Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

ELECTRONICS **ELE4**
Unit 4 Electronic Control Systems

Tuesday 12 June 2007 1.30 pm to 3.00 pm

For this paper you must have:
- a calculator
- a pencil and a ruler.

Time allowed: 1 hour 30 minutes

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- A *Data Sheet* is provided on pages 3 and 4. Detach this perforated sheet at the start of the examination.

Information
- The maximum mark for this paper is 72.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- Any correct electronics solution will gain credit.
- You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use			
Question	Mark	Question	Mark
1		5	
2		6	
3		7	
4			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Data Sheet

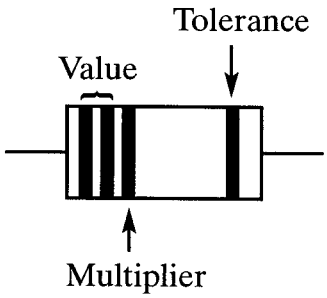
- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- Detach this perforated sheet at the start of the examination.

Resistors Preferred values for resistors (E24) series:
1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1 ohms and multiples that are ten times greater.

Resistor Printed Code (BS 1852) This code consists of letters and numbers:
R means $\times 1$
K means $\times 1000$ (i.e. 10^3)
M means $\times 1\,000\,000$ (i.e. 10^6)
Position of the letter gives the decimal point
Tolerances are given by the letter at the end of the code, F = ± 1%, G = ± 2%, J = ± 5%, K = ± 10%, M = ± 20%.

Resistor Colour Code

Number	Colour
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White



Tolerance, gold = ± 5%, silver = ± 10%, no band ± 20%.

Silicon diode $V_F = 0.7\,V$

Silicon transistor $V_{be} \approx 0.7\,V$ in the on state
$V_{ce} \approx 0.2\,V$ when saturated

Resistance $R_T = R_1 + R_2 + R_3$ series

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ parallel

Capacitance $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ series

$C_T = C_1 + C_2 + C_3$ parallel

Time constant $T = CR$

A.C. theory $I_{rms} = \frac{I_o}{\sqrt{2}}$

$V_{rms} = \frac{V_o}{\sqrt{2}}$

$X_C = \frac{1}{2\pi fC}$ reactance

$X_L = 2\pi fL$ reactance

$f = \frac{1}{T}$ frequency, period

$f_o = \frac{1}{2\pi\sqrt{LC}}$ resonant frequency

Turn over ▶

Operational amplifier

$$G_V = \frac{V_{out}}{V_{in}} \quad \text{voltage gain}$$

$$G_V = -\frac{R_f}{R_1} \quad \text{inverting}$$

$$G_V = 1 + \frac{R_f}{R_1} \quad \text{non-inverting}$$

$$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right) \quad \text{summing}$$

Astable and Monostable using NAND Gates

$$f \approx \frac{1}{2RC} \quad \text{astable}$$

$$T \approx RC \quad \text{monostable}$$

555 Astable and Monostable

$$T = 1.1RC \quad \text{monostable}$$

$$\left.\begin{aligned} t_H &= 0.7(R_A + R_B)C \\ t_L &= 0.7R_BC \end{aligned}\right] \quad \text{astable}$$

$$f = \frac{1.44}{(R_A + 2R_B)C} \quad \text{two resistor circuit}$$

Electromagnetic Waves

$$c = 3 \times 10^8 \text{ m s}^{-1} \quad \text{speed in vacuo}$$

List of BASIC Commands

DIM variable [(subscripts)]

DO [{**WHILE** | **UNTIL**} condition]
    [statement block]
LOOP

DO
    [statement block]
LOOP [{**WHILE** | **UNTIL**} condition]

FOR counter = start **TO** end [**STEP** increment]
    [statement block]
NEXT counter

GOSUB [label | line number]
    [statement block]
RETURN

IF condition **THEN**
    [statement block 1]
ELSE
    [statement block 2]

INKEY$

INP (port %)

INPUT [;] ["prompt" {;1, }] variable list (comma separated)

LPRINT [expression list] [{ ;1, }]

OUT port%, data%

PRINT [expression list] [{;1,}]

REM remark

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

1 A computer system is used to log data from an industrial process.
Below are several subroutines from the program that runs within the computer system.

(a) **service1:**
X% = INP(&H379)
X% = X% AND &HF8
RETURN

(i) What is the function of the first line **service1:** ?

.....

(ii) What is the function of the second line **X% = INP(&H379)** ?

.....

(iii) What is the function of the complete subroutine?

.....

.....

(*4 marks*)

(b) **service2:**
FOR N% = 1 TO T%
IF INKEY$ = CHR$(27) THEN END
NEXT N%
RETURN

(i) Explain why this subroutine can be used to create a time delay.

.....

.....

.....

(ii) How can this delay be changed?

.....

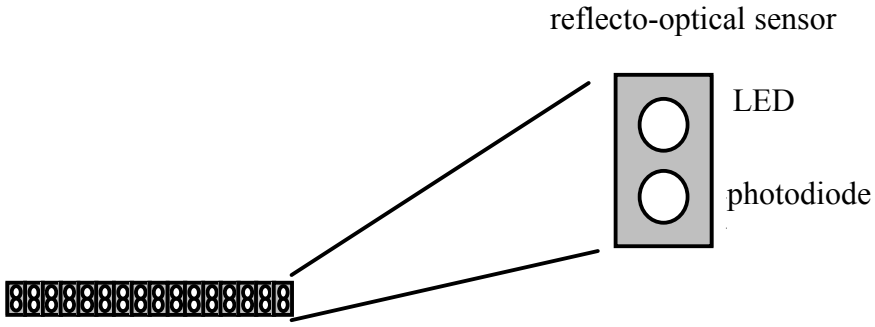
(iii) State **two** ways in which this subroutine can end or return control to the main program.

.....

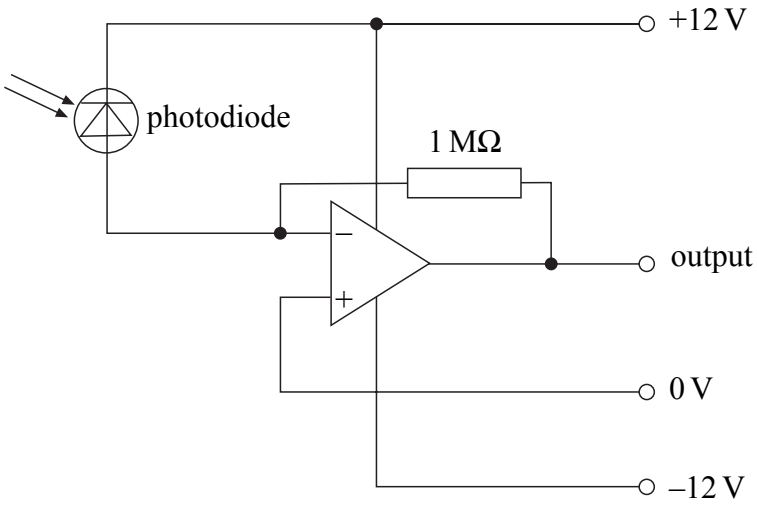
.....

(5 marks)

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.



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



(a) In the dark, the leakage current of the photodiode can be assumed to be 0 μA.

(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 μA.

.....

.....

(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?

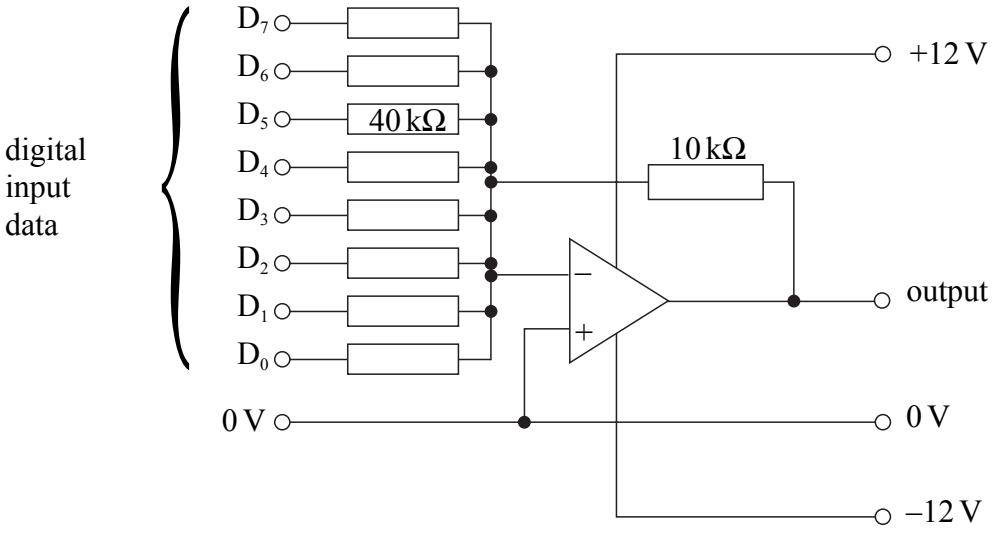
.....

(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)

9

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 7.5º 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)

9

Turn over for the next question

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*)

9

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.

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.....

(6 marks)

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

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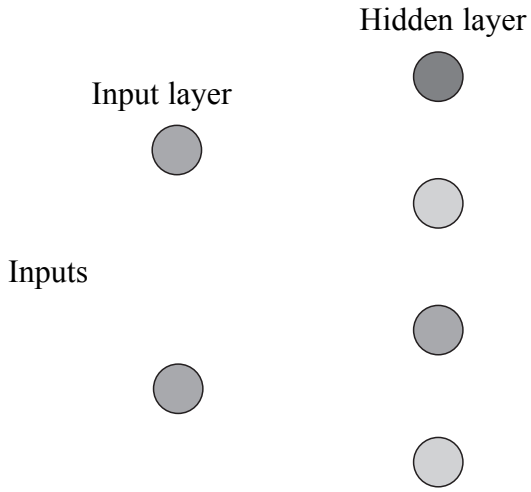
(1 mark)

(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.

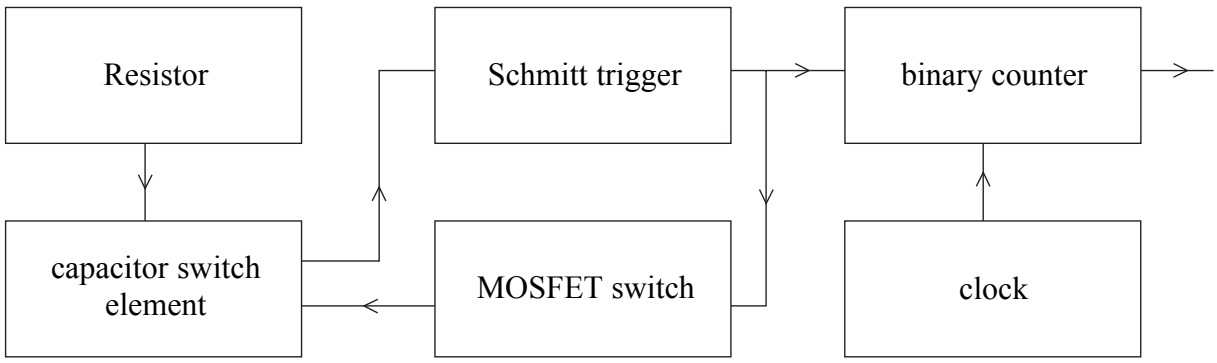


(*2 marks*)

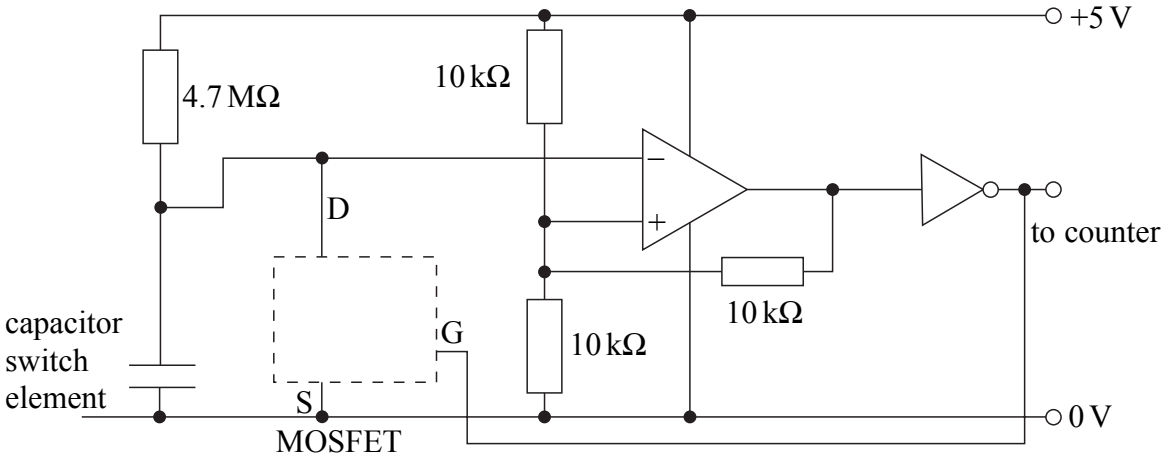
9

Turn over for the next question

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.

.....

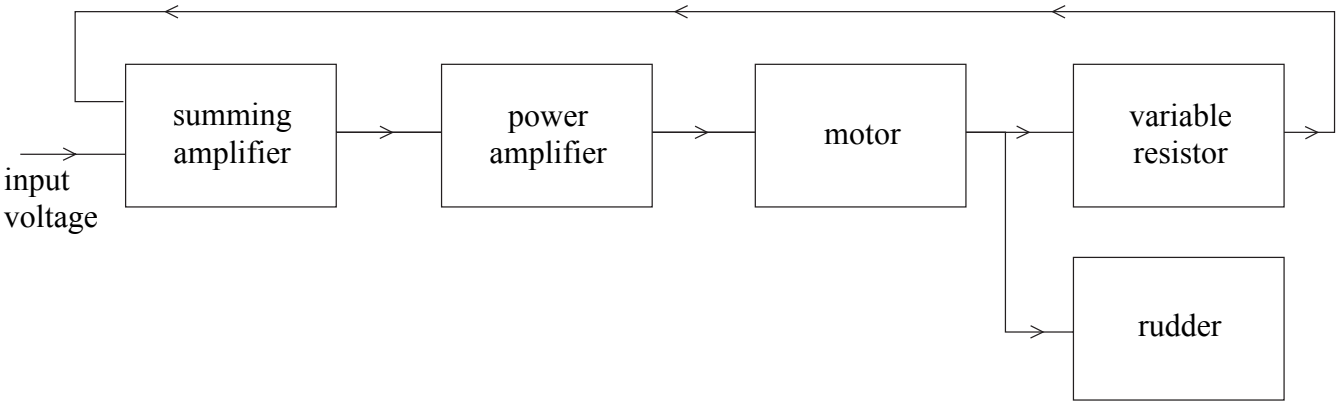
.....

(1 mark)

9

Turn over for the next question

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.

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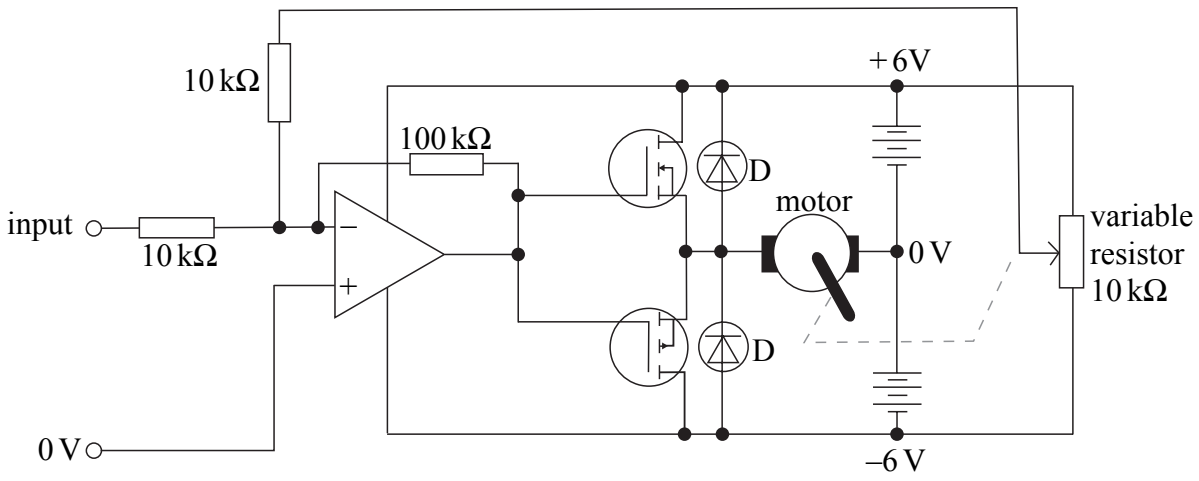
(1 mark)

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.

(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.

.....

.....

.....

(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?

.....

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.....

(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.

.....

.....

.....

(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)

18

END OF QUESTIONS

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