A-level
ELECTRONICS

Paper 5 Communications Systems

Friday 17 June 2016   Morning   Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
* a pencil and a ruler
* a calculator
* Data Sheet (enclosed).

Instructions
* Use black ink or black ball-point pen.
* Fill in the boxes at top of this page.
* Answer **all** questions.
* You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
* Do all rough work in this book. Cross through any work you do not want to be marked.

Information
* The marks for each question are shown in brackets.
* The maximum mark for this paper is 80.

Answer **all** questions in the spaces provided.

1 Bluetooth is a short-range wireless technology standard.
It operates over a number of channels, from 2402 MHz to 2480 MHz.
Bluetooth 4.0 has a channel separation of 2 MHz.

1 (a) Calculate the number of channels available in Bluetooth 4.0.

[1 mark]

1 (b) A Bluetooth device makes use of all the channels.
It switches channels at a rate of 1600 per second.
This is called Frequency Hopping.

Calculate how many times each channel is used per second.

[2 marks]

1 (c) There are three classes of Bluetooth device.
Table 1 shows the maximum power rating of the three classes.

Table 1

Bluetooth maximum power rating	Class 1	Class 2	Class 3
	0.1 W	2.5 mW	1000 μW

1 (c) (i) Assume the devices are used under the same conditions.
Circle the class which would have the longest range.

[1 mark]

Class 1   Class 2   Class 3

1 (c) (ii) The computers in a classroom have keyboards connected by Bluetooth.

Explain why Class 3 would be the best choice for use with these keyboards.

[2 marks]

1 (d) Some older keyboards use infrared to communicate with the computer.

State **one** disadvantage of this compared with Bluetooth.

[1 mark]

_____

1 (e) A Bluetooth device uses a quarter wavelength aerial.

Calculate the most suitable length for the aerial.
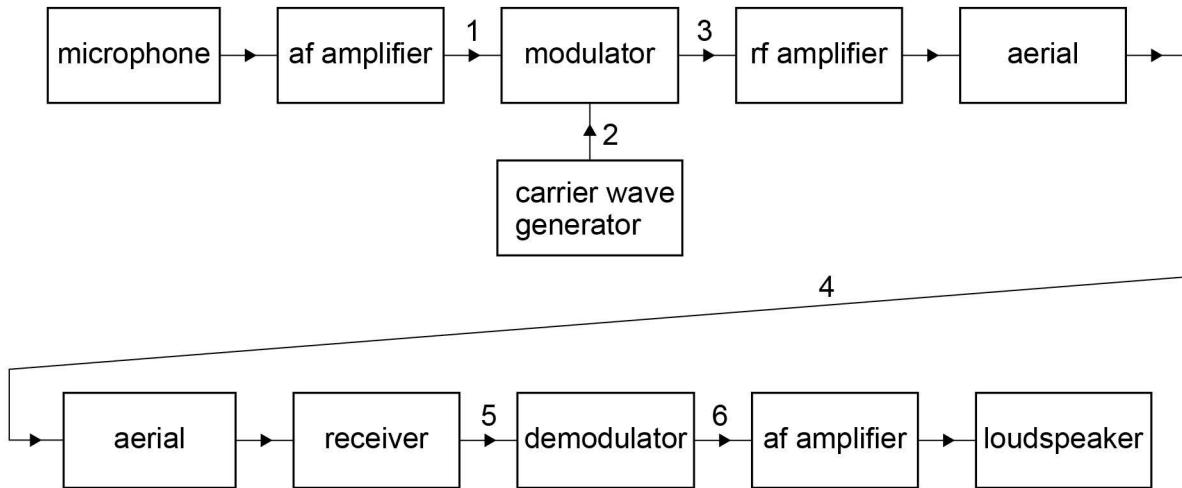
[4 marks]

_____

_____

_____

_____

Turn over for the next question

2 A baby monitor is used by a parent or carer to listen to a baby in another room. The transmitter module is placed in the room with the baby. A radio signal is transmitted to the receiver module in the room with the parent or carer.
Figure 1 shows a block diagram of the system.

Figure 1

```
┌───────────┐   ┌──────────────┐  1  ┌───────────┐  3  ┌──────────────┐   ┌──────────┐
│ microphone│──▶│ af amplifier │────▶│ modulator │────▶│ rf amplifier │──▶│  aerial  │──┐
└───────────┘   └──────────────┘     └───────────┘     └──────────────┘   └──────────┘  │
                                           ▲ 2                                            │
                                  ┌──────────────────┐                                    │
                                  │  carrier wave    │                                    │
                                  │  generator       │                                    │
                                  └──────────────────┘                                    │
                                                                             4            │
        ┌─────────────────────────────────────────────────────────────────────────────┘
        │
        ▼
   ┌──────────┐   ┌───────────┐  5  ┌─────────────┐  6  ┌──────────────┐   ┌─────────────┐
   │  aerial  │──▶│  receiver │────▶│ demodulator │────▶│ af amplifier │──▶│ loudspeaker │
   └──────────┘   └───────────┘     └─────────────┘     └──────────────┘   └─────────────┘
```

2 (a) Some of the signals in **Figure 1** are numbered.
Write the correct number (1–6) for the line that represents:

2 (a) (i) a modulated radio frequency signal in the receiver

[1 mark]

2 (a) (ii) a modulated radio frequency signal in the transmitter

[1 mark]

2 (a) (iii) an unmodulated radio frequency signal

[1 mark]

2 (a) (iv) electromagnetic waves

[1 mark]

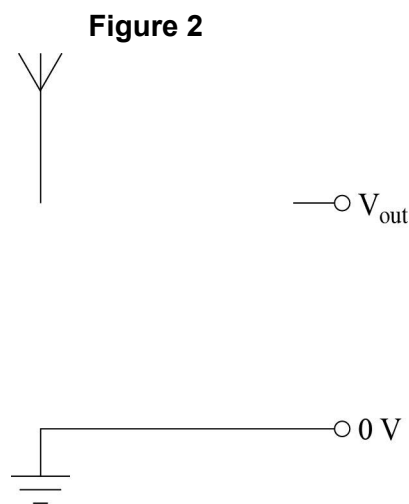**2 (a) (v)** an audio signal in the transmitter

[1 mark]

2 (b) The receiver in **Figure 1** contains a tuned circuit.

2 (b) (i) State the function of the tuned circuit in the receiver.

[1 mark]

_____

_____

2 (b) (ii) Add a capacitor and an inductor to **Figure 2** to form a tuned circuit.
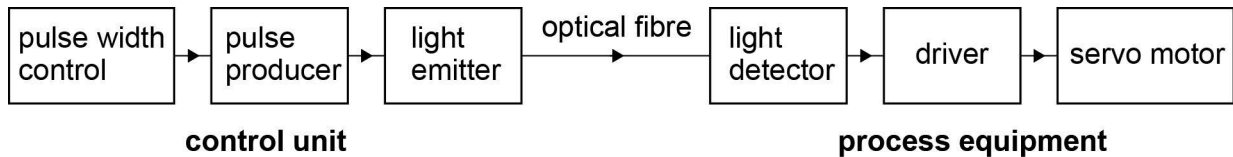
[2 marks]

Figure 2

—o V_{out}

—o 0 V

2 (b) (iii) The baby monitor uses a frequency of $434 \ \mathrm{MHz}$.
The capacitor in its tuned circuit has a value of $10 \ \mathrm{pF}$.
Calculate the value of the inductor needed.

[3 marks]

_____

_____

_____

_____

3 An industrial process uses a PWM signal to control a servo motor. The signal is generated by a control unit that is some distance from the process equipment.
An optical fibre is used to transmit the signal to the servo motor from the control unit.
Figure 3 shows the system diagram.

Figure 3

| pulse width control | → | pulse producer | → | light emitter | optical fibre → | light detector | → | driver | → | servo motor |

control unit   **process equipment**

3 (a) State the meaning of the letters PWM.

[1 mark]

3 (b) State **two** advantages of using optical fibres for this application.

[2 marks]

1 _____

2 _____

3 (c) (i) A signal can travel along an optical fibre, even when the fibre is bent.

State how this happens.

[1 mark]

3 (c) (ii) Explain why there is a minimum radius to any bend in the optical fibre.

[2 marks]

3 (d)　The light detector converts the light signal into an electrical output.
When a sudden change in light level occurs, the detector output takes time to change.
This is called the rise time (or the fall time) of the detector.
The rise time of a detector is the time for the output to go from 10% to 90% of its final value.

Table 2 shows the rise/fall times of different detectors.

Table 2

Detector	Rise/fall time
Photo diode	2 ns
PIN diode	50-100 ps

3 (d) (i)　State how the rise/fall times affect the maximum frequency that can be detected.

[1 mark]

3 (d) (ii)　In this application, the PWM signal has a frequency of 50 kHz.

Explain, using a calculation, why either detector would be suitable for this signal.

[2 marks]

3 (e)　Explain why a regenerator might be needed in the system in **Figure 3** and explain its function.
State the name of a circuit that could be used as a regenerator.

[3 marks]

4 You do not need to have completed **Question 3** before attempting this question.

The PWM circuit in an industrial control system has been designed by a student using 555 timers.
This circuit is shown in **Figure 4**.

Figure 4
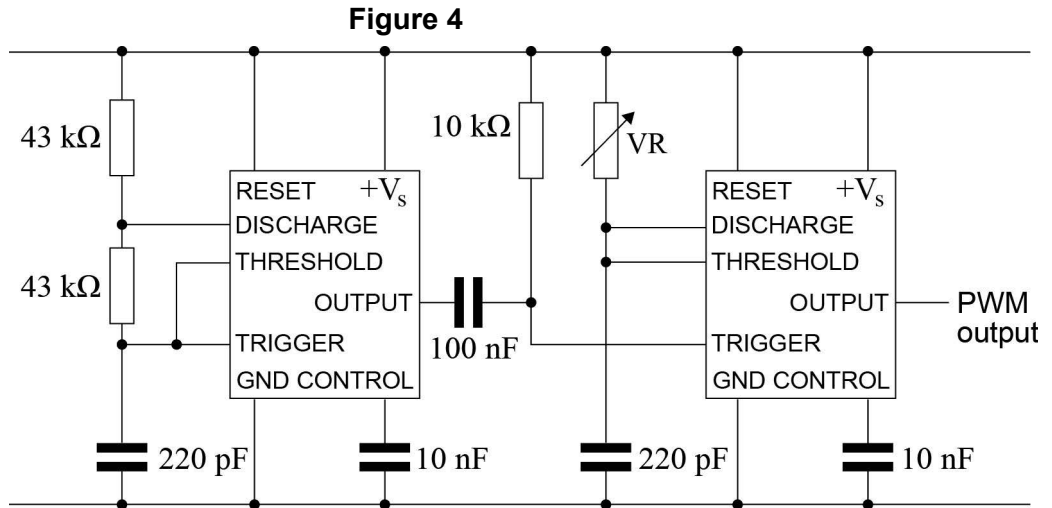
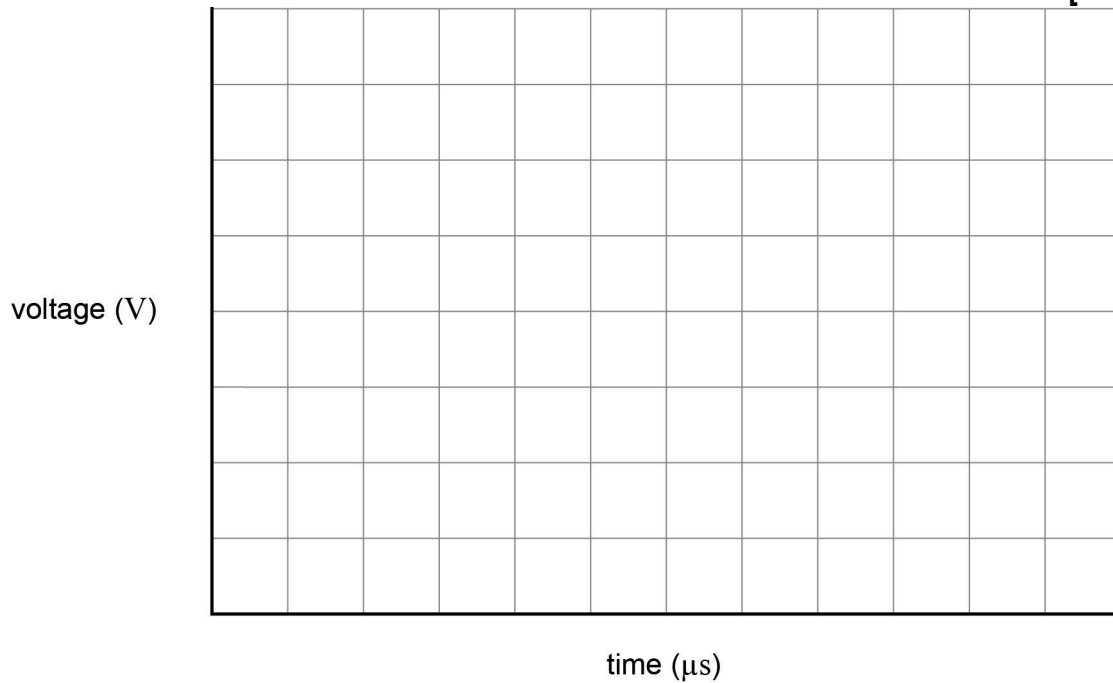**4 (a)** Show that the time period of the astable in this circuit is about $20\ \mu s$.

[4 marks]

4 (b) For a particular setting of variable resistor VR, the PWM output is high for 1.5 μs.

4 (b) (i) Calculate this value of VR.

[3 marks]

4 (b) (ii) Draw a voltage–time graph of the PWM output from the circuit.
Label the axes with suitable values.

[2 marks]

voltage (V)

time (μs)

Turn over for next question

Turn over ▶

5 Citizens' band (CB) radio is a licence-free system that operates in the 27 MHz band.

Table 3 gives the frequencies of some of the channels.

Table 3

Channel	Frequency (MHz)
1	26.965
2	26.975
3	26.985
⋮	⋮
⋮	⋮
8	27.055
9	27.065
10	27.075
⋮	⋮
⋮	⋮
38	27.385
39	27.395
40	27.405

5 (a) The modulation used can be AM or FM.

State and explain the meaning of the terms AM and FM.

[4 marks]

AM _____

_____

FM _____

_____

5 (b) Draw and label on **Figure 5** the frequency spectrum for a signal on channel 39, amplitude modulated with two sine waves of frequency 2 kHz and 3 kHz.

[4 marks]

Figure 5

27.37   27.38   27.39   27.40
frequency (MHz)
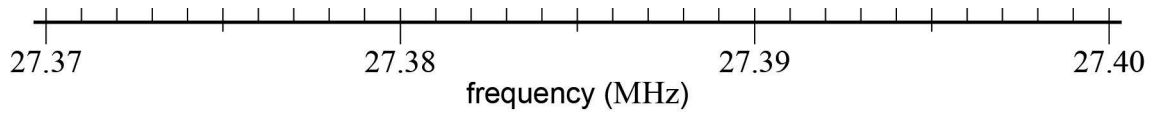
5 (c) CB radio is normally used in half-duplex mode.

State the meaning of **half-duplex**, and explain how a two-way conversation can take place.

[3 marks]

_____

_____

_____

_____

5 (d) Explain why the spacing of channels used is suitable for transmitting and receiving speech.
Use a calculation to justify your answer.

[3 marks]

_____

_____

_____

_____

Turn over ▶

6 (a) A mobile phone communicates with a base station, in full duplex mode, using two frequency channels, uplink and downlink.

State what is meant by:

[2 marks]

uplink _____

_____

downlink _____

_____

6 (b) A control channel is also needed between the base station and the mobile phone.

State **two** functions of this control channel.

[2 marks]

1 _____

2 _____

6 (c) The GSM900 network in the UK is allocated frequency bands 890–915 MHz for uplink and 935–960 MHz for downlink. Each frequency channel has a bandwidth of 200 kHz.

Calculate the number of frequency channels available for uplink.

[2 marks]

_____

_____

6 (d) The cellular system allows a large number of mobile phone conversations to take place within a limited frequency allocation.

Figure 6 represents part of a cellular system.

Figure 6
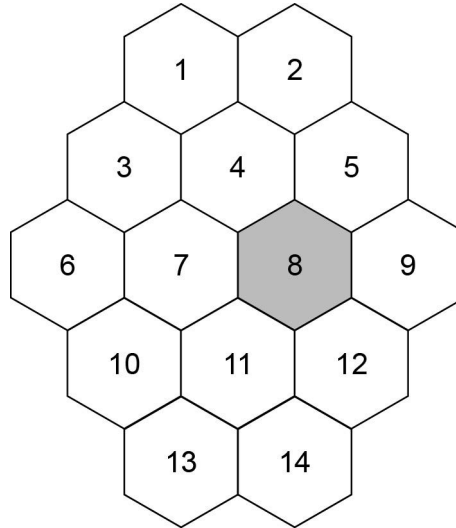
Explain how frequencies used in cell 8 may be re-used in some cells, but not in others. You should refer to the cell numbers in **Figure 6** in your answer.

[3 marks]

_____

_____

_____

_____

_____

_____

7 Stage lighting can be controlled using a system called DMX512.
The system can be used to control the brightness of up to 512 lamps.
It uses a digital multiplexed signal that is carried in a screened, twisted-pair cable.

7 (a) State why multiplexing is necessary in this situation.

[1 mark]

_____

_____

7 (b) Sketch a labelled diagram to show the construction of a screened, twisted-pair cable.

[2 marks]

7 (c) The brightness of each lamp is controlled by 8 bits of data.

Figure 7 shows the data format for setting the brightness of each lamp.
- One start bit (0).
- Eight data bits.
- Two stop bits (1).

Figure 7

start   data   stop
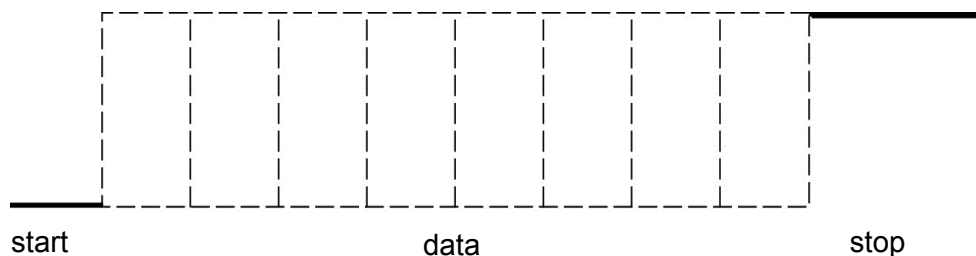
7 (c) (i) State the function of start and stop bits.

[1 mark]

_____

_____

7 (c) (ii) The signal is transmitted at a rate of 250 kbaud.

Show that the time taken to send the signal for the brightness of one lamp is 44 µs.

[2 marks]

_____

_____

_____

7 (d) The data for the 512 lamps are sent in sequence, after a signal to indicate the start of data transmission. This start signal typically takes a time of 0.16 ms.

Calculate how many times per second the brightness of a lamp can be updated.

[3 marks]

_____

_____

_____

7 (e) The electrical signal is transmitted differentially down the twisted pair cable.

Table 4 gives the voltages of the screen and wires.

Table 4

	Logic 0	Logic 1
Screen	0 V	0 V
Wire 1	–5 V	+5 V
Wire 2	+5 V	–5 V

7 (e) (i) State and explain **one** advantage of transmitting the signal differentially.

[2 marks]

_____

_____

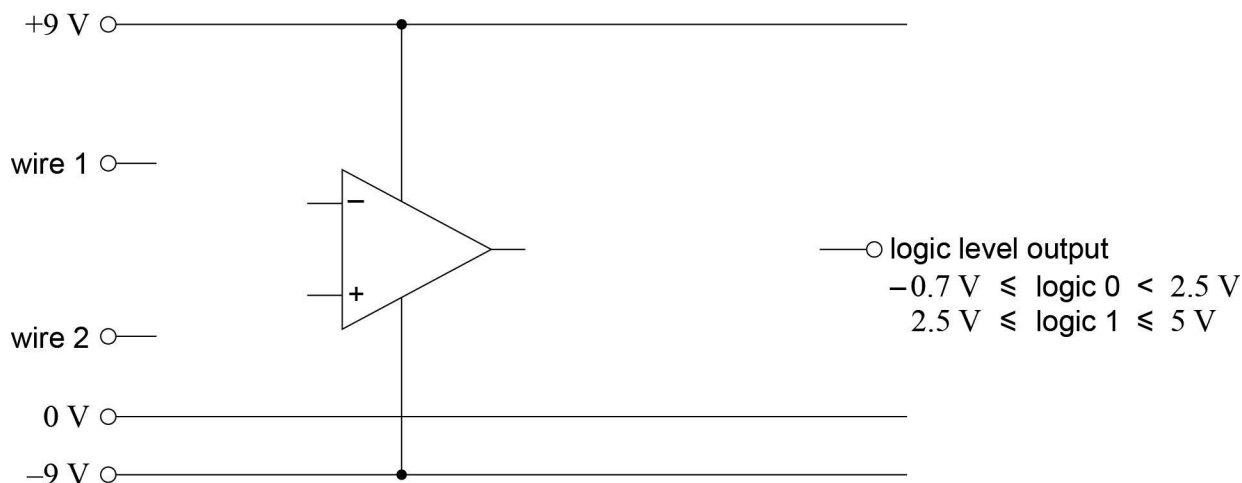**Question 7 continues on the next page**

7 (e) (ii) At the receiving end of the cable, a comparator is used to produce the logic signal for the next stage of the circuit.

Complete **Figure 8**, using a 4.7 V Zener diode and a resistor, to make a comparator that will give this logic signal.

[3 marks]

Figure 8

END OF QUESTIONS