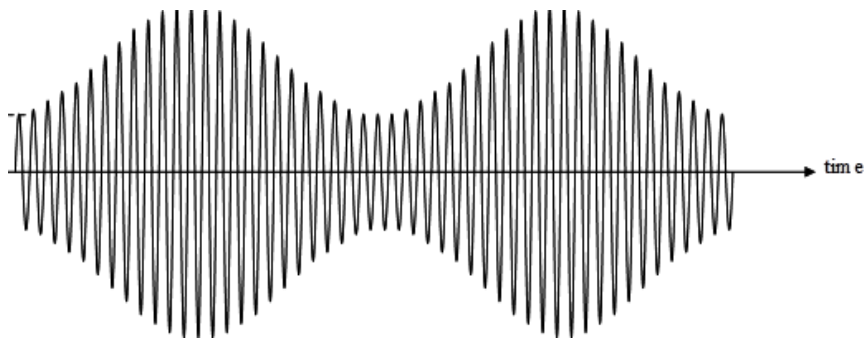


Figure A1

(8 marks)

A2. Sketch the block diagram of an AM superheterodyne radio receiver and describe the purpose and function of each block.

(7 marks)

A3. A coaxial cable has an inner conductor diameter of 0.4mm and uses a dielectric insulator of constant 2.5. Calculate the necessary outer diameter to achieve a characteristic impedance of 50Ω .

(4 marks)

A4. Explain how a successive approximation ADC works.

(5 marks)

A5. Explain the term 'aliasing' as used in ADC's.

(3 marks)

A6. With the aid of suitable diagrams, explain how the following encoding schemes work:

- a. Amplitude Shift Keying (ASK)
- b. Frequency Shift Keying (FSK)

(4 marks)

A7. With $G = 99$, a decoder with CRC receives the following 2 messages and check digits in which message must there have been errors?

Message 1- 652963, check digits 58

Message 2 - 741294, check digits 46

(4 marks)

A8. Describe 2 typical Ethernet topologies.

(6 marks)

Total Marks for Part A = 40

PART B – Only answer 2 of the following 3 questions (B1, B2, B3)

If you answer all 3, only B1 and B2 will be marked

Question B1 – Modulation and Transmission Lines

- a. A sinusoidal carrier wave of amplitude 40V and frequency 500kHz is amplitude modulated by the sinusoidal message signal v_s to produce an AM waveform, where:

$$v_s = 12 \cos(94248t) + 8 \cos(157080t) \text{ volts}$$

- Write down the expanded mathematical formula which describes the modulated carrier in the time domain.
- Using the formula $\cos a \cos b = \frac{1}{2} \cos(a+b) + \frac{1}{2} \cos(a-b)$ further expand the equation from part (i) and use it to sketch the frequency spectrum of the modulated carrier, giving a full explanation of why it takes this form.

(12 marks)

- b. A carrier wave of peak amplitude 40 volts is frequency modulated by a sinusoidal message of peak amplitude 10 volts and frequency 5KHz using an FM modulator with the transfer characteristic shown in figure B1.1 Using this transfer characteristic, determine:

- The maximum frequency deviation (δF_C)
- The modulation index (β)

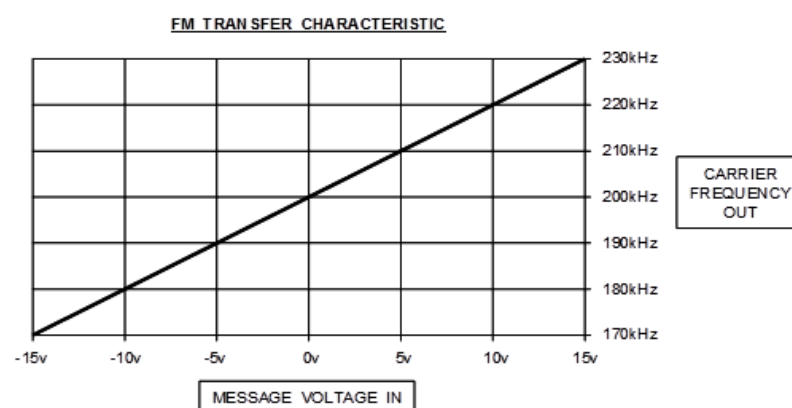


Figure B1.1

- iii. Use the Bessel Tables in Figure B1.2 below to sketch the amplitude spectrum of this FM wave. Label the amplitude and frequency of each component and explain clearly how each value was obtained.

x	Bessel-function order, n																
m_f	J_0	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}
0.00	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.25	0.98	0.12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	0.94	0.24	0.03	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	—	—	—	—	—	—	—	—	—	—	—	—
2.41	0	0.52	0.43	0.20	0.06	0.02	—	—	—	—	—	—	—	—	—	—	—
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	0.01	—	—	—	—	—	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—	—	—	—	—	—	—
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02	—	—	—	—	—	—	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	—	—	—	—	—	—	—	—

Figure B1.2

(9 marks)

- c. 25 metres of loss-free, air-spaced, 75Ω coaxial cable is terminated by a load of impedance $140 + j80\Omega$. A sinusoidal generator of internal resistance 75Ω which, on open circuit, gives an output of $24V_{\text{rms}}$ is now connected to the input to this line.
- Calculate the voltage reflection coefficient (ρ_V) at the load expressed in polar form.
 - Calculate the voltage standing wave ratio (VSWR) on the line.

(9 marks)

Total Marks for Question B1 = 30

Question B2 – Digital Modulation

- a. Explain how a R/2R DAC works.
(5 marks)
- b. Sketch a diagram showing the quantisation levels and corresponding codes of a 3 bit quantiser. Use this diagram to explain what is meant by the term ‘quantisation error’.
(5 marks)
- c. Briefly explain how a PCM signal achieves greater noise immunity than an analogue signal.
(3 marks)
- d. A speech signal with a value of $5V_{rms}$ and maximum frequency 3KHz is transmitted as a PCM signal using an 8-bit quantiser which covers the voltage range -12 to +12 volts.
- i. Calculate the dynamic range of this system in dB.
- ii. Calculate the signal-to-quantisation noise ratio for this signal giving the answer in decibels.
(8 marks)
- e. With the aid of a constellation diagram explain the basic principle of carrier modulation by 16-QAM.
(6 marks)
- f. Explain what is meant by the term “resolution” as used in describing ADCs.
(3 marks)

Total Marks for Question B2 = 30

Question B3 – Transmissions Lines and Ethernet

- a. Draw a diagram and describe each field of the IEEE 802.3 Ethernet Frame Format
(10 marks)
- b. Describe the composition and purpose of each layer of the OSI network model
(8 marks)
- c. Explain the concept of CSMA as used in Ethernet networks.
(6 marks)
- d. Explain the 3 Ethernet terms:
 - i. Unicast
 - ii. Multicast
 - iii. Broadcast
(6 marks)

Total Marks for Question B3 = 30

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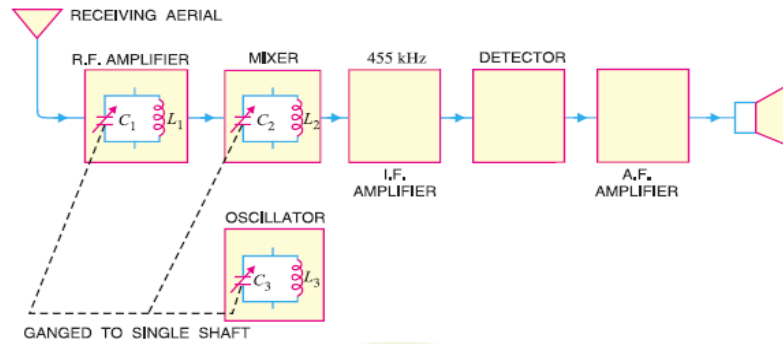


EXAMINATION SOLUTIONS
(to accompany the examination paper sent to the external examiner
but NOT to be seen by students)

Programme:	HND in Electrical & Electronic Engineering	Level:	5
Module:	PSDE5014 Signals & Digital Communications		
Author:	M Hall	Page:	Page 1 of 12

Part A	Question	Marks
A1	$f = 465\text{kHz}$, therefore $\omega_c = 2\pi f = 2\pi \times 465 \times 10^3 = 314159 \text{ rad/s}$ $R_L = 50\Omega$ $V_{\max} = 18\text{V}$ $V_{\min} = 4\text{V}$	
	$m = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} = \frac{18 - 4}{18 + 4} = 0.636$	2
	$E_c = \frac{V_{\max} + V_{\min}}{2} = \frac{22}{2} = 11\text{V}$	2
	$E_s = \frac{V_{\max} - V_{\min}}{2} = \frac{14}{2} = 7\text{V}$	1
	Each sideband has amplitude $= E_s/2 = 3.5\text{V}$ and spaced by the modulating frequency f_s of 5KHz. The diagram shows a horizontal axis representing frequency in kHz, with labels at 460, 465, and 470. Three vertical lines represent the spectral components: a central line at 465 kHz reaching a height of 11, and two side lines at 460 kHz and 470 kHz, each reaching a height of 3.5.	3

A2



1

RF Amp

The purpose of the RF amplifier stage is to select the radio station required and give some initial amplification to the often weak radio signal from the antenna.

1

Local Oscillator

Produces a very stable signal, usually crystal controlled and ganged to the RF amplifier tuned circuit.

1

Mixer

The purpose of the mixer stage is to alter the carrier frequency of the incoming station from whatever it is to a fixed IF frequency at its output

1

IF Amp

Once the carrier frequency is a constant value the IF stage provides of a number of high gain amplifiers of high selectivity to produce a clean, large amplitude AM signal.

1

Detector (demodulator)

The demodulator is a simple diode detector optimally designed to recover the audio message from the AM signal.

1

AF Amp

Finally, the recovered audio signal is passed through the AF amplifier stage which provides enough gain to power the low impedance loudspeaker.

1

A3

$$Z_o = \frac{138}{\sqrt{k}} \log\left(\frac{D}{d}\right)$$

$$50 = \frac{138}{\sqrt{2.5}} \log\left(\frac{D}{0.4}\right)$$

$$50 = 87.3 \log\left(\frac{D}{0.3}\right)$$

$$\text{antilog}\left(\frac{50}{87.3}\right) = \frac{D}{0.3}$$

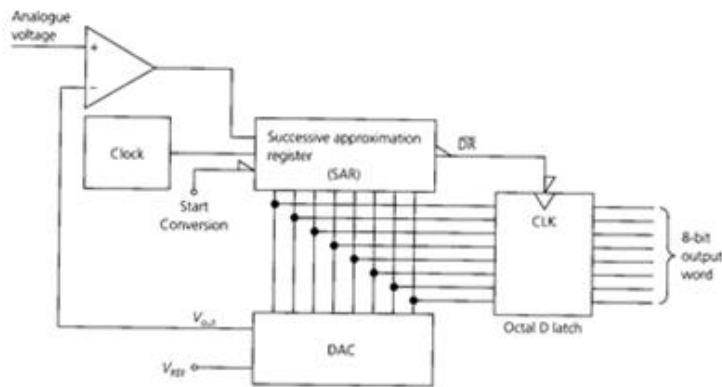
2

1

1

$$D = 1.12\text{mm}$$

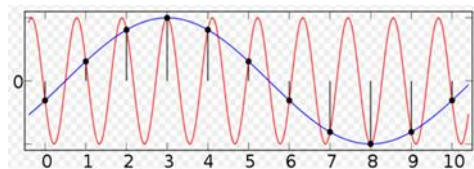
A4



The circuit operates by repeatedly comparing the analogue signal voltage with a number of approximate voltages which are generated at the DAC output. Initially, the shift register (SAR) is cleared and then the DAC output is zero. Conversion is initiated by taking the start conversion line LOW. The first clock pulse sets the MSB to 1 and applies it to DAC. The output of the DAC is then one half of its full scale voltage range (FSR). If the analogue voltage is greater than $\text{FSR}/2$ the MSB is stored by a latch. If it is less than $\text{FSR}/2$ the MSB is taken LOW by the successive approximation register (SAR). The next clock pulse applies the next bit to the DAC, producing a DAC output of $\text{FSR}/4$. If the MSB has been retained, the total DAC output voltage is now $3\text{FSR}/4$; if the MSB had been lost the output of the DAC is now $\text{FSR}/4$. In either case the analogue and DAC voltages are again compared. If the analogue voltage is the larger of the two, the second MSB is retained (latched); if it is not, the second MSB is lost.

5

A5

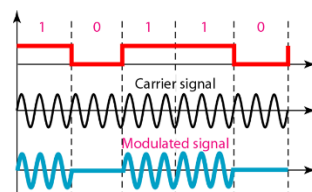


Aliasing results in improper conversion of the input signal and high and low frequency samples are indistinguishable. Usually exists when Nyquist Criterion is violated. Prevented through the use of Low-Pass (Anti-aliasing) Filters.

3

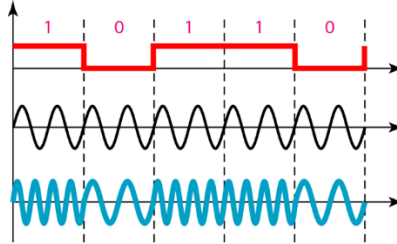
A6

ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.



2

FSK - The digital data stream changes the frequency of the carrier signal, f_c . For example, a "1" could be represented by $f_1 = f_c + \delta f$, and a "0" could be represented by $f_2 = f_c - \delta f$.



A7

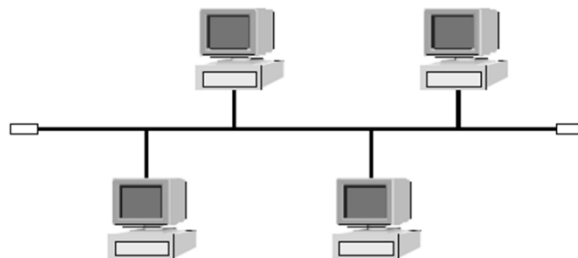
The remainder on dividing 652963 by 99 is 58, which is the same as the received check, so there is no reason to suspect that there have been any errors. The remainder on dividing 741294 by 99 is 81, which is not the same as the received check, so there must have been some errors.

2

4

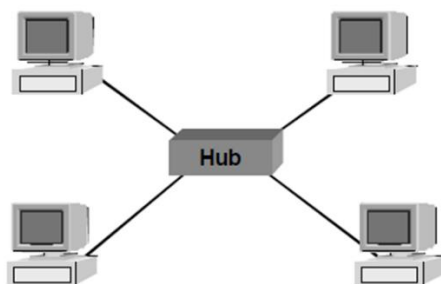
A8

Ethernet Physical Bus Topology

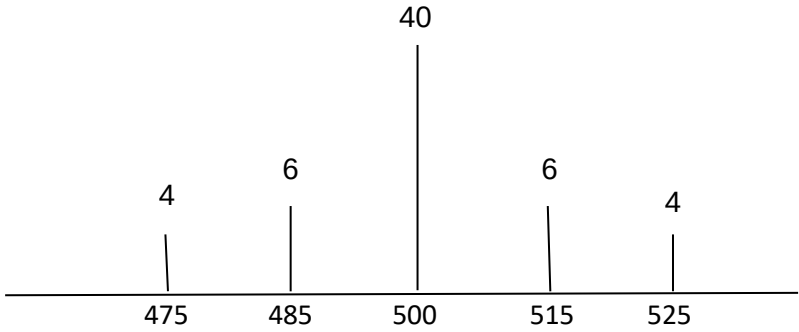


3

Ethernet Physical Star/Logical Bus Topology



3

Q. B1	Question	Marks
	a. $E_c = 40V$ $f = 500kHz$, therefore $\omega_c = 2\pi f = 2\pi \times 500 \times 10^3 = 3141592 \text{ rad/s}$ $v_c = E_c \cos(\omega_c t) = 40 \cos(3141592t)$ $v_s = 12 \cos(94248t) + 8 \cos(157080t)$ $v = [E_c + v_s] \cos(\omega_c t)$ $= [40 + 12 \cos(94248t) + 8 \cos(157080t)] \cos 3141592t$ In Hz $= [40 + 12\cos(2\pi \times 15000t) + 8 \cos(2\pi \times 25000t)] \times \cos(2\pi \times 500000t)$ Multiplying out $v = 40\cos(2\pi \times 500000t) + 12\cos(2\pi \times 15000t) \cos(2\pi \times 500000t) + 8\cos(2\pi \times 25000t) \cos(2\pi \times 500000t)$ ii. Using the formula $\cos a \cos b = \frac{1}{2} \cos(a+b) + \frac{1}{2} \cos(a-b)$ $v = 40\cos(2\pi \times 500000t) + 6\cos(2\pi \times 515000t) + 6\cos(2\pi \times 485000t) + 4\cos(2\pi \times 525000t) + 4\cos(2\pi \times 475000t)$ Therefore: Carrier is 40V @ 500kHz Sidebands of 6V @ 485kHz and 515kHz Sidebands of 4V @ 475kHz and 525kHz 	1 3 2 3 2 1

b.	Frequency deviation (δf_c) = $f_{\max} - f_c = 220 - 200 = 20\text{kHz}$ Modulation Index (β) = $\delta f_c / f_m = 20 / 5 = 4$ Component amplitudes are calculated from the Bessel table for $\beta = 4$: $J_0 = 40 \times -0.4 = -16\text{V}$ $J_1 = 40 \times -0.07 = -2.8\text{V}$ $J_2 = 40 \times 0.36 = 14.4\text{V}$ $J_3 = 40 \times 0.43 = 17.2\text{V}$ $J_4 = 40 \times 0.28 = 11.2\text{V}$ $J_5 = 40 \times 0.13 = 5.2\text{V}$ $J_6 = 40 \times 0.05 = 2\text{V}$ $J_7 = 40 \times 0.02 = 0.8\text{V}$ Diagram showing each component spaced by the modulating frequency of 5kHz	2 2 3 2
c.	Reflection co-efficient $\overline{\rho_v} = \frac{\overline{Z_L} - Z_0}{\overline{Z_L} + Z_0}$ $\rho_v = \frac{(140 + j80 - 75)}{(140 + j80 + 75)}$ $\rho_v = \frac{(65 + j80)}{(215 + j80)}$ Converting to polar form: $\rho_v = \frac{103.1 \angle 53.1}{229.4 \angle 20.4}$ $\rho_v = 0.45 \angle 32.7$ VSWR $VSWR = \frac{1 + \overline{\rho_v} }{1 - \overline{\rho_v} } = \frac{1 + 0.45}{1 - 0.45} = 2.64$	2 1 3 1 2

Q.B2	Question	Marks
a.	The circuit uses resistors of only two different values, one of which is twice the other. The principal of operation relies on the fact that the total resistance of 2 equal resistors in parallel is equal to halve their individual value. ie the total resistance of 2R in parallel in with 2R is R. In the above diagram, half the input current flows through each resistor. In fig (b), half flows through the left hand resistor while only a quarter flows in the other 2. In fig(c), half flows in the left resistor, quarter in the next and one eighth in the last 2. It follows that for each additional R/2R resistor pair added the current flowing in the final 2 resistors is halved. b. Quantising approximates a continuous range of values and replaces it with a binary number. Error is introduced between input voltage and output binary representation which depends on the resolution of the ADC. c. Analogue Digital	5 3 2 1

Noise is accumulative and increases with the length of the transmission path. With analogue signals, noise is very difficult to remove and once added results in a degraded signal. With a PCM digital signal, the system only has to differentiate between a 0 and 1, so as long as the noise isn't sufficient to blur this distinction the signal can be regenerated effectively noise free.

2

d.

$$DR = 20\log_{10}(N)$$

Where $N = 2^n = 256$

$$\text{In dB} = 20\log 256 = 48.16\text{dB}$$

2

$$q = \frac{\text{Voltage Range}}{N} = \frac{24}{256} = 0.09375$$

2

$$V_{QN} = \frac{q}{\sqrt{12}} = 0.027$$

2

$$SQNR = \frac{5}{0.027} = 184.75$$

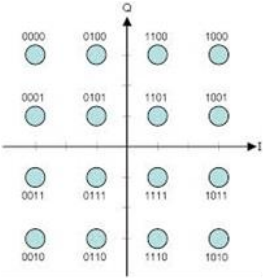
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$$\text{In dB} = 20\log 184.75 = 45.33\text{dB}$$

1

e.

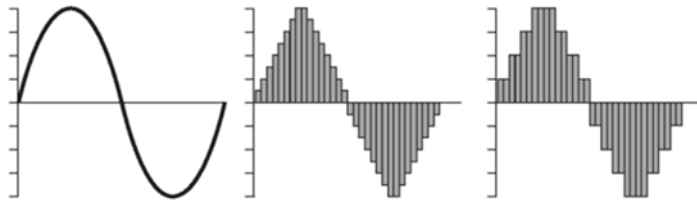
In the 16-QAM scheme, 4 'I' values and 4 'Q' values are used which gives 16 possible symbols from 0000 to 1111. In addition to the 3 phases per quadrant, there are 3 amplitude levels. Therefore QAM modulates both amplitude and phase at the same time. For example:



1101 is phase shifted 45° and the amplitude is reduced to 0.33 of $V_{\max}$
 1001 is phase shifted 15° and the amplitude is reduced to 0.75 of $V_{\max}$
 1100 is phase shifted 75° and the amplitude is reduced to 0.75 of $V_{\max}$
 1000 is phase shifted 45° and the amplitude is $V_{\max}$

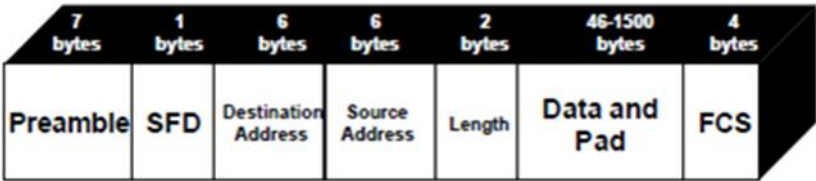
6

f.



Resolution determines the number of quantisation levels, the higher the resolution, the smaller the quantisation interval and the better the quality.

3

Q. B3	Question	Marks
a.		2
	The IEEE standard was adopted in 1985. The 802.3 frame format is below: The Preamble indicates the start of a new frame and establishes synchronization conditions between devices. The Start Frame Delimiter (SFD) has the sequence 10101011 The Destination and Source Addresses can be either 2 or 6 bytes. Whether 2 or 6 bytes are used, all devices within the same network must use the same format. IEEE protocols specify that a 10Mbps network must use 6 bytes. The 2 byte length is generally now obsolete. The Length field indicates the number of bytes in the data field. If the data field is less than the required 46 bytes, a pad field is added to the data frame. The bytes added for padding purposes are usually zeros. The data field contains the data to be transmitted from device to device. The Frame Check Sequence (FCS) field is used as an error detection function. The error detection function is a calculation completed by both the source and destination devices. If the calculations do not match, an error is then generated.	8
	b. <u>The physical layer</u> defines connector and interface specifications, as well as the medium (cable) requirements. Electrical, mechanical, functional, and procedural specifications are provided for sending a bit stream on a computer network.	1
	<u>The data link layer</u> provides the following functions: • Allows a device to access the network to send and receive messages • Offers a physical address so a device's data can be sent on the network • Works with a device's networking software when sending and receiving messages • Provides error-detection capability	2
	<u>The network layer</u> of the OSI model, provides an end-to-end logical addressing system so that a packet of data can be routed across several layer 2 networks (Ethernet, Token Ring, Frame Relay, etc.). <u>The transport layer</u> of the OSI model, offers end-to-end communication between end devices through a network. Depending on the application, the transport layer either offers reliable, connection-oriented or connectionless, best-effort communications.	1

c.	<u>The session layer</u>, provides various services, including tracking the number of bytes that each end of the session has acknowledged receiving from the other end of the session. This session layer allows applications functioning on devices to establish, manage, and terminate a dialog through a network.	1
	<u>The presentation layer</u>, is responsible for how an application formats the data to be sent out onto the network. The presentation layer basically allows an application to read (or understand) the message.	1
	<u>The application layer</u>, provides an interface for the end user operating a device connected to a network. This layer is what the user sees, in terms of loading an application (such as Web browser or e-mail); that is, this application layer is the data the user views while using these applications.	1
	Collision Detection means that a sending device can “detect” simultaneous transmission attempts. When two or more devices try to send data at the same time, the signals collide. When this happens, each device then transmits a jam signal, called a carrier, to alert all other devices that a collision has occurred. All devices then go into back off mode and wait a random amount of time before attempting to retransmit data. The random time provision prevents simultaneous retransmissions. When a collision occurs it affects all the devices on the same collision domain. It does not affect devices on any other collision domains within the same network. You can think of two collision domains as two roads that are on different sides of a bridge. You can travel up to the bridge on either side, but must get permission to cross the bridge. On an Ethernet collision domain, frames of data travel within their own domain unless they need to talk to a device on the other side of the bridge. If it is necessary to talk to a device on the other side of a bridge, the bridge must give permission for the frame to cross the bridge to reach the other collision domain. Bridges are capable of this because they are store and forward devices: they store the frame from the source domain until permission is granted to forward it. Data transmitted from one device to another on the same collision domain will not affect any other collision domains. This allows each collision domain to continue to transmit with no effect on each other except when a device needs to talk to a device on another collision domain. In summary, a computer device checks to see if the transmission media is busy, recognizes that multiple devices access the network, and detects when a collision has taken place and goes into back off mode.	6

d.	<u>A Unicast frame</u> is addressed to a single network device. This means that the frame is to be read only by the device that matches the destination address. All other devices in the collision domain will receive a copy of the frame but will discard it because it does not match their destination address. The address used is the MAC address or hardware address of the network device. <u>A multicast frame</u> is addressed to several but not all devices. All devices that are a part of the specified group may read the frame. A multicast address is a deviation from the normal hardware address. For example, a group of devices are assigned access to a particular server on the network. They are the only devices that receive frames announcing the availability of that server. Any device that does not belong to this group will ignore or discard these frames. <u>A broadcast frame</u> is addressed for all network devices to read and process. A broadcast address is a unique address used only for broadcast frames. It is not a hardware address. Broadcast frames are transmitted across bridges and switches; however, routers will stop broadcast frames.	2 2 2
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