Teacher Resource Bank

GCE Electronics

Exemplar Exam Questions

- ELEC4: Programmable Control Systems

ELEC4 – Programmable Control Systems

Control Systems, Feedback, Motor Driver, Flow Chart   (ELE4, Q5, 2008)

5   A solar panel system tracks the sun during the day in order to maximise its power output. The system consists of two motors, one to control horizontal direction and one to control elevation. It also has a light-level sensor which moves with the solar panels.
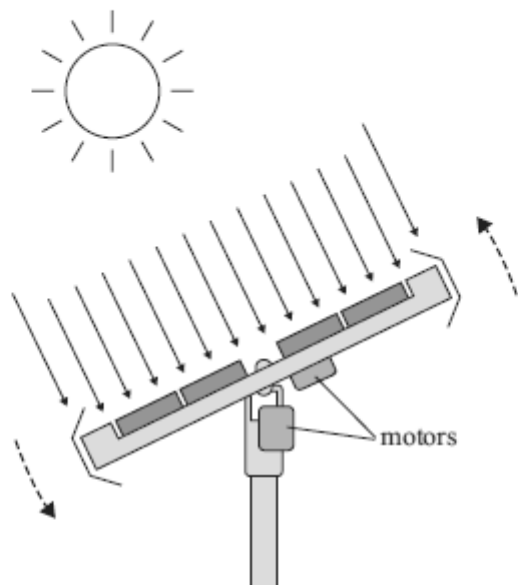
A system diagram is shown below.
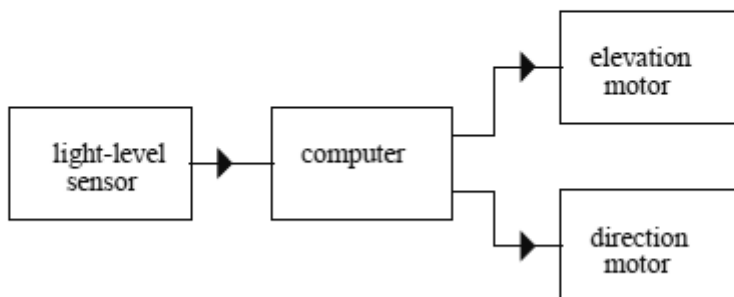
5   (a)   Explain whether this is an open or closed loop system.

....

....

(1 mark)

5 (b) The drive circuit for each of the dc motors is shown below.
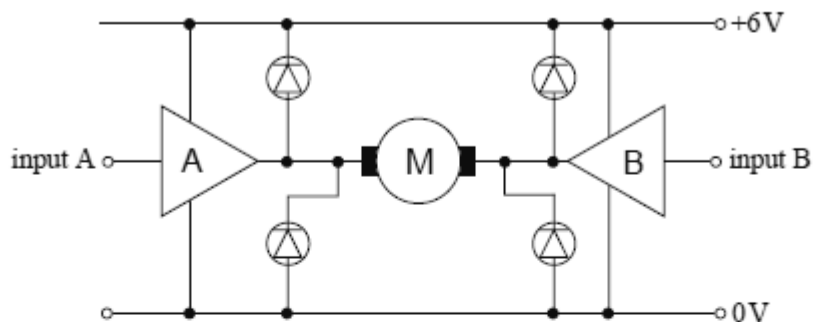
A and B are both high current switching circuits. Each has a truth table as shown below.

Input	Output
0	0
1	1

5 (b) (i) What is the function of the diodes in the circuit?

....

....

5 (b) (ii) Complete the truth table below, indicating what the motor will do.

Input A	Input B	Motor
0	0	
0	1	
1	0	
1	1	

(4 marks)

Question 5 continues on the next page

5   (c)   In operation, the computer will change the horizontal direction of the solar panels
slightly and check to see if the output from the light level sensor increases. If it does,
it will leave the panels pointing in that direction. If the light level decreases, then it
will move the panels in the other horizontal direction. It will then do the same for the
elevation of the panels. It repeats this continuously throughout the day until the light
level falls too low for electricity to be generated.
Draw a flow chart in the space below to represent the operation of this system.

(4 marks)

Control System, Motor Driver (ELE4, Q7, 2007)

7   A servo system is to be designed to accurately control the position of a rudder, and hence the direction, of a radio controlled boat.
A proposed system diagram is shown below.
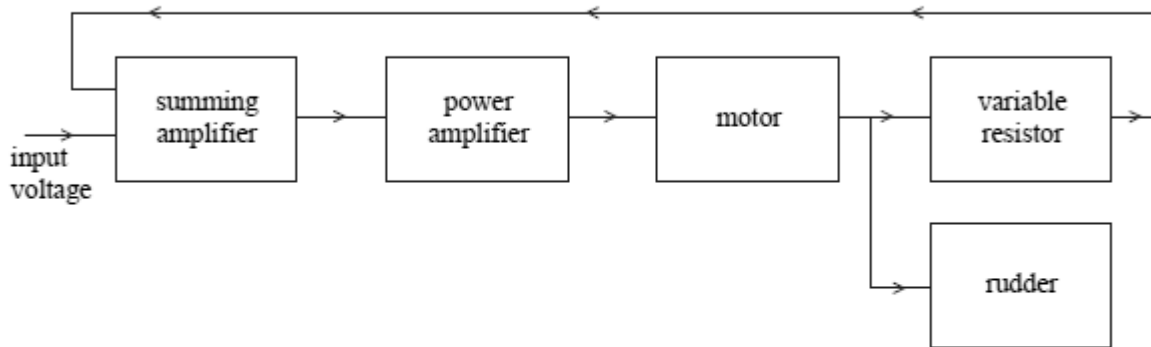
As the motor rotates it alters the position of the rudder and the variable resistor.
The variable resistor sends a control voltage back to the summing amplifier.

(a)   Explain whether this is an open or closed loop system.

....

....

(1 mark)

The circuit diagram for the system is shown below.
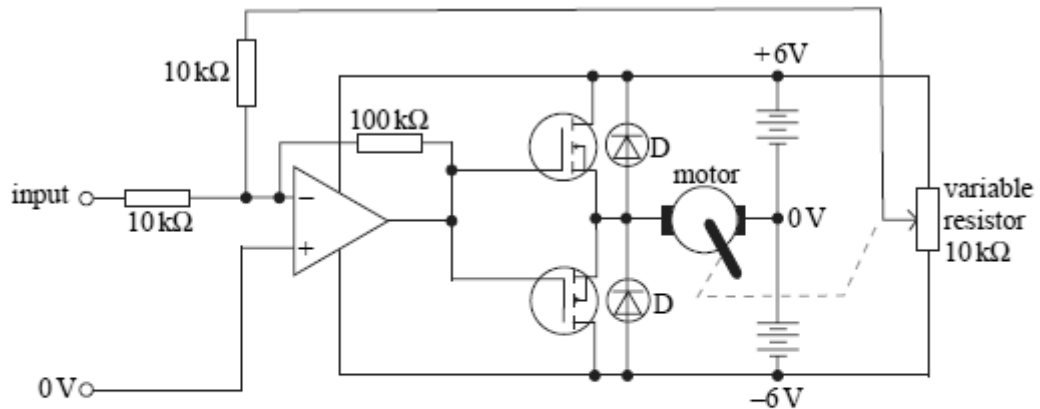
(b)   (i)   Clearly label a virtual earth point on the diagram with the letter P.

   (ii)   Clearly label the n-channel MOSFET with the letter N.

AQA

(iii) When the n-channel MOSFET is conducting and the p-channel MOSFET is switched off the motor rotates clockwise turning the rudder and the variable resistor.
Explain what will happen when the p-channel MOSFET is conducting and the n-channel MOSFET is switched off.

....

....

(iv) State the function of the diodes, D.

....

....

(4 marks)

(c) When the input voltage is 0 V, and the voltage from the variable resistor is also 0 V, the motor is stationary, and the rudder is set to make the boat steer straight ahead.

(i) An input of +3 V is applied to the input of the system and the motor begins to rotate. Explain which MOSFET has been switched on.

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(ii) As the motor rotates it turns the variable resistor which produces a negative voltage. With an input of +3.00 V and a voltage from the variable resistor of –2.75 V, calculate the output voltage from the summing amplifier.

....

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....

(iii) Explain the effect this will have on the motor.

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....

....

Question 7 continues on the next page

(iv) When will the motor stop?

....

....

....

(v) The motor has come to rest when the input voltage is 3 V. The input voltage is now set to 0 V. Explain what will happen to the motor.

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(11 marks)

(d) It is found that when the input voltage is between ±0.2 V, the motor does not move. What changes would you make to the circuit in order to ensure that the motor responded to small input voltages?

....

....

....

(2 marks)

6

AQA

Control System, Stepper Motors, Optical Shaft Encoder   (ELE4, Q2, 2006)

2   European regulations require all car manufacturers who fit HID (High Intensity Discharge) headlamps to also fit them with self-levelling systems in order to avoid glare to oncoming motorists. Information for the *levelness* of a car is obtained from sensors connected to the front and rear suspension of the car.
A simplified system diagram is shown below.
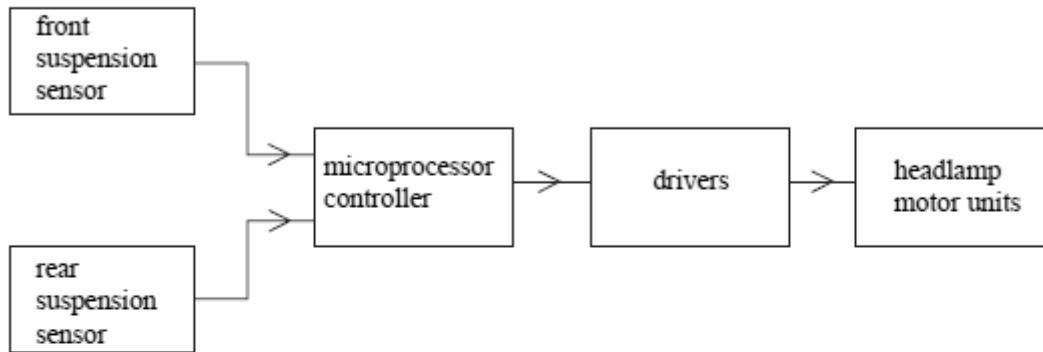
   (a)   State, with a reason, whether this is an open or closed loop control system.

       ....

       ....
                                                  (2 marks)

The motors operating the headlamps can be stepper motors or conventional motors.
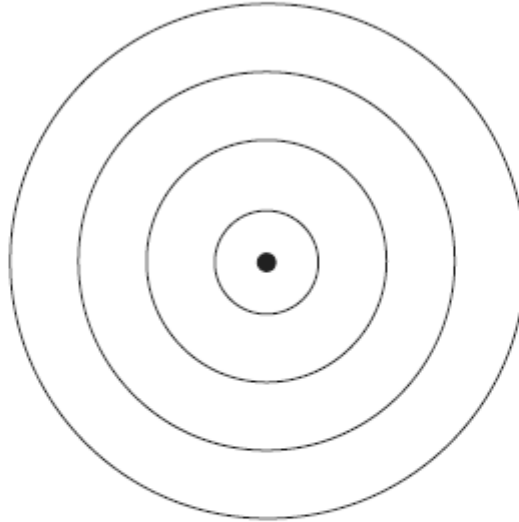
   (b)   (i)   What is a stepper motor?

           ....

           ....

      (ii)   Describe the sequence of signals that must be applied to a stepper motor in order for it to rotate.

           ....

            ....

            ....

            ....

            ....

            ....
                                                  (3 marks)

(c) In order to determine the rotation of a conventional motor an optical shaft encoder can be used.

(i) Complete the diagram of a 4-bit optical shaft encoder.

(ii) What is the smallest change in rotation that can be measured using a 4-bit optical shaft encoder?

....

(iii) What additional information about the rotation of a motor shaft is obtainable from an optical shaft encoder that would not be so easily available from an optical slotted disk encoder?

....

(4 marks)

AQA

Control System, Feedback   (ELE4, Q5, 2005)

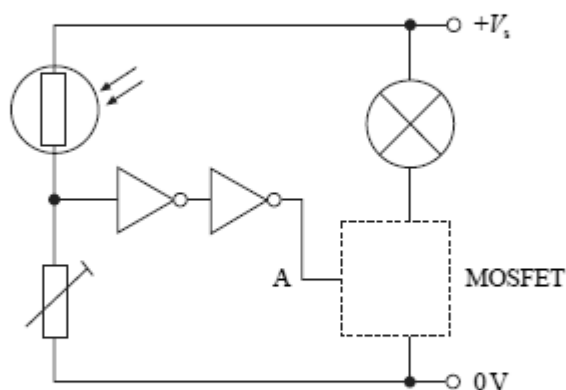5   (a)   Explain how an open loop control system differs from a closed loop control system.

....

....

....
(2 marks)

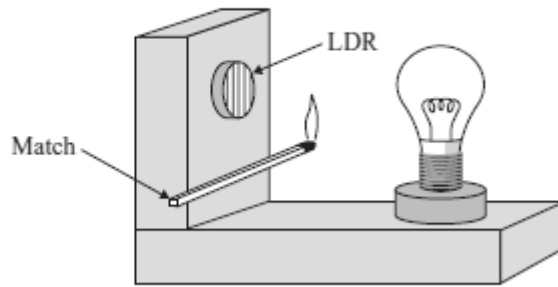(b)   The circuit diagram for an electronic control system is shown below.

(i)   Draw, in the dotted box on the circuit diagram above, the correctly connected symbol for a MOSFET.

(ii) Explain why point A is at logic 1 when the LDR is strongly illuminated.

....

....
(4 marks)

(c) The lamp and LDR are arranged as shown below.

When a lighted match is held near to the LDR, the lamp lights and remains lit even when the match is removed.

(i) State the type of feedback used in the system.

....

(ii) Explain why the lamp remains lit even when the match is removed.

....

....

(3 marks)

PICs/AVRs, Flow Charts   (ELE4, Q4, 2007)

4   Most domestic white goods appliances e.g. microwave ovens, washing machines, etc
contain control systems that use microcontrollers e.g. PICs or AVRs.

(a)   Explain why such microcontrollers are often described as a "system on a chip".

....

....

(2 marks)

(b)   Manufacturers used to use electromechanical controllers in domestic appliances. What
two fundamental benefits do manufacturers now gain from using microcontrollers in
such appliances?

....

....

(2 marks)

(c)   State **one** significant difference between the architecture of a PIC/AVR and that of a
traditional computer system.

....

....

(1 mark)

(d)   To use a microwave oven, the food to be heated is placed inside the oven. The power
level is set and then the cooking time is entered. These are both shown on a display
panel.
When the "Start" button is pressed, the microwave generator is switched on and the
microcontroller starts to time the process, updating the display with the time left, every
second. At the end of the timing period, the microwave generator is switched off, a
buzzer sounds for 5 seconds and the display reads "Remove Food".
Draw a flow chart on **page 11** for the control program that performs this sequence of
operations within the microcontroller of the oven.

(4 marks)

Buses, Tri-State, ADC   (ELE4, Q1, 2006)

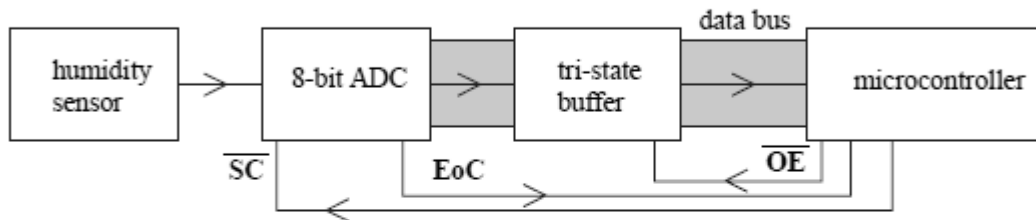1   A microcontroller system has an 8-bit data bus.
    (a)   Explain the meaning of the terms

        (i)   bit, ...

        (ii)   data bus. ....

(2 marks)

In order to connect an analogue humidity sensor to the microcontroller, the arrangement below is used.

SC is the Start Conversion, **OE** is the Output Enable and **EoC** is the End of Conversion.

(b)   (i)   What is the function of the tri-state buffer?

        ....

    (ii)   What must the microcontroller do in order to read information from the ADC?

        ....

(2 marks)

(c)   (i)   Why is an ADC needed in this application?

        ....

    (ii)   What sequence of signals is required between the microcontroller and the ADC for the microcontroller to make a humidity reading?
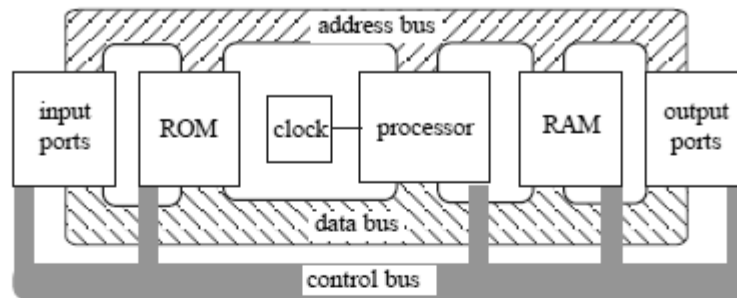
        ....

        ....

        ....

(4 marks)

(d)   The humidity range is 0% to 100%. What is the smallest change in humidity that can be measured by this 8-bit system?

    ....

(1 mark)

Microprocessor Control System   (ELE4, Q1, 2005)

1   The sub-system diagram of a general purpose microcontroller system for controlling industrial processes is shown below.

(a)   What is the function of the clock?

....
(1 mark)

(b)   Explain why the data bus has to be bidirectional.

....

....
(1 mark)

(c)   Which sub-system:

(i)   contains the Arithmetic Logic Unit; ....

(ii)   is most likely to contain the control program code; ....

(iii)   is used for the temporary storage of information; ....

(iv)   writes information onto the address bus? ....
(4 marks)

(d)   The address bus is 12-bit and the data bus is 8-bit. What is the maximum amount of memory that can be addressed directly by the system?

....
(1 mark)

(e)   Explain why memory mapping the input and output ports would reduce the maximum amount of memory that could be addressed.

....

....

....
(2 marks)

Optical Shaft Encoder   (ELE4, Q1, 2009)

1   The binary optical shaft encoder shown below is attached to a motor.
     A white space represents a logic 0 and a black space represents a logic 1.
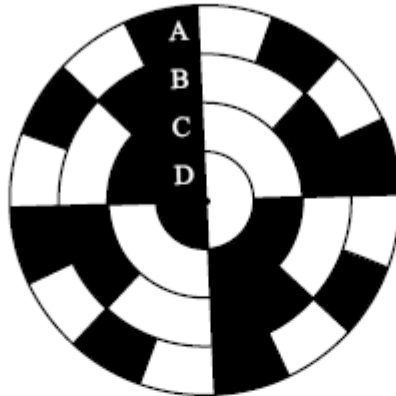
1   (a)   Explain why the inner ring, D, represents the most significant bit of the binary value.

     ....

     ....

     ....
                                                                                                              (2 marks)

1   (b)   (i)   Show, by calculation, that the angular resolution of the encoder is 22.5°.

            ....

            ....

1   (b)   (ii)   How many rings would be needed if the angular resolution were to be
                    approximately 2.8°?

            ....

            ....
                                                                                                              (2 marks)

1 (c) The binary output from the encoder when the motor is stationary is 1011. The motor rotates and after 0.1 s the binary output is 0110.

1 (c) (i) What is the smallest angle that the motor could have rotated through?

....

....

1 (c) (ii) Explain whether the direction of rotation is clockwise or anticlockwise.

....

....

1 (c) (iii) If the motor continues to rotate at this rate, calculate its speed in revolutions per second.

....

....

(5 marks)

AQA

Optical Shaft Encoder, Slotted Disk Encoder, Stepper Motor   (ELE4, Q4, 2008)

4   To sense the angular rotation of a conventional motor, a designer can either use an optical shaft encoder or a slotted disk.

Optical shaft encoder   Slotted disk
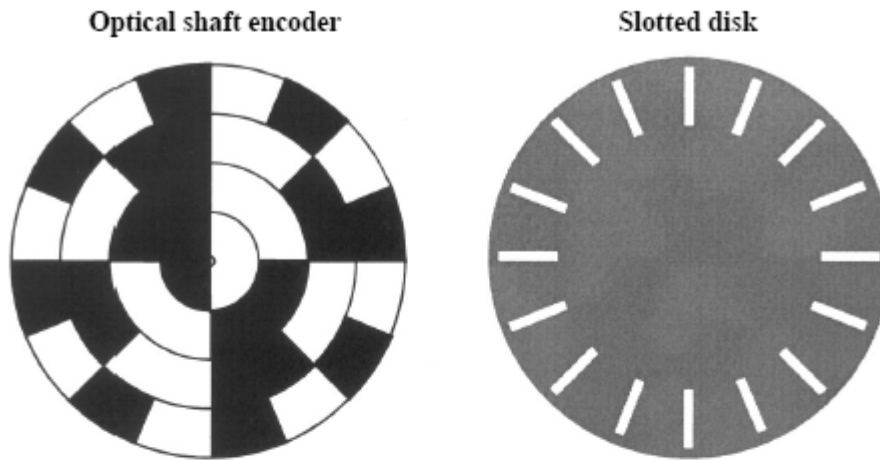
4   (a)   (i)   What is the angular resolution of the slotted disk shown in the diagram above?

....

4   (a)   (ii)   What is the angular resolution of the optical shaft encoder shown in the diagram above?

....

4   (a)   (iii)   Explain how the angular resolution of the optical shaft encoder could be increased.

....

....

(3 marks)

4   (b)   The slotted disk, when operated with a single LED and light sensor, provides information about how far the disk has rotated. What additional information can be obtained when an optical shaft encoder is used?

....

....

(2 marks)

4 (c) The photograph below shows part of the read head control mechanism for a CD-ROM drive.
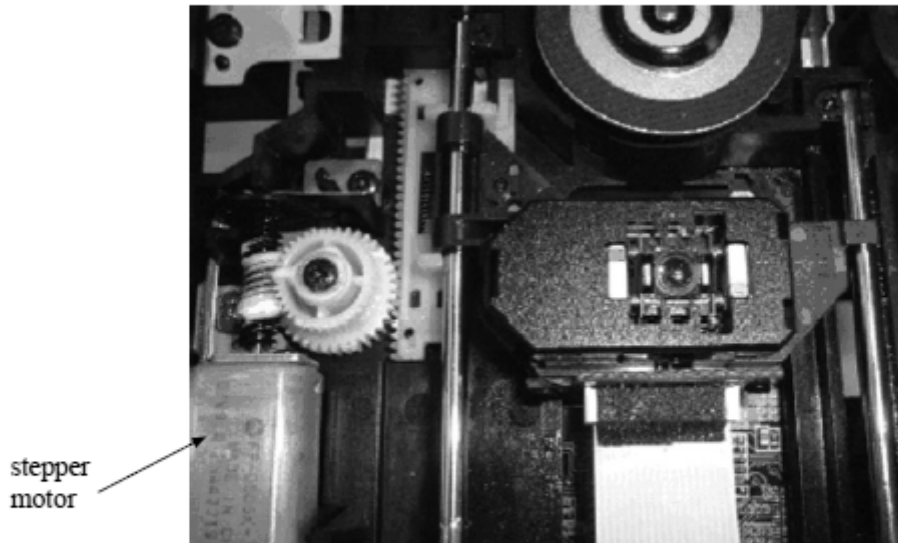
stepper
motor

The position of the head is controlled by a stepper motor in the bottom left-hand corner of the photograph. Give two reasons, with supporting explanations, why a conventional motor would not be suitable for controlling the position of the CD-ROM drive head.

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....

....

....

....

....

(4 marks)

AQA

Ramp ADC, DAC   (ELE4, Q2, 2007)

2 Dynamic fingerprint readers are being increasingly used for access control on computer systems. In use, the finger tip is slowly dragged across the reader, which consists of a line of reflecto-optical sensors, as shown below.

reflecto-optical sensor

LED
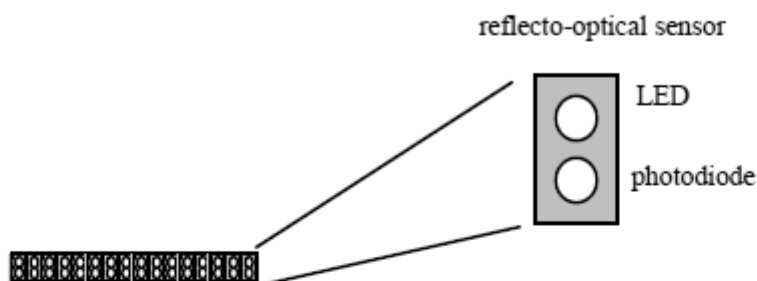
photodiode

Each photodiode in the line of sensors is connected to an op-amp buffer circuit as shown below.

photodiode

1 MΩ

+12 V

output

0 V

−12 V
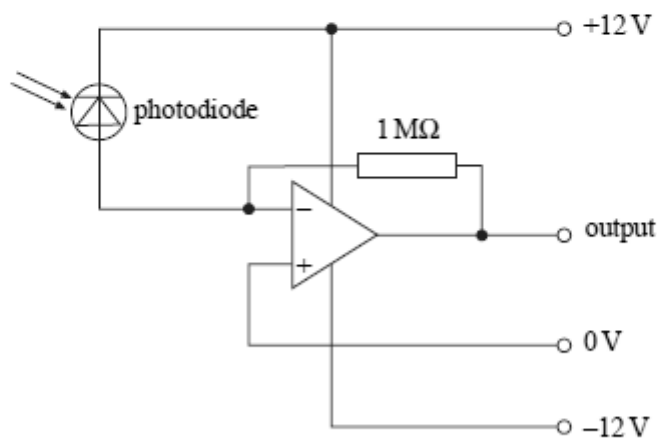
(a) In the dark, the leakage current of the photodiode can be assumed to be $0\,\mu A$.

(i) What will be the output voltage of the circuit when the photodiode is in the dark?

....

(ii) Calculate the output voltage when the photodiode leakage current is $3\,\mu A$.

....

....

(3 marks)

(b) The output of each buffer circuit is converted into a binary number using an 8-bit digital ramp ADC which contains an 8-bit DAC and a comparator.

    (i) What property of an op-amp makes it suitable to function as a comparator?

....

    (ii) How many different input voltage levels can be uniquely detected with an 8-bit ADC?

....

                                                   (2 marks)

(c) The DAC is made using an op-amp, arranged as a summing amplifier. Part of the circuit diagram is shown below. D_0 is the least significant bit.
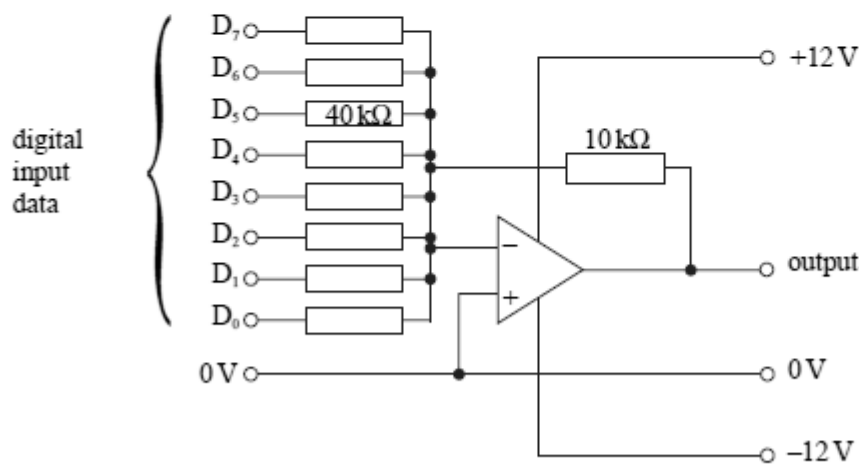
    (i) Calculate the values for the resistors for the D_6 and D_1 inputs.

....

....

    (ii) If a logic 1 input to the DAC is +5 V and a logic 0 is 0 V, calculate the output voltage from the DAC when D_5 is logic 1 and all of the other inputs are logic 0.

....

....

                                                   (4 marks)

Flash ADC   (ELE4, Q3, 2005)

3   (a)   State one advantage and one disadvantage of a flash ADC (Analogue to Digital Converter) compared to a digital ramp ADC.

....

....
(2 marks)

(b)   The circuit diagram for a 3-bit flash ADC is shown below.
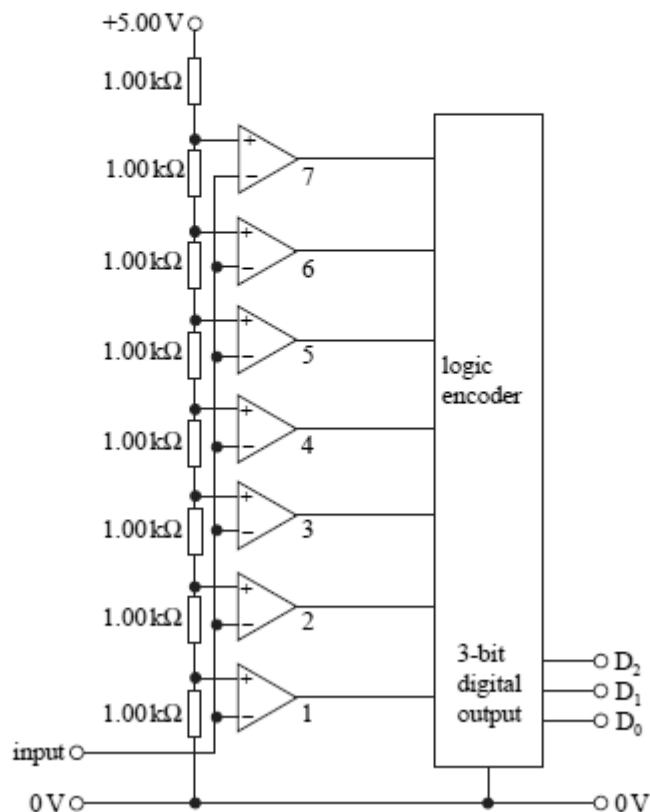
(i)   Calculate the resolution of the ADC.

....

(ii)   What is the function of each op-amp?

....

(iii)   Calculate the number of op-amps required for a 12-bit flash ADC?

....

....
(3 marks)

(c) Complete the truth table for the logic encoder.

logic encoder output			output of op-amps						
D_2	D_1	D_0	1	2	3	4	5	6	7
0	0	0	0						
0	0	1	1						
0	1	0	1						
0	1	1	1						
1	0	0	1						
1	0	1	1						
1	1	0	1						
1	1	1	1						

(2 marks)

(d) Draw a logic circuit to encode the outputs from the op-amps to output D_1.

(2 marks)

AQA

ADC, Tri-State   (ELE4, Q6, 2005)

6   An Analogue to Digital Converter (ADC) has three control lines:

EoC   End of Conversion

$\overline{OE}$ Output Enable for tristate buffer

$\overline{SC}$ Start Conversion

(a)   (i)   Explain what is meant by a tristate buffer.

....

....

(ii)   Explain why a tristate buffer is necessary for interfacing the ADC to the data bus of a microprocessor system.

....

....

(iii)   Under what conditions will $\overline{OE}$ be logic 0.

....

(3 marks)

(b)   Draw a flow diagram for a program which continuously reads analogue data into a microprocessor system.

(4 marks)

(c)   State two factors which limit the speed of conversion of a digital ramp ADC.

....

....

(2 marks)

Opto-Switch, Schmitt-Trigger, Stepper Motor   (ELE4, Q7, 2005)

7   An infrared reflective switch is used to maintain constant speed of rotation of the tape head in a video recorder.
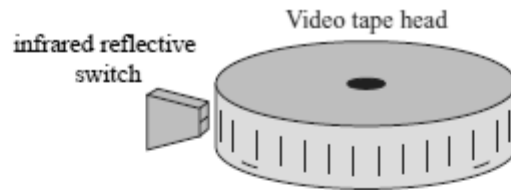
(a)   The diagram for the infrared LED circuit is shown below. The forward voltage of the LED is 1.5 V and its maximum current is 20 mA. It is operated from a 12 V supply.
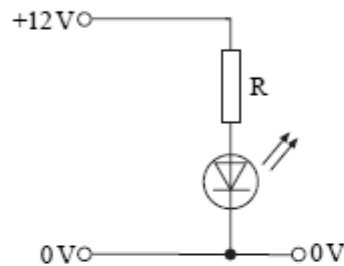
Calculate a suitable preferred value for the resistor, R.

(3 marks)

(b)   The photodiode circuit is shown below.
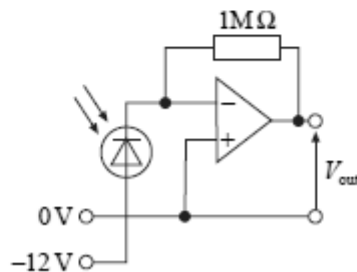
The photodiode current in the dark is 0.1 μA and in the light is 6 μA.

(i)   Show that the output voltage when the photodiode is in the light is +6 V.

(ii)   Calculate the output voltage when the photodiode is in the dark.

(3 marks)

QUESTION 7 CONTINUES ON THE NEXT PAGE

AQA

(c) The resulting signal from the photodiode op-amp is noisy and is shown in the graph below.
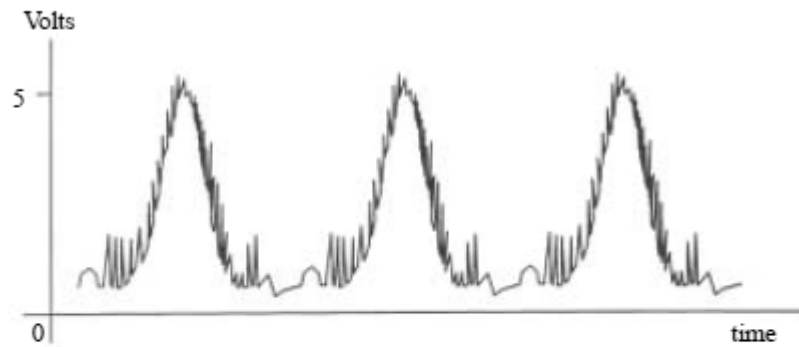
The signal is cleaned using a Schmitt trigger circuit.
Explain why a Schmitt trigger is able to clean the signal.

....

....

(2 marks)

(d) The Schmitt trigger circuit is shown below.
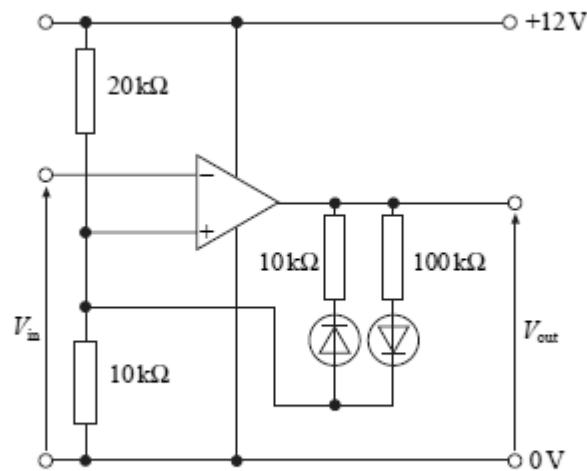
Assume that the op-amp is ideal and the diodes have no forward voltage drop and zero reverse leakage current.

Estimate, showing your working:

    (i)   the lower switching voltage;

....

....

    (ii)   the upper switching voltage.

....

....

(4 marks)

(e) It is suggested that if the tape head were driven by a stepper motor then the quantity of electronics would be reduced and the speed of rotation would be more accurate.

    (i)   What is a stepper motor?

....

....

    (ii) Would a stepper motor reduce the quantity of electronics needed, and would the speed of rotation be more accurate? Justify your answer.

....

....

....

....

....

....

(6 marks)

AQA

Stepper Motor   (ELE4, Q3, 2007)

3 Motorised control valves are extensively used in the chemical industry to remotely control the rate of flow of reactants and products within a chemical plant. The motors used on these valves can be either stepper motors or conventional motors.

   (a) Compare the following characteristics of the two types of motor.

        (i)   The number of electrical connections

        ....

        ....

        ....

        ....

        (ii) Accuracy of rotational movement

        ....

        ....

        ....

        ....

                                                                                               (4 marks)

   (b) A unipolar stepper motor has five connections. One is a common connection and is connected to the positive power supply.
        The other four connections are labelled, in order, A, B, C and D.
        When the current passing through coil A is switched to pass through coil B, the motor armature rotates 7.5° clockwise. What will the armature do if:

        (i)   the current is switched back to coil A,

        ....

        (ii) the current is then switched from coil A, to coil B, to coil C, to coil D and then to coil A?

        ....

        ....

                                                                                               (3 marks)

(c) Explain how the stepper motor armature could be made to rotate continuously.

....

....

(1 mark)

(d) Explain how the speed of rotation of the stepper motor armature can be varied.

....

....

(1 mark)

AQA

Dot-Matrix Display, Data Latches   (ELE4, Q5, 2006)

5   (a)   Give **one** advantage and **one** disadvantage of a dot matrix display over a seven-segment display.

....

....

(2 marks)

(b)   A seven by five LED matrix display is to be operated by a computer.
The circuit diagram of the matrix display is shown below.

$R \equiv ROW$

$C \equiv COLUMN$
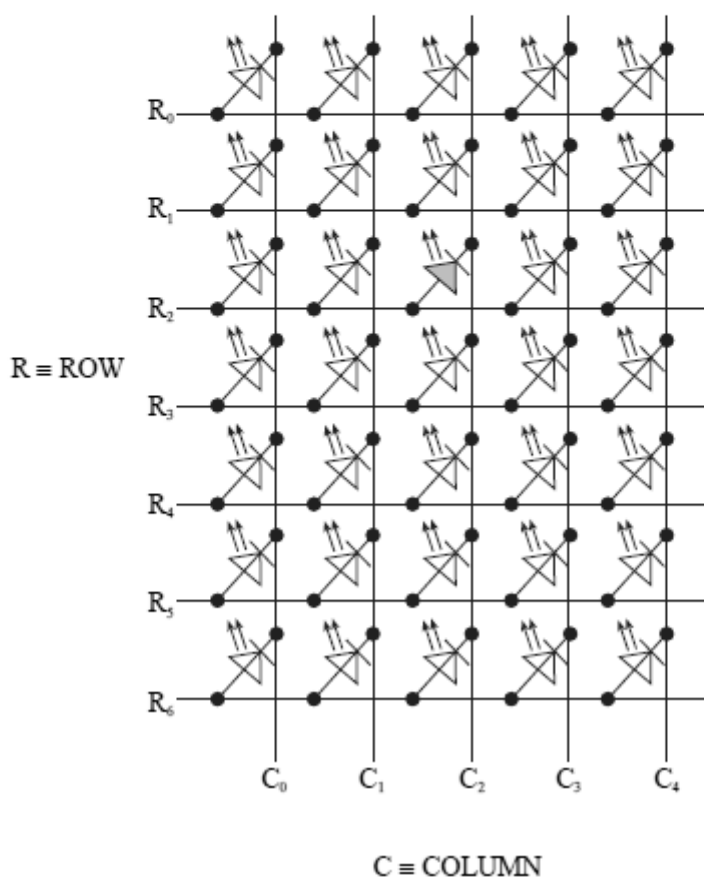
Explain how the LED shaded in the diagram above can be lit.

....

....

(2 marks)

Question 5 continues on the next page

(c) The interface circuit for the dot matrix display is shown below.
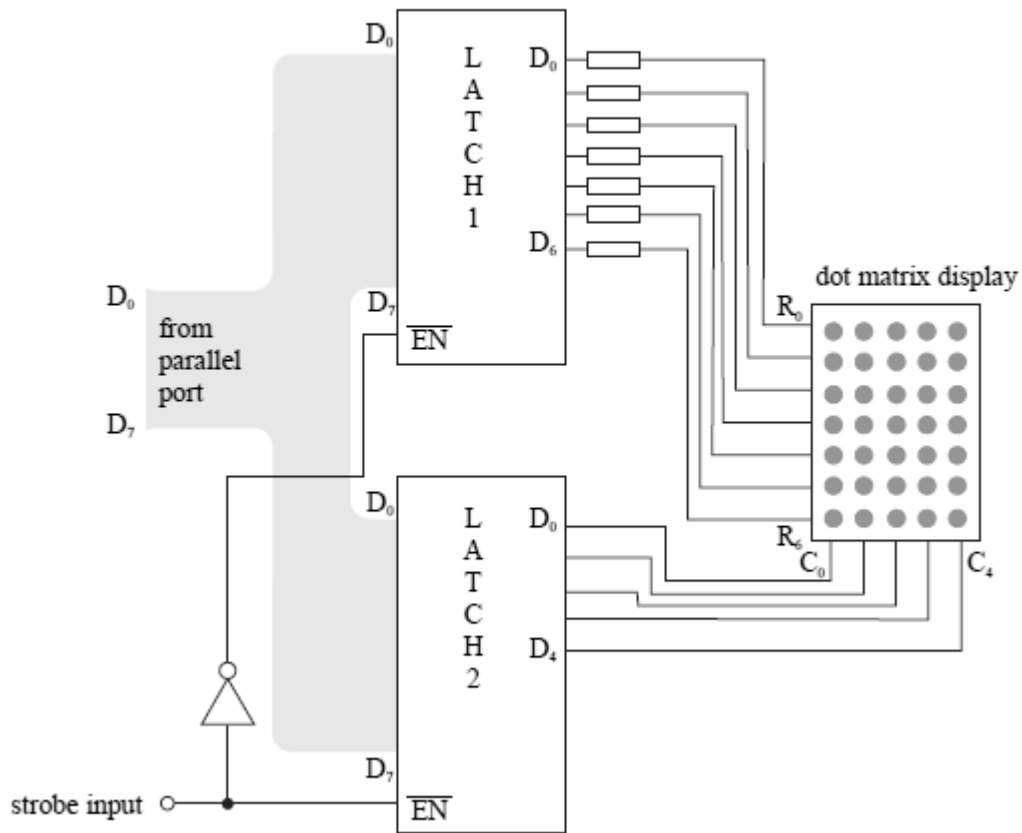
(i) Explain the function of the latches used in this application.

....

....

....

....

(ii) Explain which latch is written to when the strobe input is at logic 1.

....

....

(iii) List, in sequence, the binary values that must be written to the COLUMN latch in order for the display to be scanned once.

....

....

(3 marks)

(d) The letter A is to be displayed on the dot matrix display as shown below.
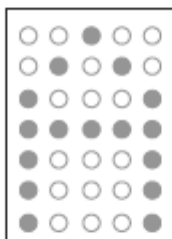
List, in sequence, the binary values that must be written to the ROW latch.

....

....

....

(2 marks)

Opto-Switch, Schmitt Trigger   (ELE4, Q4, 2009)

4   A photocopier uses reflective opto-switches to detect the presence of paper in the print path, so that it can track the movement of the paper and also detect paper jams. Such a switch is shown below together with its circuit symbol.
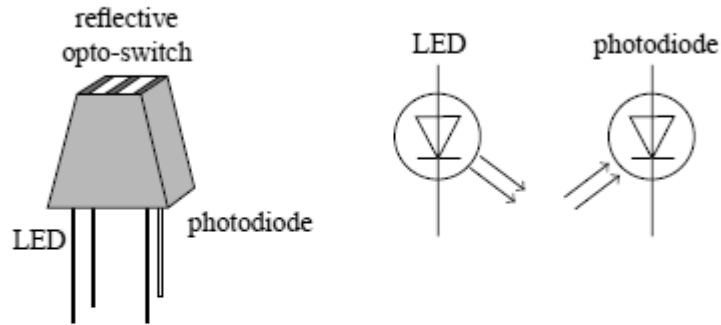
4   (a)   The LED has a forward voltage of 1.6 V at its maximum working current of 25 mA. The LED is powered from a 5 V supply. Using a calculation, select a preferred value for the series resistor.

                                                                                          (3 marks)

4 (b) The photodiode is used in the circuit below with an inverting Schmitt trigger. The input switching voltages are 2.1 V and 2.7 V.
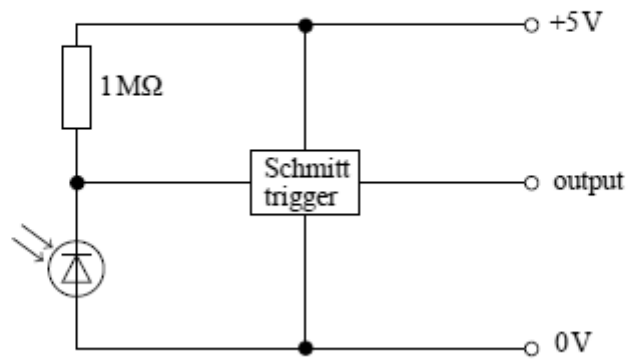
Complete the graph of the input and output voltages for the Schmitt trigger in this circuit.
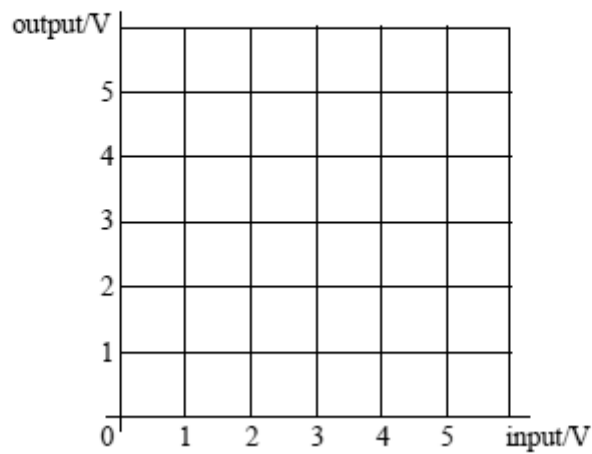
(4 marks)

4 (c) Explain whether the output of the Schmitt trigger is high or low when there is paper across the reflective opto-switch.

....

....

....

(2 marks)

Schmitt Trigger   (ELE4, Q2, 2008)

2 In the circuit diagram below the op-amp is functioning as a comparator.
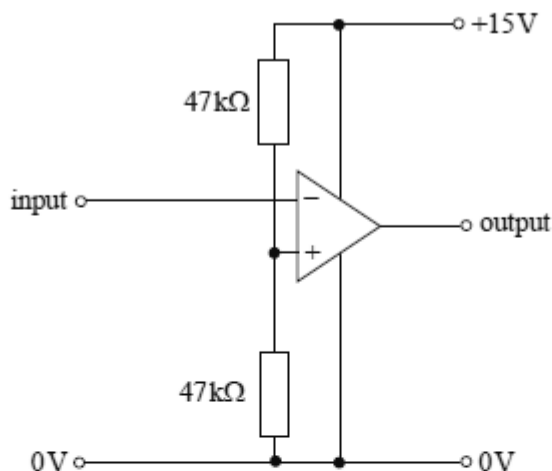
2 (a) (i) What property of an op-amp makes it suitable for use as a comparator?

....

2 (a) (ii) For an ideal op-amp, what range of input voltages is needed to make the output saturate at +15V?

....

(2 marks)

2 (b) When a 47kΩ resistor is added to the circuit, as shown below, the range of input voltages needed to make the output saturate at +15V changes.
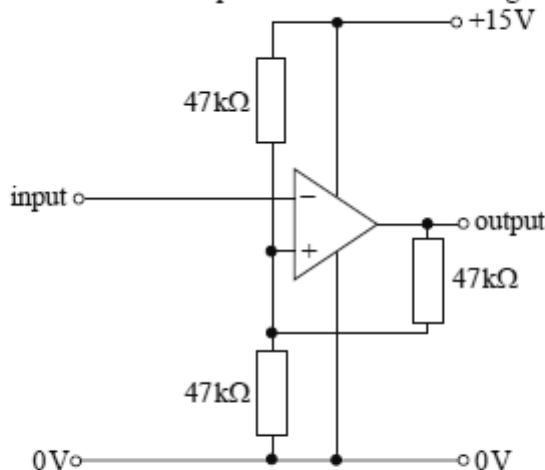
2 (b) (i) Show, by calculation, that if the output is +15V, the input must be less than +10V.

....

....

AQA

2 (b) (ii) Show, by calculation, that the input voltage must be greater than +5 V for the output to be 0 V.

....

....

(3 marks)

2 (c) On the axes below, sketch a graph to show how the output voltage varies with the input voltage.
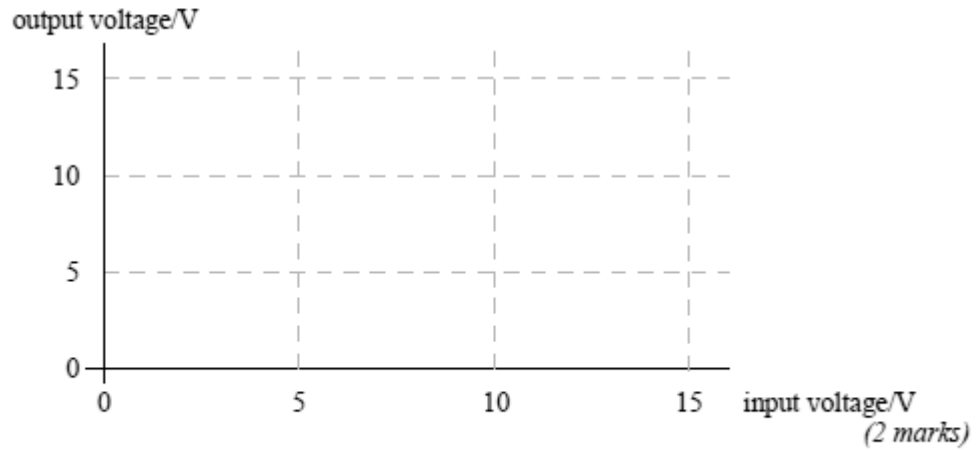
(2 marks)

2 (d) A capacitor and resistor are added to the circuit as shown in the diagram below.
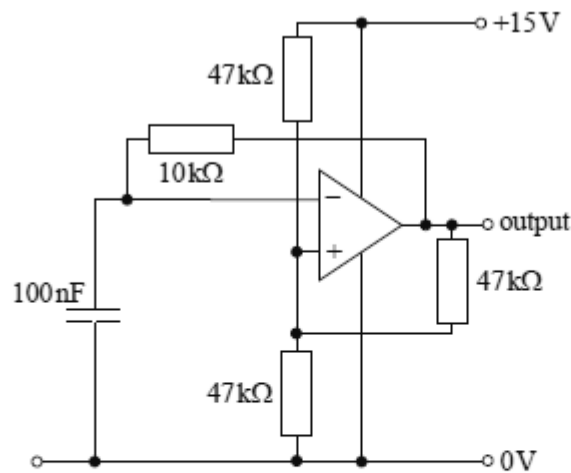
Hence, by comparison with a 555 timer, or otherwise, calculate the time period of the pulses from the output of the circuit.

....

....

(2 marks)

Schmitt Trigger   (ELE4, Q6, 2007)

6   Many manufacturers of switches for use on keyboards are experimenting with using capacitor switches, since they are more robust than traditional switches. A system diagram for such a switch is shown below.
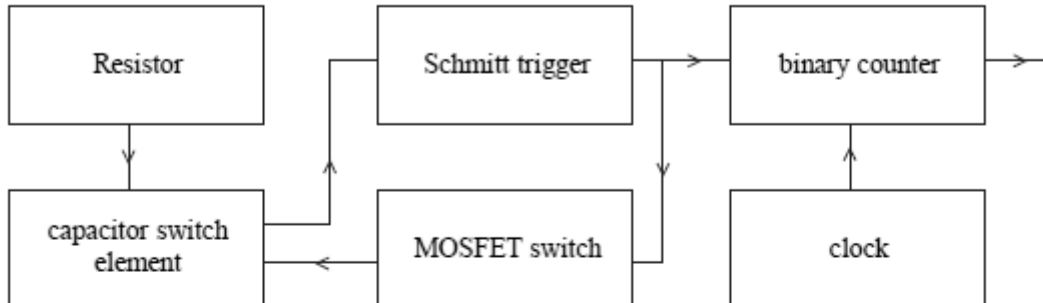
The capacitor switch element charges through the resistor.
When the voltage across the element exceeds a certain value, the Schmitt trigger turns on the MOSFET switch which fully discharges the capacitor, allowing the process to repeat.
The frequency of the process is recorded by the binary counter. When a finger is near the capacitor switch element, the capacitance of the element increases and the frequency decreases. This enables the system to detect whether the switch is being pressed or not.
The circuit diagram for part of the capacitor switch system is shown below.
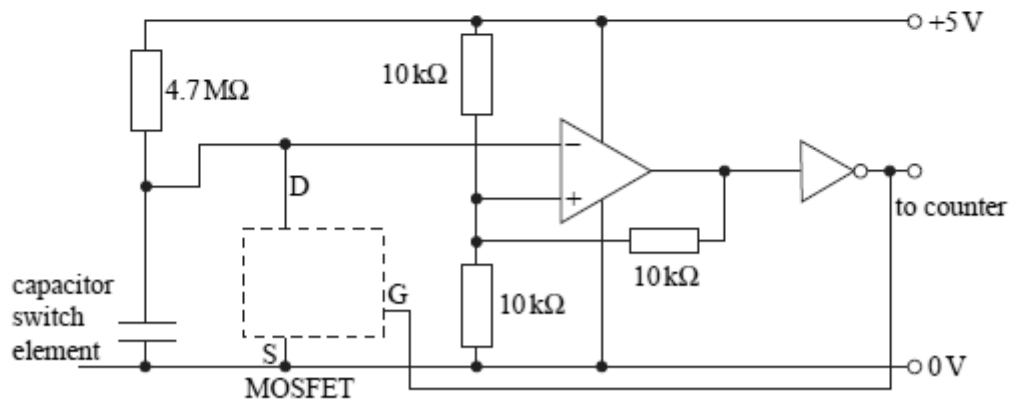
(a)   Draw the symbol for the MOSFET in the space provided on the circuit diagram.

(2 marks)

(b)   (i)   Show that the upper switching level for the Schmitt trigger is 3.33 V.

....

....

(ii)   Calculate the lower switching level for the Schmitt trigger.

....

....

(4 marks)

(c) (i) In the absence of anyone touching the capacitor switch element it has a capacitance of 30 pF.
Calculate the time constant for the capacitor switch element and its charging resistor.

....

....

(ii) What will be the voltage across the capacitor switch element one time constant after it has been fully discharged by the MOSFET?

....

(2 marks)

(d) Calculate the approximate frequency of oscillation of the system when no one is touching the switch.

....

....

(1 mark)

Neural Network   (ELE4, Q3, 2008)

3   A Network Attached Storage (NAS) system contains four 500 GB hard disk drives, which provide a total storage of 2 TB (2×10^{12} bytes). It is estimated that a human brain contains of the order of 10^{12} neurons. By considering the brain as a Neural Network, compare the brain and the NAS under the following headings

3   (a)   (i)   how the information is stored,

....

....

3   (a)   (ii)   total storage capacity,

....

....

3   (a)   (iii)   reliability of the stored information.

....

....

(3 marks)

3   (b)   In order to reduce the effects of global warming local authorities, are increasingly using Artificial Neural Network (ANN) systems to control traffic lights in order to optimise the flow of traffic.

3   (b)   (i)   Compare the processing of data in an ANN with that of a conventional computer.

....

....

....

3   (b)   (ii)   Explain why the control of traffic lights is better suited to an ANN than a conventional computer.

....

....

(4 marks)

3   (c)   Suggest, with a reason, an application for which an ANN would be unsuitable.

....

....

(2 marks)

Neural Network   (ELE4, Q5, 2007)

5 In order to comply with the Reduction of Hazardous Substances (RoHS) legislation, all electronic circuit manufacturers have switched to using lead free solder.
The joints produced by lead free solder can have more defects than those of leaded solder and so, to maintain the quality of production, manufacturers use video camera systems to examine the solder joints.
The data from the video cameras is often processed by a neural network.

   (a)   (i)   Where is the data stored within a neural network?

   ....

   ....

   (ii)   How do the processors in a neural network compare with those in a PC?

   ....

   ....

   (iii)   Explain how a neural network can be trained.

   ....

   ....

   ....

   ....

   (6 marks)

   (b)   Explain why a neural network is more suitable for this application than a traditional PC based system.

   ....

   ....

   ....

   (1 mark)

(c) Neural networks can be considered to consist of layers representing neurons.
There is always an input and an output layer and then one or more hidden layers.
Below is a representation of the input layer and the first of the hidden layers of a very simple neural network.
Mark on to the diagram lines to show the connections between the input layer neurons and those of the first of the hidden layers.
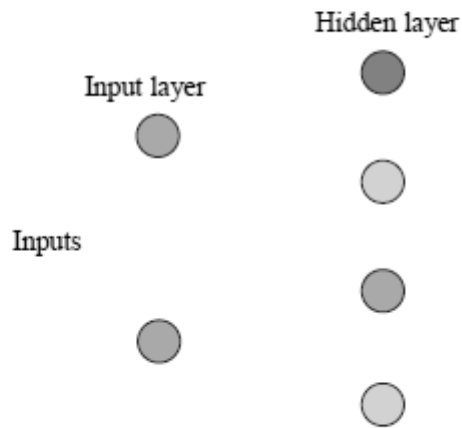
(2 marks)

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Teacher Resource Bank

GCE Electronics

Exemplar Exam Questions – Mark Scheme

- ELEC4: Programmable Control Systems

Control Systems, Feedback, Motor Driver, Flow Chart   (ELE4, Q5, 2008)

5   (a)   Closed loop + reason ✓

       (b)   (i)   Eliminate reverse voltages generated as the motor coils
                     switch off ✓

              (ii)

Input A	Input B	Motor
0	0	Stop – 0
0	1	Rotate in one direction – 1
1	0	Rotate in the other direction – 0
1	1	Stop – 0

                     First and last row ✓
                     Middle two rows ✓ ✓

       (c)   e.g.
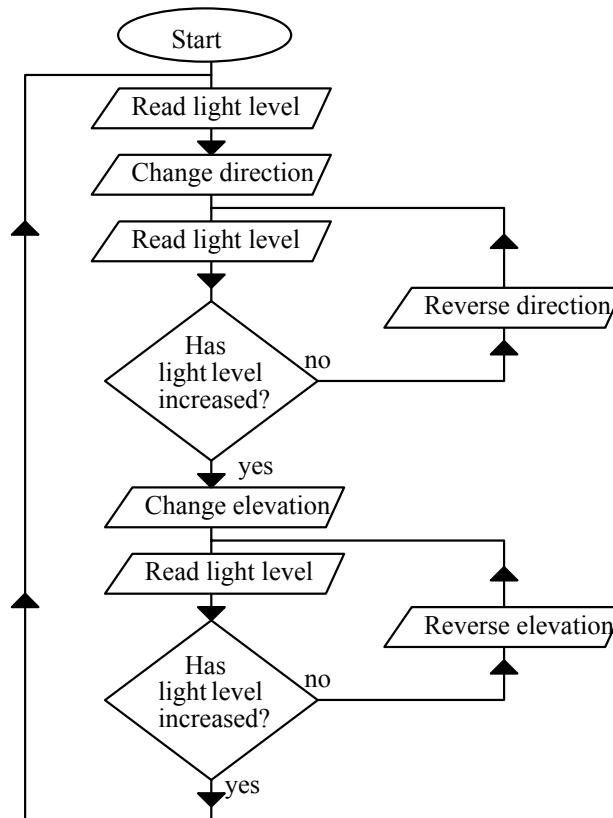
              Horizontal direction changes ✓
              Vertical direction changes ✓
              Appropriate elements to flow chart ✓
              Largely correct symbols ✓

                                                        Total – 9

Control System, Motor Driver   (ELE4, Q7, 2007)

7 (a) Closed loop system because there is feedback ✓

(1 mark)

(b) (i) correctly labelled virtual earth point on inverting input of op-amp ✓

(ii) top MOSFET labelled with N ✓

(iii) rudder and variable resistor rotate in other direction ✓

(iv) Diodes protect MOSFETs from induced high voltages from motor ✓

(4 marks)

(c) (i) Op-amp output goes negative ✓
so P channel MOSFET switches on ✓

(ii) $V_{out} = -100\left(\dfrac{3}{10} - \dfrac{2.75}{10}\right) = -2.5V$ ✓ ✓

(iii) This will reduce the speed of the motor ✓
since the voltage has decreased ✓

(iv) The motor will stop when there is no (very small) voltage across it ✓
which occurs when the voltage from the variable resistor is -3V ✓

(v) voltage from VR is -3V, ✓
output of summing amp goes positive, ✓
motor rotates in opposite direction until VR voltage is 0V ✓

(11 marks)

(d) bias MOSFETs into conduction, ✓
by an appropriate method e.g. voltage dividers to gates of MOSFETs ✓
include MOSFETs in the op-amp feedback loop ✓

(max 2 marks)
(Total 18 marks)

Control System, Stepper Motors, Optical Shaft Encoder   (ELE4, Q2, 2006)

2   (a)   open loop ✓
since there is no feedback from the direction of the beam of the
lamps to the control system ✓

(2 marks)

(b)   (i)   Stepper motor - a motor which moves in discrete steps ✓

(1 mark)

(ii)   Pulses of current are applied in sequence ✓
to the pairs of field coils ✓

(2 marks)

(c)   (i)   4-bit optical shaft encoder

✓✓
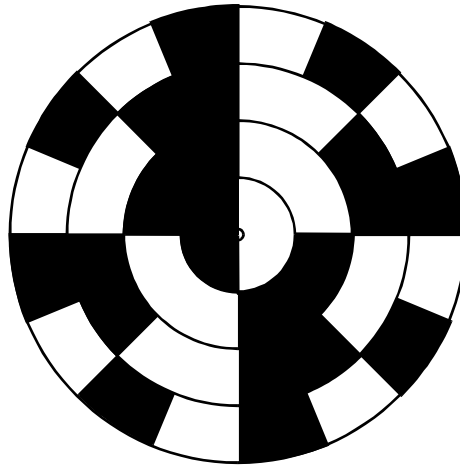
(2 marks)

(ii)   360 / 16 = 22.5° ✓

(1 mark)

(iii)   absolute position OR direction of rotation ✓

(1 mark)
(question total 9 marks)

Control System, Feedback   (ELE4, Q5, 2005)

5   (a)   An open loop system does not have any feedback ✓
so it is unable to monitor its own output unlike a closed
system which can ✓   (2 marks)

   (b)   (i)
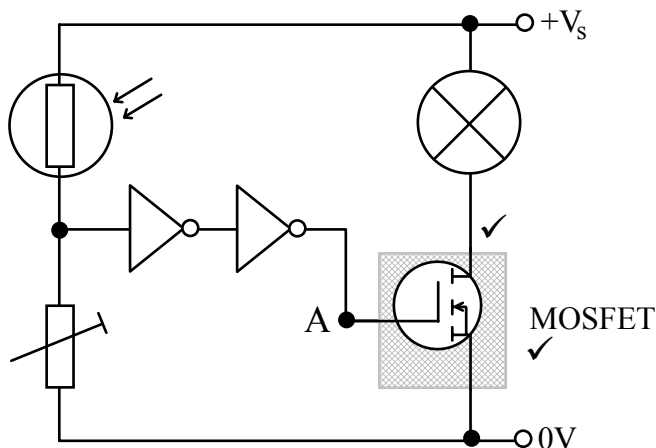
   (ii)   When the LDR is illuminated it has a low
resistance ✓
so input to first NOT gate is a logic 1 => point A is
logic 1 ✓   (4 marks)

   (c)   (i)   positive feedback ✓

   (ii)   light from the lamp falls onto the LDR which keeps
its resistance low ✓
this keeps point A at logic 1 and the lamp lit ✓   (3 marks)

Total 9 marks

PICs/AVRs, Flow Charts   (ELE4, Q4, 2007)

4   (a)   They contain ROM, RAM, CPU, I/O ports etc ✓
all formed onto a single piece of silicon ✓

(2 marks)

   (b)   Cheap to purchase ✓
Easily updated ✓
small physical size ✓
reliable - no moving parts etc ✓

(max 2 marks)

   (c)   Separate instruction bus ✓

(1 mark)

(d)   start
      input "power setting"
      output "power setting to power supply"
      input "cooking time"
      output "switch on magnetron" ✓
      output "display cooking time"
      wait one second
      decrement cooking time
      does cooking time remaining equal to zero - no
      yes ✓
      switch off magnetron
      output "Remove Food"
      output "turn on buzzer"
      has buzzer sounded for 5 seconds yes - stop ✓
      no
      stop
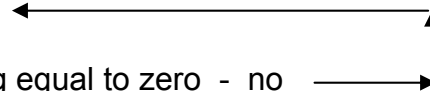
      ✓ for valid symbols

(4 marks)

(Total 9 marks)

Buses, Tri-State, ADC   (ELE4, Q1, 2006)

1   (a)   (i)   Binary digit; one binary piece of information ✓

        (ii)   Data bus - a set of wires connecting together all parts
             of a computer system and allowing data to flow in both
             directions along them ✓   *(2 marks)*

     (b)   (i)   To ensure that the ADC only puts data onto the data
             bus when the microcontroller is ready to receive it. ✓   *(1 mark)*

        (ii)   When microcontroller takes **OE** low. ✓   *(1 mark)*

     (c)   (i)   Output from humidity sensor is analogue and
             microcontroller needs digital. ✓   *(1 mark)*

        (ii)   Microcontroller takes **SC** low - so starting conversion
             process ✓
             When conversion finished **EoC** goes high ✓
             Microcontroller takes **OE** low and reads data ✓   *(3 marks)*

     (d)   readings to 1 in 256 (eight bits) =>resolution = 100/256
             = 0.39% ✓   *(1 mark)*
                                      (question total 9 marks)

Microprocessor Control System   (ELE4, Q1, 2005)

1   (a)   To keep all parts of the system synchronised ✓   (1 mark)

   (b)   Data has to travel to and from the processor along the data
        bus ✓   (1 mark)

   (c)   (i)   processor ✓

        (ii)   ROM ✓

        (iii) RAM ✓

        (iv)   processor ✓   (4 marks)

   (d)   Data bus uses 8 bits i.e. 1 byte at a time
        Address bus has 2^{12} different addresses => 4096 bytes
        can be addressed ✓   (1 mark)

   (e)   Memory mapping I/O ports places I/O ports in memory
        locations ✓
        so the amount of locations available for memory is
        reduced ✓   (2 marks)

                                                                    Total 9 marks

Optical Shaft Encoder   (ELE4, Q1, 2009)

1   (a)   Only changes once per revolution giving either a 0 or a 1, ✓
        The other rings give more changes than this and so represent less
        significant bits ✓

   (b)   (i)   360/16=22.5° ✓

        (ii)   360/2.8=128.5 => 7 rings ✓

   (c)   (i)   1011-0110 = 0101 = 5 ✓
               => angle = 5 x 22.5 = 112.5°   (90°) ✓

        (ii)   clockwise – because of rotating through the smallest
               angle etc ✓

        (iii) 112.5° in 0.1s ✓
               =>1125°/s = 3.125 revolutions per second   (2.5rps) ✓
                                                                    (9 marks)

Optical Shaft Encoder, Slotted Disk Encoder, Stepper Motor   (ELE4, Q4, 2008)

4   (a)   (i)   360 / 16 = 22.5° ✓

          (ii)   360 / 16 = 22.5° ✓

          (iii)   (Add more rings), each with twice as many divisions (bits)
                   as the previous ✓

        (b)   Absolute position and direction ✓ ✓

        (c)   e.g. Accuracy of rotation + explanation ✓ ✓
                Speed of response + explanation ✓ ✓

                                                                          Total – 9

Ramp ADC, DAC   (ELE4, Q2, 2007)

2   (a)   (i)   0V (since no current passes through the 1MΩ resistor) ✓

          (ii)   3μA passes through 1MΩ resistor so output voltage is - ✓
                   3V ✓

                                                                          (3 marks)

        (b)   (i)   Very large voltage gain ✓

          (ii) 2^8 => 256 ✓

                                                                          (2 marks)

        (c)   (i) D_6 is half of D_5 => 20kΩ ✓
                        D_1 is 640kΩ ✓

          (ii) V_{out} = -R_f { V / R } ✓
                   => V_{out} = -10 (5 / 40) = (-)1.25V ✓

                                                                          (4 marks)

                                                                      (Total 9 marks)

Flash ADC   (ELE4, Q3, 2005)

3   (a)   Flash ADC - very fast ✓
                Flash ADC - expensive ✓   (2 marks)

        (b)   (i)   5/8V (0.625V) ✓

          (ii)   comparator ✓

          (iii) $2^{12} - 1$ = 4095 ✓   (3 marks)

(c)

D$_2$	D$_1$	D$_0$	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	0	0
0	1	0	1	1	0	0	0	0	0
0	1	1	1	1	1	0	0	0	0
1	0	0	1	1	1	1	0	0	0
1	0	1	1	1	1	1	1	0	0
1	1	0	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1

✓ ✓ (2 marks)

(d)   e.g.

✓ ✓
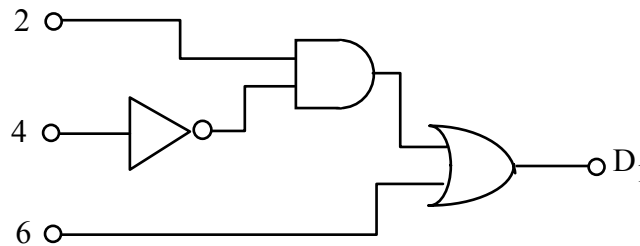
(2 marks)
Total 9 marks

ADC, Tri-State   (ELE4, Q6, 2005)

6   (a)   (i)   A tristate buffer has three possible output states, logic 1,0 and disconnected (high impedance) ✓

(ii)   To prevent bus contentions between the Microprocessor system and ADC (to enable the microprocessor to select when the data from the ADC is applied to the data bus) ✓

(iii)   When the ADC is writing to the data bus ✓   (3 marks)

(b) e.g.
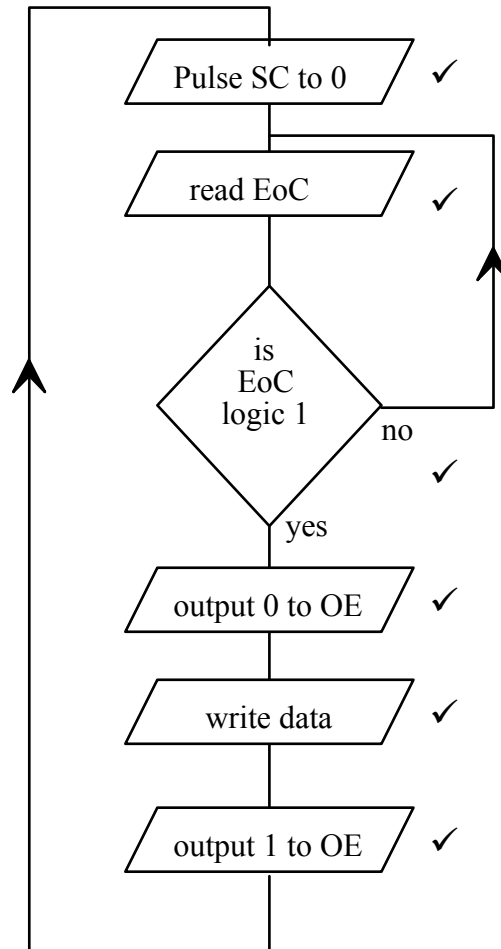
(4 marks)

(c)   e.g. speed of computer; the program; the number of bits
etc ✓ ✓   (2 marks)

Total 9 marks

Opto-Switch, Schmitt-Trigger, Stepper Motor   (ELE4, Q7, 2005)

7   (a)   voltage across R = 12 – 1.5 = 10.5V ✓
maximum current is 20mA => R = 10.5 / 0.02 = 525Ω ✓
=> suitable R = 560Ω ✓   (3 marks)

(b)   (i)   The inverting input of the op-amp is a virtual earth ✓
The 6µA passes through the 1MΩ resistor
=> the output will be 6V ✓

(ii)   Current in the dark is 0.1µA.
Output voltage is 10^{-7} x 10^6 = 0.1V ✓   (3 marks)

(c)   eliminates multiple (false) triggering ✓
by having two distinct switching levels ✓   (2 marks)

(d) (i) output low => 10kΩ resistor in parallel with 10kΩ resistor of voltage divider
combined resistance = 5kΩ ✓
lower voltage = (12 x 5) / (20 + 5) = 2.4V ✓

      (ii) output high => 100kΩ resistor in parallel with 20kΩ resistor of voltage divider => combined resistance = 16.67kΩ ✓
upper voltage = (12 x 10) / (26.67) = 4.5V ✓   (4 marks)

(e) (i) A stepper motor has a set of stator coils and a permanent magnet armature.
When adjacent coils are sequentially energised the armature turns through a defined angle ✓ ✓

      (ii) Answer should include:
discussion of control electronics needed for conventional motor
(photo sensor, pulse generator reference signal, phase comparator, error amplifier, buffer) ✓
discussion of control electronics needed for stepper motor (pulse generator, counter, decoder, buffer per coil) ✓
less electronics needed for stepper motor ✓
speed of rotation more constant with stepper motor because the speed is only dependent upon the speed the pulses are applied to the coils (so long as load is not too great or the pulses too fast) ✓ etc   (6 marks)

Total 18 marks

Stepper Motor (ELE4, Q3, 2007)

3 (a) (i) Conventional motor - 2 connections ✓
(allow credit for mention of separate field windings etc)
Stepper motor - at least 4 connections ✓

      (ii) Conventional motor has no control over accuracy of rotation ✓
Stepper motor - angle of rotation accurate ✓

                                (4 marks)

(b) (i) Armature moves 7.5° anticlockwise ✓

      (ii) The armature moves 7.5° each time the current is switched to the next coil so armature rotates 30°, ✓ clockwise ✓

                                  (3 marks)

(c)   To rotate the current has to be continuously switched, in order, to coils A, B, C and D ✓

(1 mark)

(d)   The speed of rotation can be changed by varying the time that the current passes through each coil (or delay between advancing current to next coil) ✓

(1 mark)

(Total 9 marks)

Dot-Matrix Display, Data Latches   (ELE4, Q5, 2006)

5   (a)   Advantages - e.g.   seven segment display easier to drive, brighter ✓
Disadvantages - e.g.   seven segment displays produce limited characters ✓

(2 marks)

(b)   R2 positive with respect to C2 ✓
by the forward voltage of the LED ✓

(2 marks)

(c)   (i)   Top latch stores the row address, bottom latch stores the column address ✓

(1 mark)

(ii)   When strobe at logic 1, the top latch is written to ✓

(1 mark)

(iii)   XXX11110, XXX11101, XXX11011, XXX10111, XXX01111 ✓

(1 mark)

(d)   X1111100, X0001010, X0001001, X0001010, X1111100 ✓✓

(2 marks)
(question total 9 marks)

Opto-Switch, Schmitt Trigger   (ELE4, Q4, 2009)

4   (a)   V across R = 3.4V, ✓
R = 3.4/0.025 = 136Ω, ✓
Preferred value = 150Ω ✓

(b)
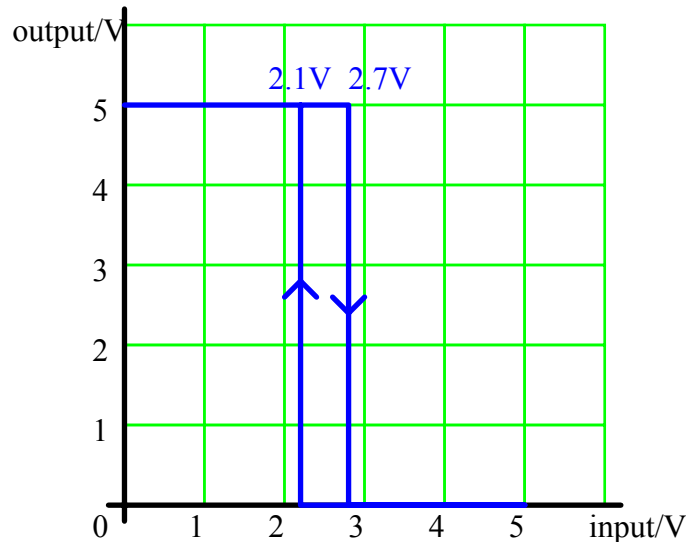
Has two switching levels, ✓
output goes low when upper level is exceeded, ✓
output goes high when input goes below the lower switching
level, ✓
diagram completed correctly ✓

(c)   Paper present so light reflected, ✓
photodiode conducts making input of NOT gate logic 0 so
output is logic 1 ✓

(9 marks)

Schmitt Trigger   (ELE4, Q2, 2008)

2   (a)   (i)   Very large open loop voltage gain ✓

(ii) V_{in} must be between 0V and 7.5V ✓

(b)   (i)   Feedback resistor in parallel with top 47kΩ resistor
giving 23.5kΩ ✓
=> voltage at non-inverting input terminal is 10V ✓
=> for output to be at +15V, the input voltage must be
less than 10V ✓   (max 2)

    (ii)   Feedback resistor in parallel with bottom 47kΩ resistor giving 23.5kΩ
=> voltage at non-inverting input terminal is 5V
=> for output to be at 0V, the input voltage must be greater than 5V ✓

(c)
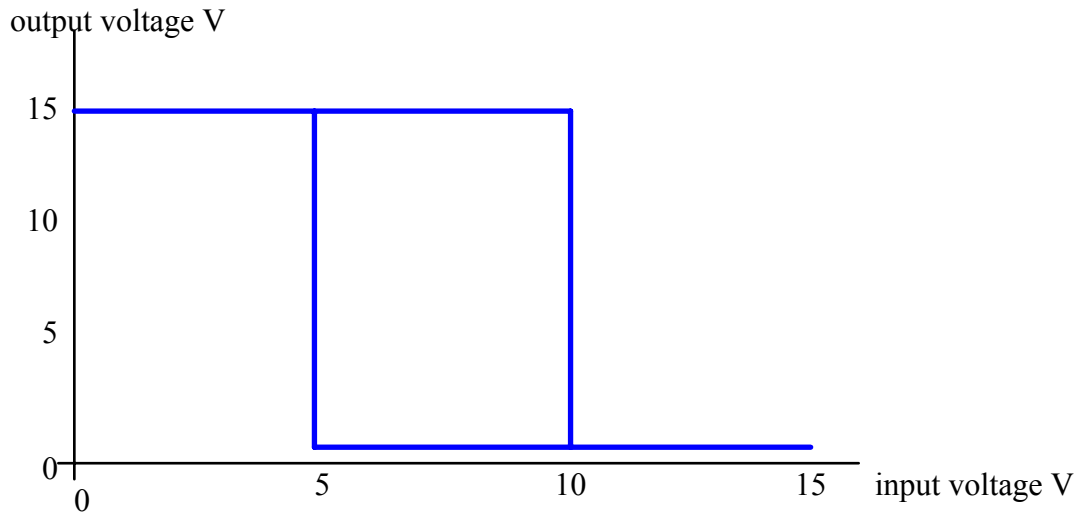
General shape ✓
Correct switching levels ✓

(d)   (Capacitor charges and discharges between $\frac{1}{3}$ and $\frac{2}{3}$ of supply voltage)
(This is the same as the 555 timer)
=> T = 1.4 R C ✓
=> T = $1.4 \times 10^4 \times 10^{-7}$ = 1.4ms ✓

Total – 9

Schmitt Trigger   (ELE4, Q6, 2007)

6   (a)   Accurate MOSFET symbol ✓ correctly positioned ✓

(2 marks)

    (b)   (i)   When output of op-amp high, top resistor of voltage divider is effectively 5kΩ so voltage split in ratio 1:2 ✓
=> voltage at non-inverting input of op-amp is 3.33V ✓

           (ii)   When output of op-amp low, bottom resistor of voltage divider is effectively 5kΩ so voltage split in ratio 2:1 ✓
=> voltage at non-inverting input of op-amp is 1.67V ✓

(4 marks)

    (c)   (i)   T = C R = $4.7 \times 10^6 \times 30 \times 10^{-12}$ = 1.41×10^{-4}s ✓

(ii)   63% of 5V = 3.15V ✓

(2 marks)

(d)   Recognition of charging between $^1/_3$ and $^2/_3V_s$ taking 0.69RC so giving a frequency of 10.3kHz ✓

(1 mark)

(Total 9 marks)

Neural Network   (ELE4, Q3, 2008)

3   (a)   (i)   e.g. Information is stored in the connections between neurons
in an ANN whereas it is stored at specific locations in the NAS ✓

(ii)   e.g. The NAS is limited by the number of locations at which to store information
The ANN is essentially unlimited since there are so many possible interconnections between neurons ✓

(iii)   e.g. The information in a NAS is more reliable than an ANN since connections between neurons are not stable, while that of the magnetic field is (relatively) ✓

(b)   (i)   e.g. ANN information processed in parallel by many neurons, in a computer it is processed in a few processors serially ✓ ✓

(ii)   e.g. ANNs can learn and adapt to maximise traffic flow, whereas PCs cannot. ✓ ✓

(c)   e.g. ANNs unsuitable for applications which require precision since they operate essentially through probability (fuzzy logic). ✓ ✓

Total – 9

Neural Network   (ELE4, Q5, 2007)

5 (a) (i) connections between neurons, ✓
weighting attached to each connection ✓

(ii) ANN - simple but lots of them ✓
compared to few but complex ✓

(iii) When the ANN compares its output with the required
output for a set of inputs and adjusts the weightings etc
of the inputs to create a match ✓
Programmed by providing examples of outputs that
should be gained from given sets of inputs and allowing
the ANN to adjust its neuron weightings ✓

(6 marks)

(b) PCs better at matching for exact items whereas ANNs are
Better to interpret the input data to find patterns ✓

(1 mark)

(c) lines joining each input layer neuron to each neuron in the
hidden layer ✓✓

(2 marks)

(Total 9 marks)