OCR

Thursday 5 June 2014 – Afternoon

A2 GCE ELECTRONICS

F614/01 Electronic Control Systems

Candidates answer on the Question Paper.

OCR supplied materials:
None

Other materials required:
- Scientific calculator

Duration: 1 hour 40 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **110**.
- You will be awarded marks for your Quality of Written Communication.
- You are advised to show all the steps in any calculations.
- This document consists of **20** pages. Any blank pages are indicated.

A scientific calculator may be used for this paper

Microcontroller instructions

The microcontroller contains eight general purpose registers Sn, where n = 0, 1, 2 ... 7.
The microcontroller has an eight bit input port, I, an eight bit output port, Q, and an analogue input, ADC.

In the table of assembler instructions given below, Sd is the destination register and Ss the source register.

assembler	function
MOVI Sd,n	Copy the byte n into register Sd
MOV Sd,Ss	Copy the byte from Ss to Sd
ADD Sd,Ss	Add the byte in Ss to the byte in Sd and store the result in Sd
SUB Sd,Ss	Subtract the byte in Ss from the byte in Sd and store the result in Sd
AND Sd,Ss	Logical AND the byte in Ss with the byte in Sd and store the result in Sd
EOR Sd,Ss	Logical EOR the byte in Ss with the byte in Sd and store the result in Sd
INC Sd	Add 1 to Sd
DEC Sd	Subtract 1 from Sd
IN Sd,I	Copy the byte at the input port into Sd
OUT Q,Ss	Copy the byte in Ss to the output port
JP e	Jump to label e
JZ e	Jump to label e if the result of the last ADD, SUB, AND, EOR, INC, DEC, SHL or SHR was zero
JNZ e	Jump to label e if the result of the last ADD, SUB, AND, EOR, INC, DEC SHL or SHR was not zero
RCALL s	Push the program counter onto the stack to store the return address and then jump to label s
RET	Pop the program counter from the stack to return to the place the subroutine was called from
SHL Sd	Shift the byte in Sd one bit left putting a 0 into the lsb
SHR Sd	Shift the byte in Sd one bit right putting a 0 into the msb

There are three subroutines provided:

- readtable – copies the byte in the lookup table pointed at by S7 into S0. The lookup table is labelled table: When S7=0 the first byte from the table is returned in S0
- wait1ms – waits 1ms before returning
- readadc – returns a byte in S0 proportional to the voltage at ADC

Datasheet

Unless otherwise indicated, you can assume that:

- op-amps are run off supply rails at +15V and –15V
- logic circuits are run off supply rails at +5V and OV.

resistance	$R = \frac{V}{I}$
power	$P = VI$
series resistors	$R = R_1 + R_2$
time constant	$\tau = RC$
monostable pulse time	$T = 0.7RC$
relaxation oscillator period	$T = 0.5RC$
frequency	$f = \frac{1}{T}$
voltage gain	$G = \frac{V_{out}}{V_{in}}$
open-loop op-amp	$V_{\text{out}} = A(V_+ - V_-)$
non-inverting amplifier gain	$G = 1 + \frac{R_f}{R_\text{d}}$
inverting amplifier gain	$G = -\frac{R_f}{R_{in}}$
summing amplifier	$-\frac{V_{out}}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} \ldots$
break frequency	$f_0 = \frac{1}{2\pi RC}$
Boolean Algebra	$\text{A}.\overline{\text{A}} = 0$ $\text{A} + \overline{\text{A}} = 1$
	$\text{A}.(\text{B} + \text{C}) = \text{A}.\text{B} + \text{A}.\text{C}$
	$\overline{\text{A}.\text{B}} = \overline{\text{A}} + \overline{\text{B}}$ $\overline{\text{A} + \text{B}} = \overline{\text{A}}.\overline{\text{B}}$
	$\text{A} + \text{A}.\text{B} = \text{A}$ $\text{A}.\text{B}. + \overline{\text{A}}.\text{C} = \text{A}.\text{B} + \overline{\text{A}}.\text{C} + \text{B}.\text{C}$
amplifier gain	$G = -g_\text{m}R_\text{d}$
ramp generator	$\Delta V_{out} = -V_{in}\frac{\Delta t}{RC}$

Answer **all** questions.

1 A circuit containing a MOSFET analogue switch connected to a loudspeaker is shown in Fig. 1.1. Fig. 1.2 shows the characteristics of the MOSFET.

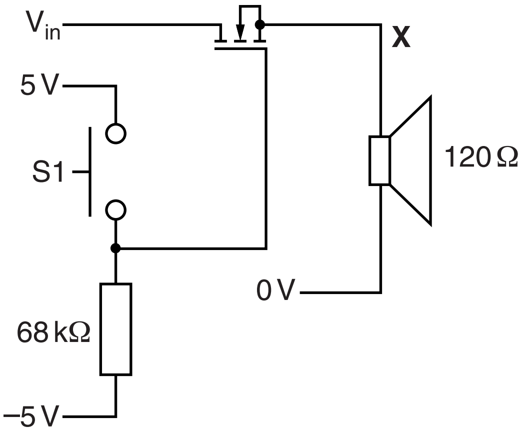


Fig. 1.1

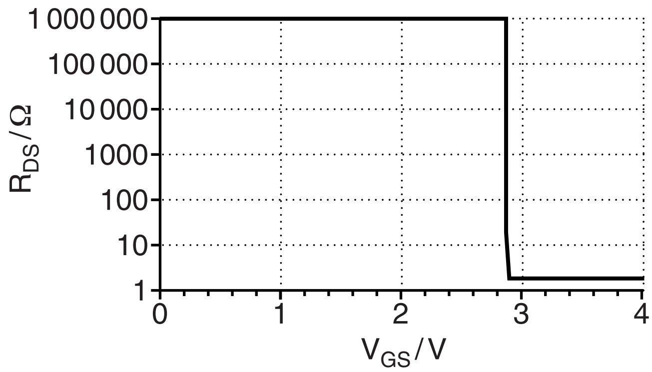


Fig. 1.2

(a) Use the graph to find the threshold voltage of the MOSFET.

threshold voltage = ... V **[1]**

(b) Fig. 1.3 shows the sound signal at V_{in}.

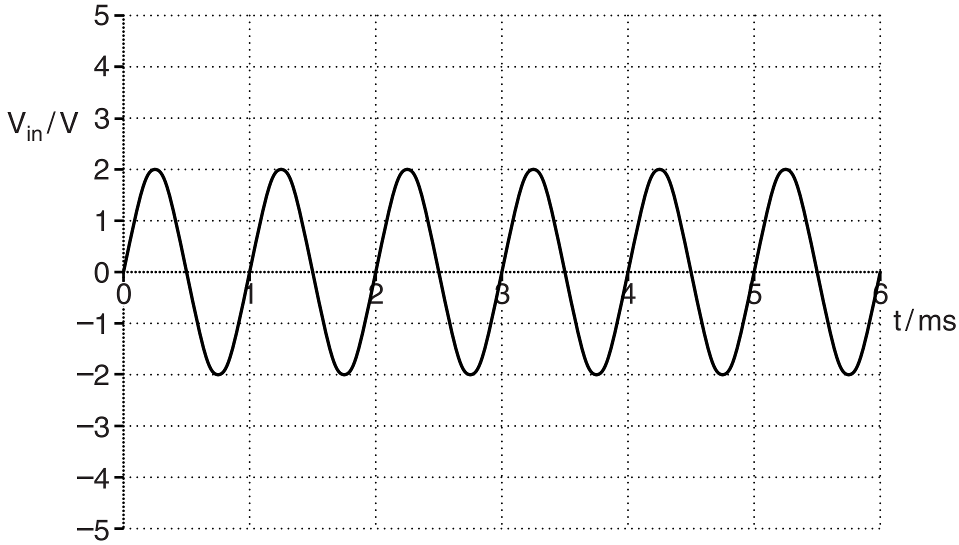


Fig. 1.3

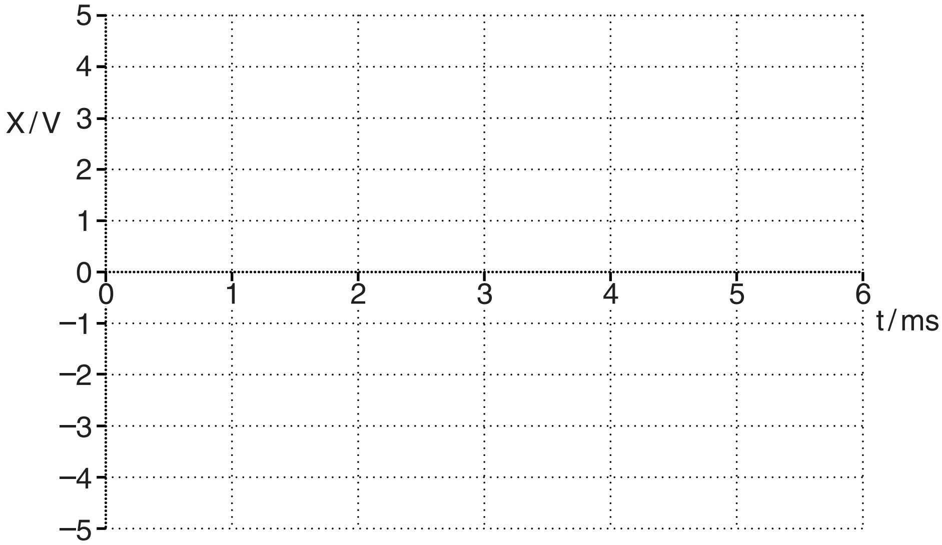
(i) Explain why there is no sound from the speaker in Fig 1.1 when the switch is **not** pressed.

....

....

.... **[3]**

(ii) The switch is not pressed to start with. At 4 ms the switch is pressed and held down. Draw on the axes below to show how the voltage at **X** in Fig. 1.1 varies with time.



[3]

[Total: 7]

2 Shift registers can be used for processing digital information.

(a) Draw the circuit diagram for a six-bit serial-in parallel-out shift register.
Label the serial input, outputs and clock.

[5]

(b) The diagram in Fig. 2.1 shows two numbers being EORed using shift registers. The LSB is at serial out, the information shifts on the rising edge of the clock.

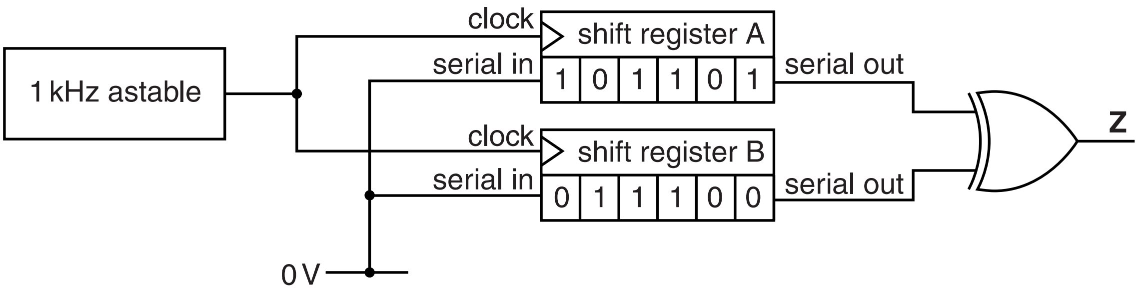
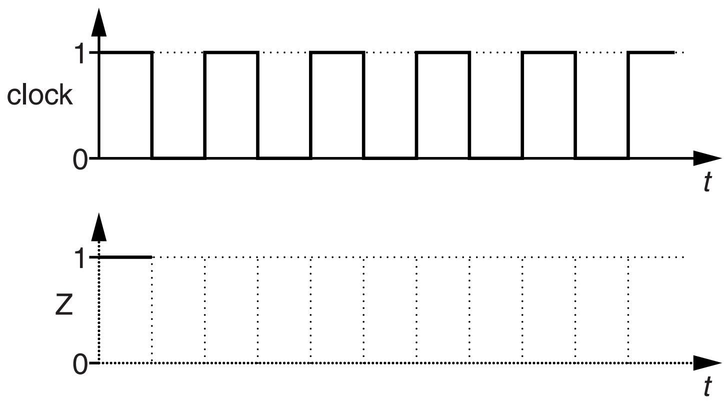


Fig. 2.1

(i) Complete the timing diagram to show the signal at **Z**.



[3]

(ii) State the binary number that is output at Z in Fig. 2.1.

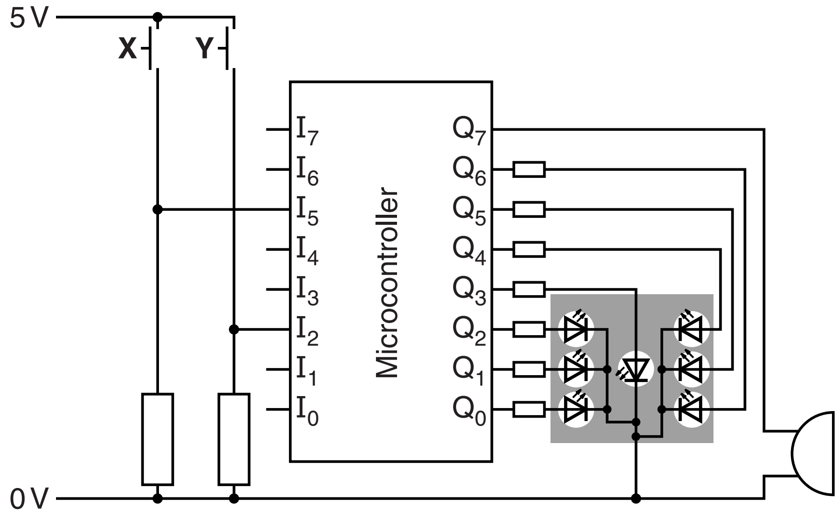
.... **[1]**

(iii) State the decimal equivalent of the number that is output at Z in Fig. 2.1.

.... **[1]**

[Total: 10]

3 Fig. 3.1 shows a microcontroller circuit and the main program to make the circuit function as an electronic dice.




```
start: RCALL  go
       RCALL  roll
       RCALL  beep
       JP     start
```

Fig. 3.1

(a) The subroutine go waits until switch **Y** has been pressed and then returns to the main program. Write the code for the subroutine go.

go: ....

....

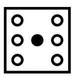
....

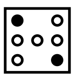
....

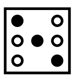
.... **[5]**

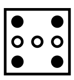
(b) The program uses a table to store the codes to light the correct LEDs for the dice. Complete the hexadecimal values for the table to make the LEDs of Fig. 3.1 light in the patterns shown.

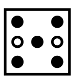
table:

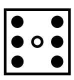

08
....


....


....


....


....


....

[3]

(c) The subroutine `roll` is shown below.

```
roll:     MOVI   S7,00
loop:     RCALL  readtable
          OUT    Q,S0
          INC    S7
          MOVI   S6,06
          SUB    S6,S7
          JNZ    skip
          MOVI   S7,00
skip:     MOVI   S4,20
          IN     S5,I
          AND    S4,S5
          JZ     loop
          RET
```

Explain the effect that subroutine `roll` has on the circuit. A copy of Fig. 3.1 is shown below.

....

....

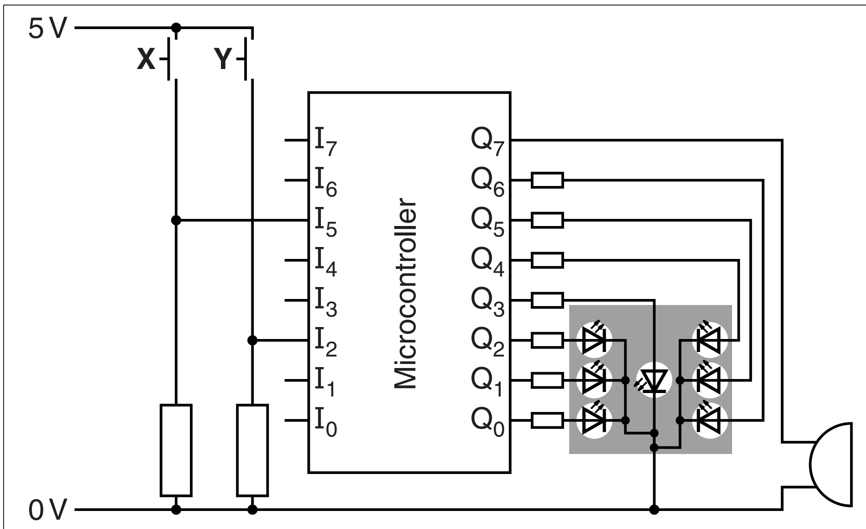
....

....

....

....

.... **[7]**




```
start:  RCALL  go
        RCALL  roll
        RCALL  beep
        JP     start
```

(d) The subroutine `beep` makes the buzzer sound for 0.2 s without affecting the display on the LEDs and then returns to the main program.
Write the subroutine `beep`. Call the subroutine `wait1ms` in your code.

....

....

....

....

....

....

....

....

....

.... **[6]**

[Total: 21]

4 This question is about power supplies.

(a) Draw on Fig. 4.1 to show how an unstabilised dc voltage can be produced from an ac supply.

[2]

Fig. 4.1

(b) A voltage regulator can be used to turn the unstabilised dc voltage into a regulated dc voltage. Describe the difference between an unstabilised dc supply and a regulated dc supply.

....

....

....

.... **[2]**

(c) Add a MOSFET, zener diode, resistor and the necessary connections to complete the circuit diagram of a voltage regulator on Fig. 4.2.

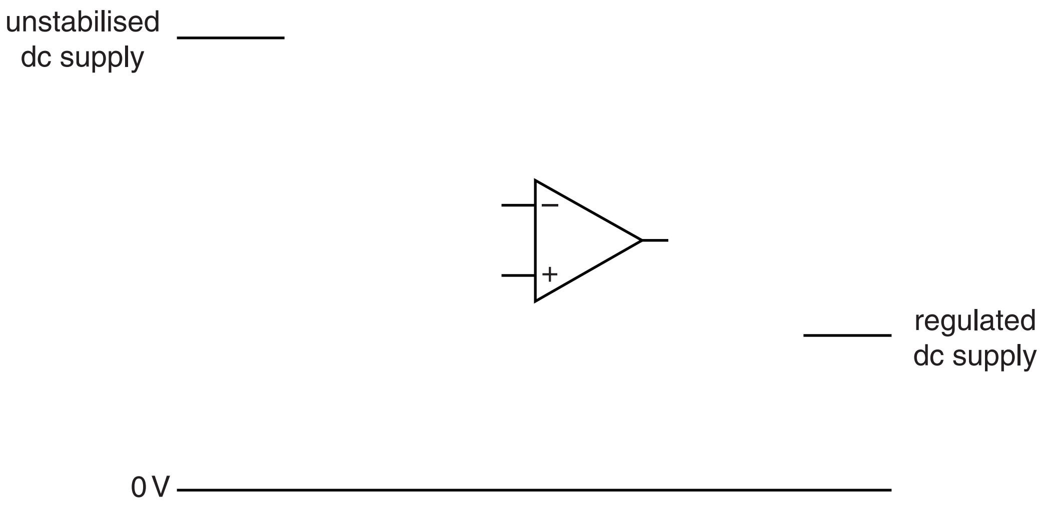


Fig. 4.2

[4]

[Total: 8]

5 Fig. 5.1 shows the circuit for controlling the speed of a motor and a graph of the characteristics of the MOSFET.

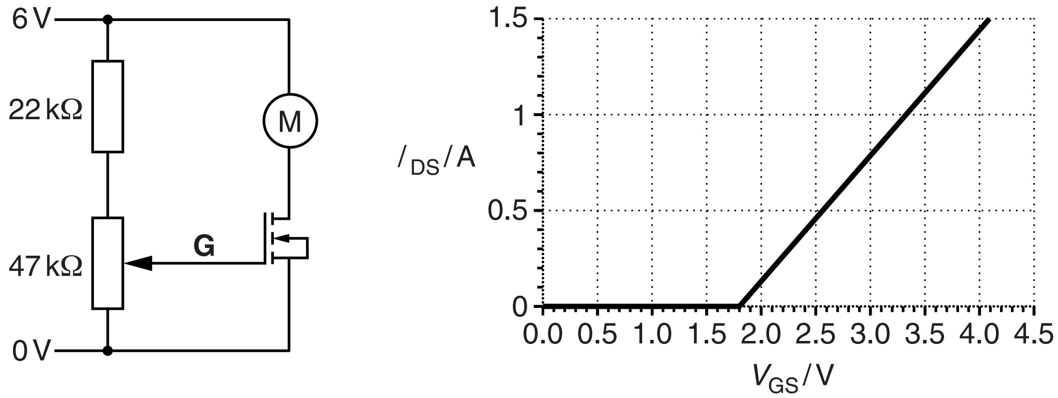


Fig. 5.1

(a) Do a calculation to show that the maximum voltage at **G** is about 4V.

[2]

(b) Explain what happens to the motor as the voltage at **G** is slowly increased from 0V to 4V.

....

....

.... **[3]**

(c) The motor needs to spin at a particular steady speed, regardless of the conditions. Explain why the circuit shown in Fig. 5.1 will not do this well.

....

....

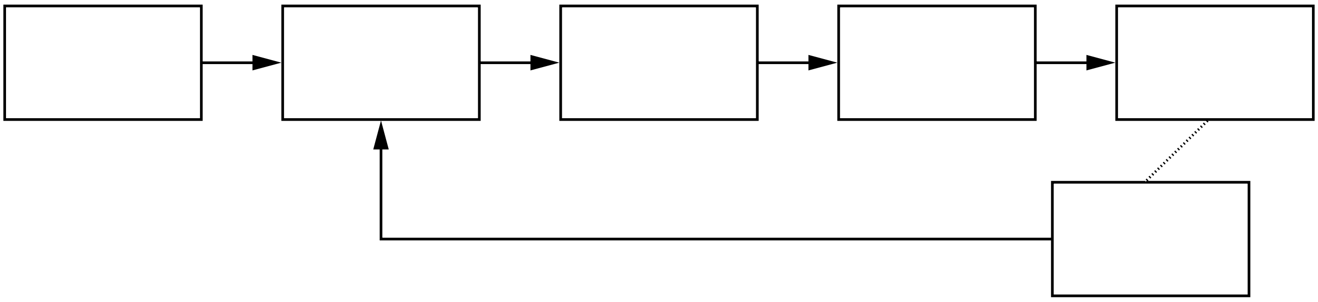
....

.... **[2]**

(d) A proportional speed control works well at controlling the speed of a motor.

(i) Complete the block diagram in Fig. 5.2 of a proportional speed control circuit by using some of the terms below.

difference amplifier **motor** **oscillator** **power amplifier** **ramp generator** **reference** **Schmitt trigger** **speed sensor**



[6]

Fig. 5.2

(ii) As the motor starts, it spins too slowly. Explain how the system of Fig. 5.2 increases the speed of the motor to its correct value. Refer to the voltage changes at the output of each block in your answer.

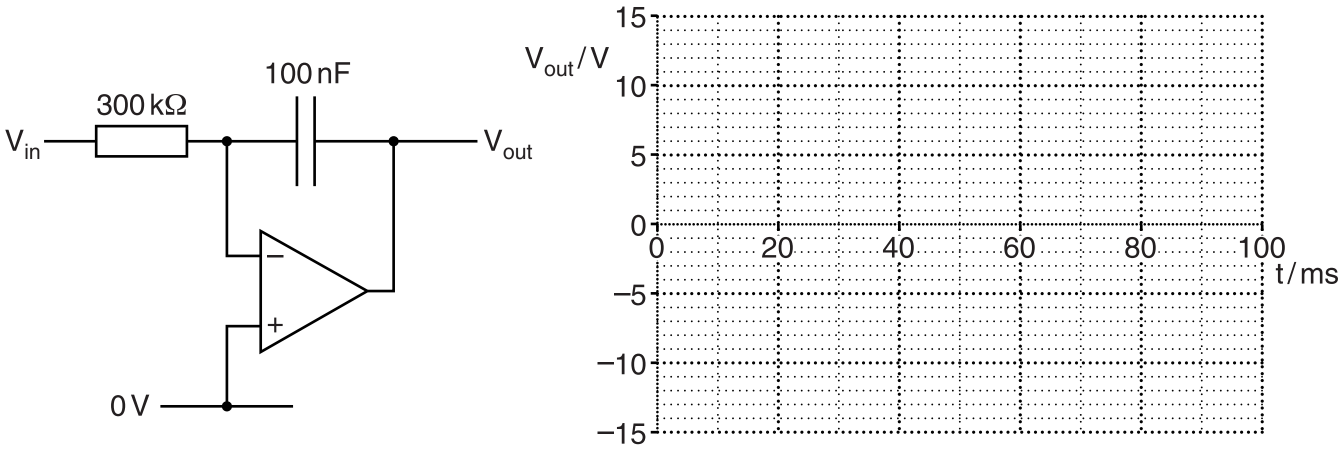
....

....

....

.... **[3]**

(e) The circuit of a ramp generator is shown in Fig. 5.3. Draw on the graph below to show how the output of the ramp generator varies with time if V_{in} = –6 V and V_{out} is initially 2 V.



[4]

Fig. 5.3

[Total: 20]

6 Subroutines are used when writing programs for microcontrollers.

(a) Explain the advantages of designing programs using subroutines.

....

....

....

.... **[4]**

(b) Explain what happens when a RET instruction is executed.

....

....

....

.... **[3]**

(c) Here are the contents of the memory and two of the registers in a microcontroller at a particular time.

address	**instruction**
…	…
2B	RCALL 2E
2C	OUT Q,S3
2D	JP 2B
2E	IN S3,I
2F	SHL S3
30	RET

program counter = 2B

stack pointer = 57

address	**data**
55	32
56	13
57	6A
58	B2
59	7C

Show below the contents of the memory and the registers one machine cycle later.

address	**instruction**
…	…
2B	
2C	
2D	
2E	
2F	
30	

program counter = ...

stack pointer = ...

address	**data**
55	
56	
57	
58	
59	

[5]

[Total: 12]

7 An incomplete MOSFET amplifier circuit is shown in Fig. 7.1.

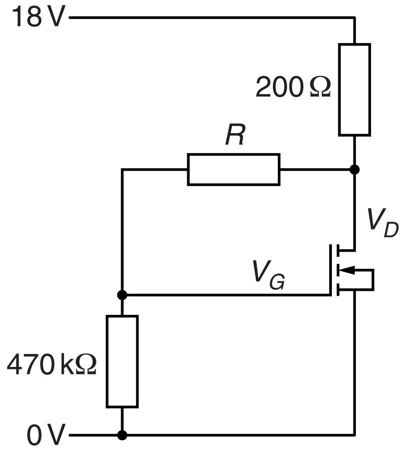


Fig. 7.1

(a) Draw on Fig. 7.1 to show how two capacitors can be added to the circuit to connect ac input and output circuits. Label the input and the output. **[3]**

(b) The characteristics of the MOSFET are shown in Fig. 7.2.

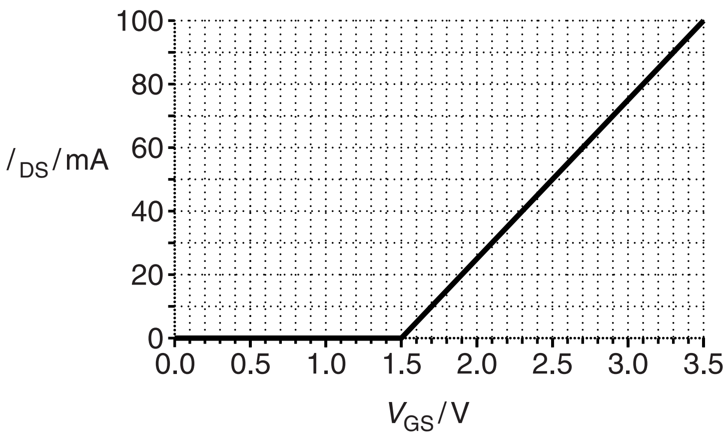


Fig. 7.2

(i) Calculate the gain of the amplifier for small input signals.

gain = ... **[3]**

(ii) The amplifier is designed to have V_D = 10 V when there is no signal at the input. Calculate the required value for the resistor R.

R = ... MΩ **[6]**

(c) Explain why it is better to design the amplifier with R connected to V_D rather than the 18 V supply rail if the design is going to be used to make several amplifiers.

....

....

....

.... **[2]**

[Total: 14]

8 A tristate and truth table are shown in Fig. 8.1.

E	A	Q
0	0	0
0	1	1
1	0	High impedance
1	1	High impedance

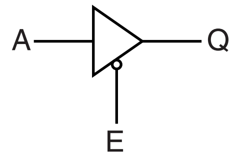


Fig. 8.1

(a) The diagram in Fig. 8.2 shows an incomplete circuit diagram for the tristate using two analogue switches, U and L.

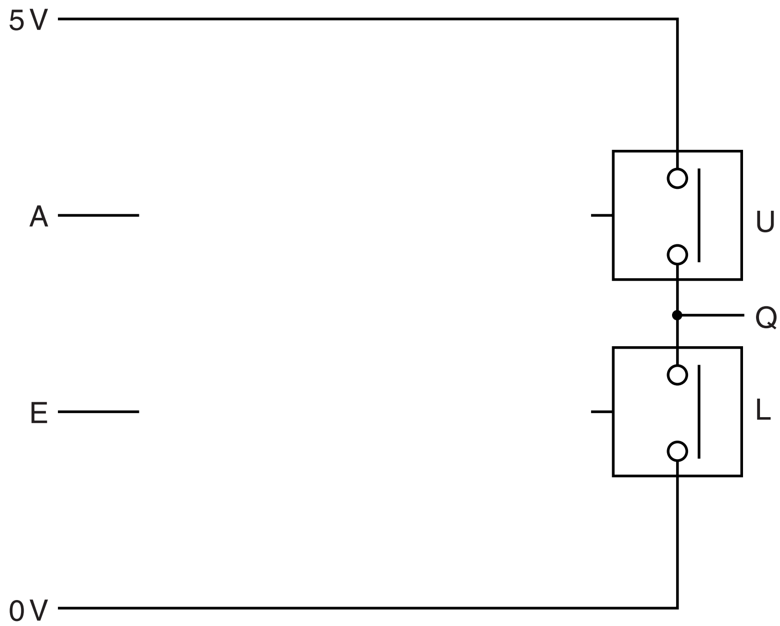


Fig. 8.2

(i) Complete the table below by writing **open** or **closed** to produce the required output Q.

Q	U	L
0		
1		
High impedance		

[3]

(ii) Complete the diagram in Fig. 8.2 to show how the tristate can be built by adding any logic gates and connections you need. The analogue switch is closed when its input is high. **[3]**

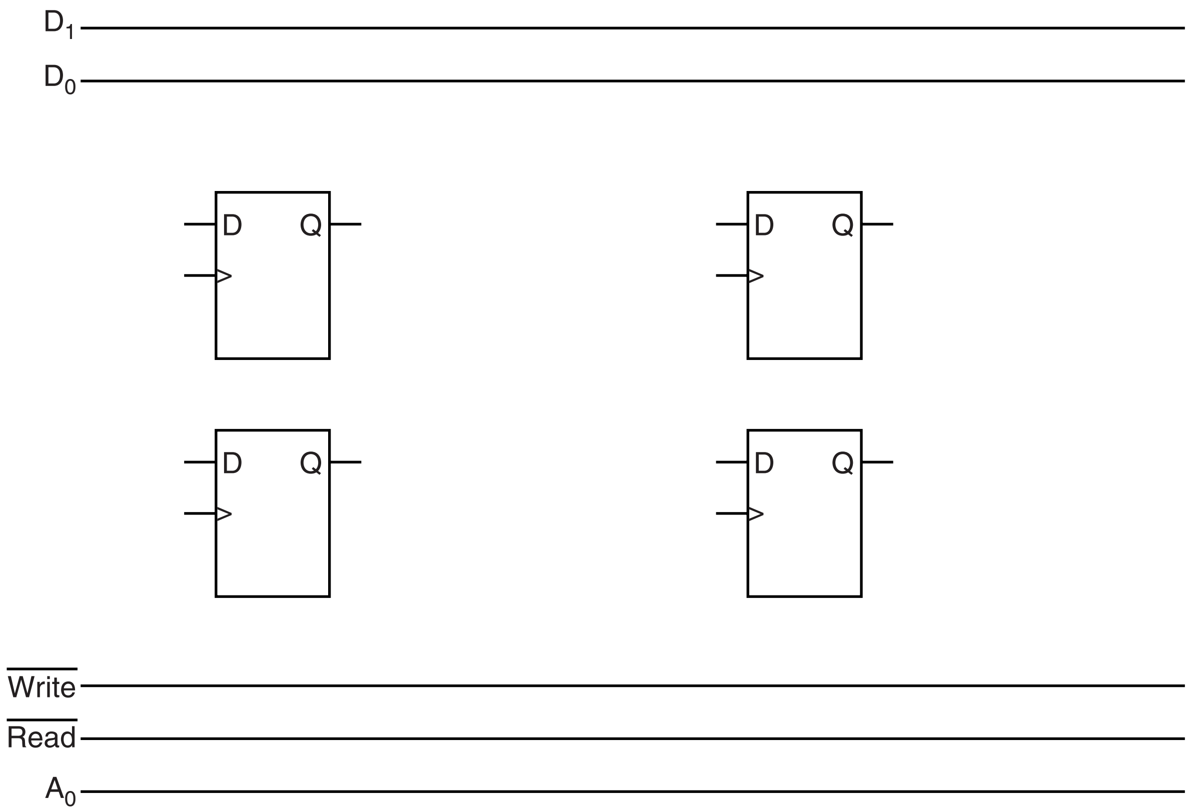
(b) Explain why tristates are used to connect the outputs of memories to a data bus.

....

....

.... **[2]**

(c) Show how logic gates and tristates can be added to Fig. 8.3 to make a 2 × 2 bit memory module.



[6]

Fig. 8.3

(d) The memory cell in Fig. 8.3 is a volatile memory. State what **volatile** means in this context.

....

.... **[1]**

[Total: 15]

Quality of written communication [3]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE