



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	
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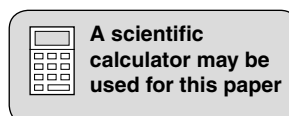
Centre number						Candidate number				
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INSTRUCTIONS TO CANDIDATES

- 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.



Microcontroller instructions

The microcontroller contains eight general purpose registers S_n , where $n = 0, 1, 2 \dots 7$. 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, S_d is the destination register and S_s the source register.

assembler	function
MOVI S_d, n	Copy the byte n into register S_d
MOV S_d, S_s	Copy the byte from S_s to S_d
ADD S_d, S_s	Add the byte in S_s to the byte in S_d and store the result in S_d
SUB S_d, S_s	Subtract the byte in S_s from the byte in S_d and store the result in S_d
AND S_d, S_s	Logical AND the byte in S_s with the byte in S_d and store the result in S_d
EOR S_d, S_s	Logical EOR the byte in S_s with the byte in S_d and store the result in S_d
INC S_d	Add 1 to S_d
DEC S_d	Subtract 1 from S_d
IN S_d, I	Copy the byte at the input port into S_d
OUT Q, S_s	Copy the byte in S_s 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 S_d	Shift the byte in S_d one bit left putting a 0 into the lsb
SHR S_d	Shift the byte in S_d 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 S_7 into S_0 . The lookup table is labelled table: When $S_7=0$ the first byte from the table is returned in S_0
- wait1ms – waits 1ms before returning
- readadc – returns a byte in S_0 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 0V.

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	$V_{out} = A(V_+ - V_-)$	
non-inverting amplifier gain	$G = 1 + \frac{R_f}{R_d}$	
inverting amplifier gain	$G = -\frac{R_f}{R_{in}}$	
summing amplifier	$-\frac{V_{out}}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} \dots$	
break frequency	$f_0 = \frac{1}{2\pi RC}$	
Boolean Algebra	$A.\bar{A} = 0$	$A + \bar{A} = 1$
		$A.(B + C) = A.B + A.C$
	$\overline{A.B} = \bar{A} + \bar{B}$	$\overline{A + B} = \bar{A}.\bar{B}$
	$A + A.B = A$	$A.B. + \bar{A}.C = A.B + \bar{A}.C + B.C$
amplifier gain	$G = -g_m R_d$	
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.

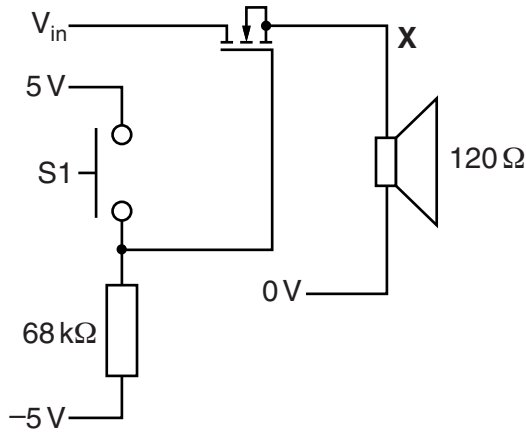


Fig. 1.1

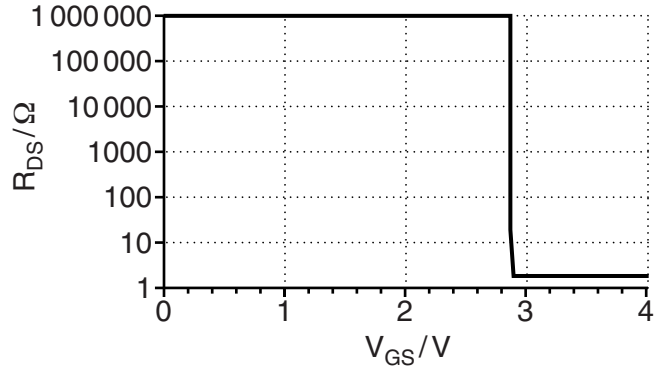


Fig. 1.2

- (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} .

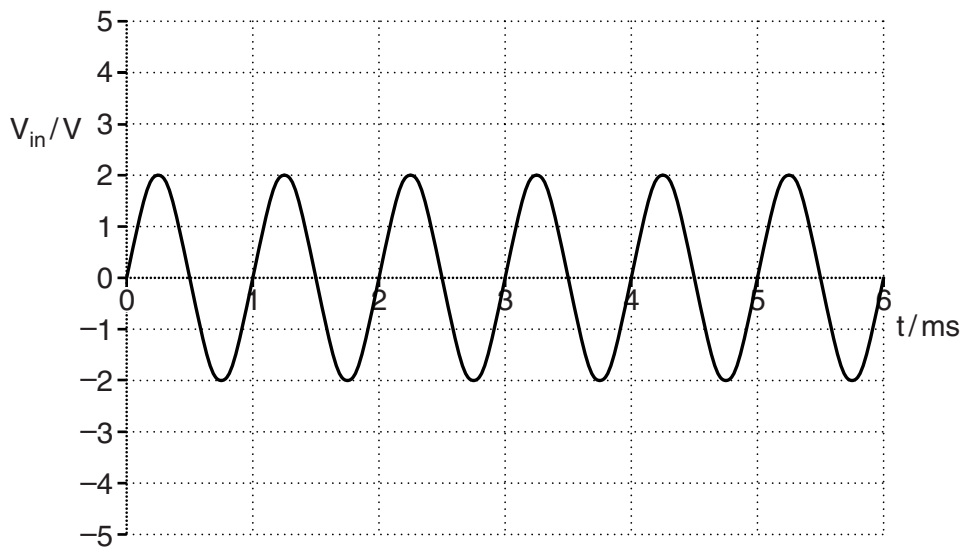


Fig. 1.3

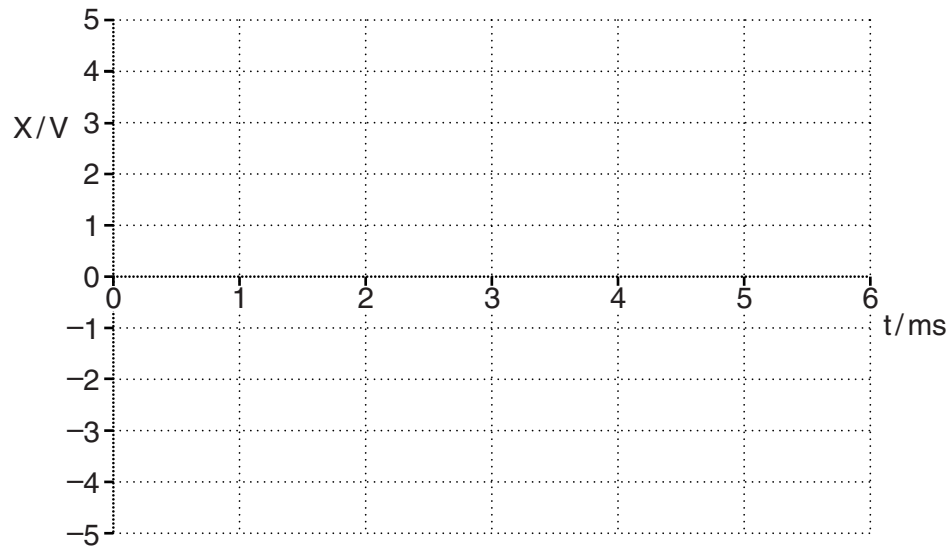
- (i) Explain why there is no sound from the speaker in Fig 1.1 when the switch is **not** pressed.

.....

 [3]

5

- (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.

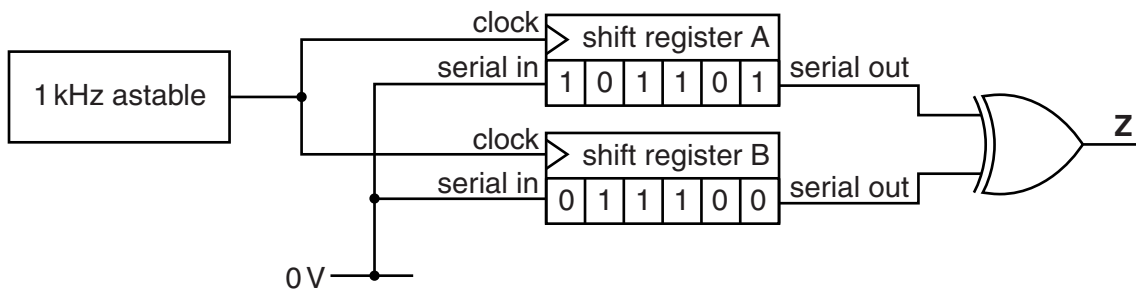
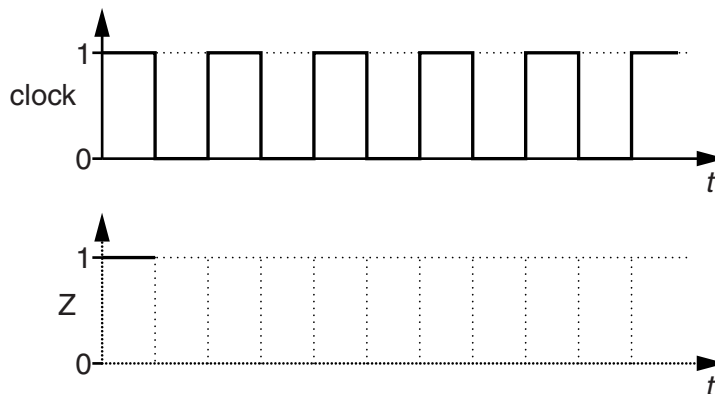


Fig. 2.1

- (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.

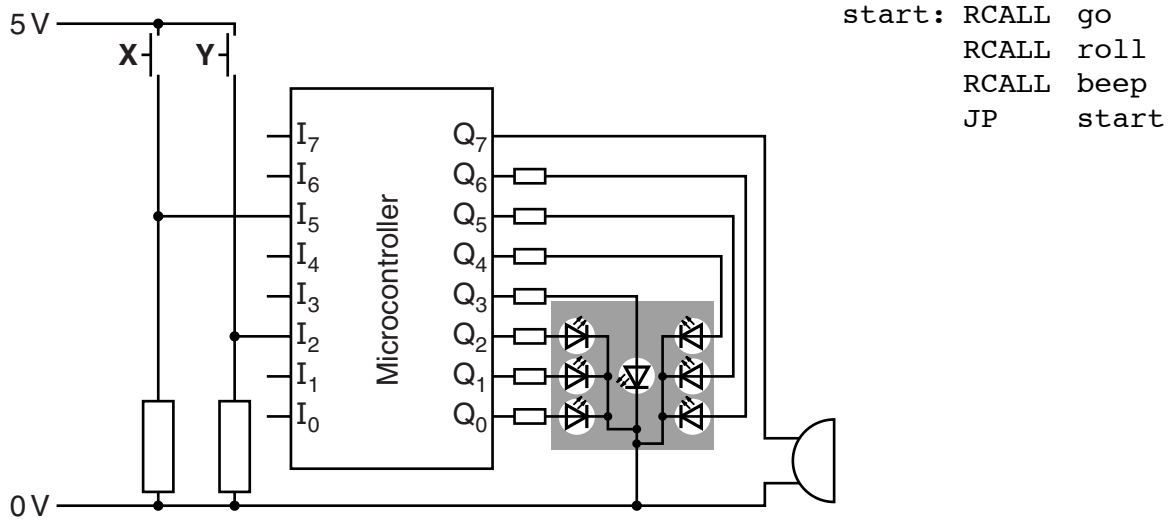


Fig. 3.1

- (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:	<i>08</i>
		
		
		
		
		

[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.

.....

.....

.....

.....

.....

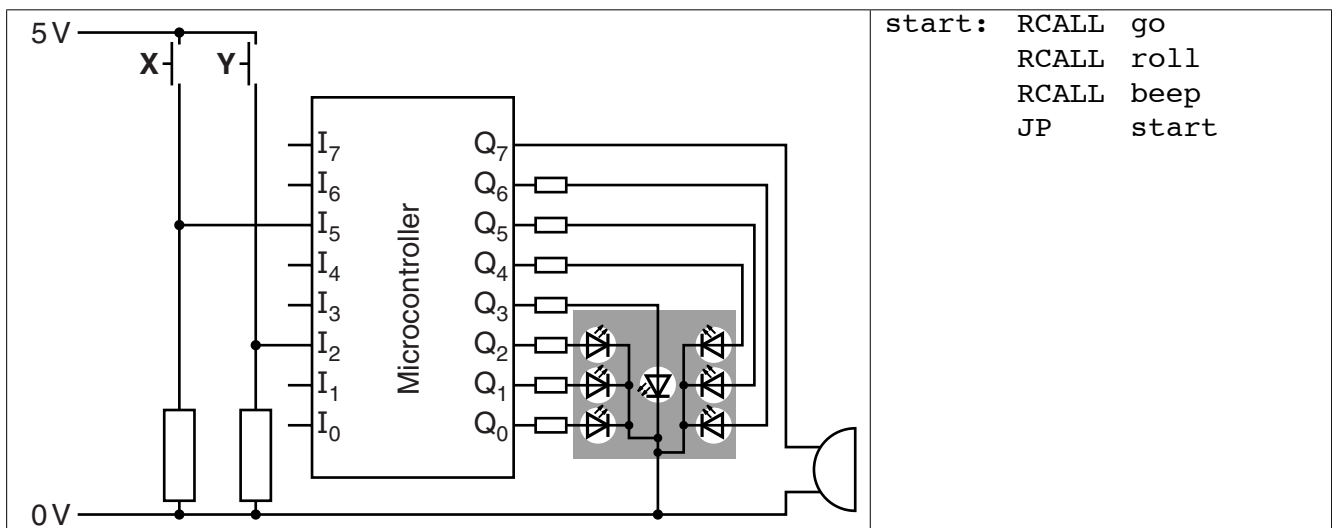
.....

.....

.....

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..... [7]



9

- (d) The subroutine `beep` makes the buzzer sound for 0.2s 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 un stabilised dc voltage can be produced from an ac supply.



[2]

Fig. 4.1

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

.....

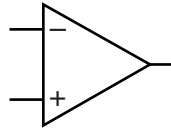
.....

.....

..... [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.

unstabilised
dc supply _____



_____ regulated
dc supply

0V _____

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.

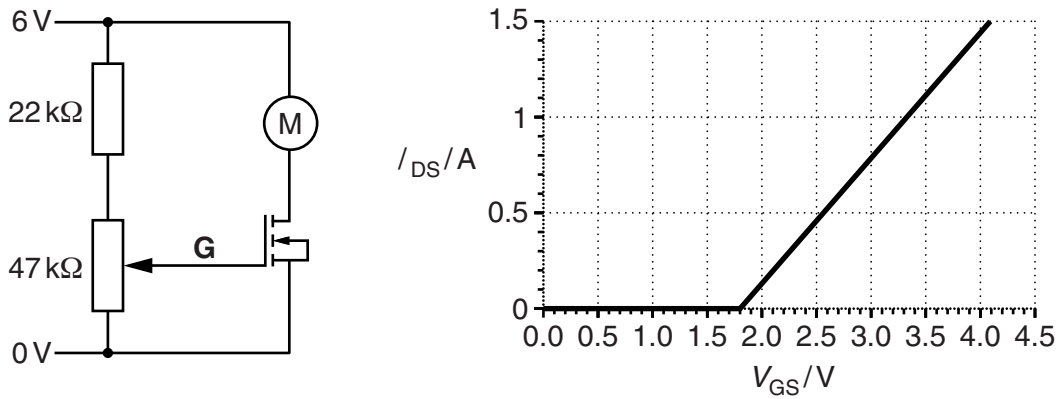


Fig. 5.1

- (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]

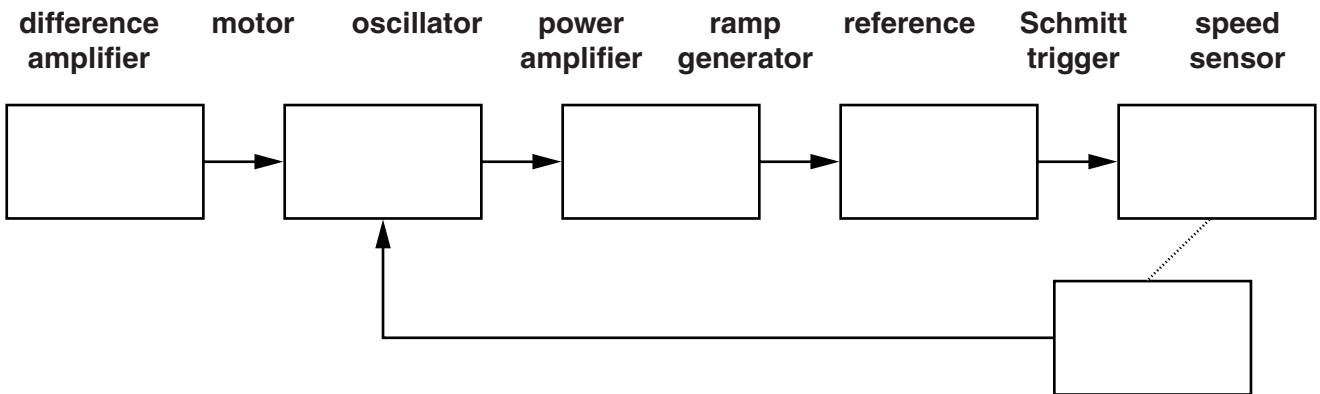
- (c) The motor needs to spin at a particular steady speed, regardless of the conditions. Explain why the circuit shown in Fig. 5.1 will not do this well.

.....

 [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.



[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 $V_{in} = -6V$ and V_{out} is initially $2V$.

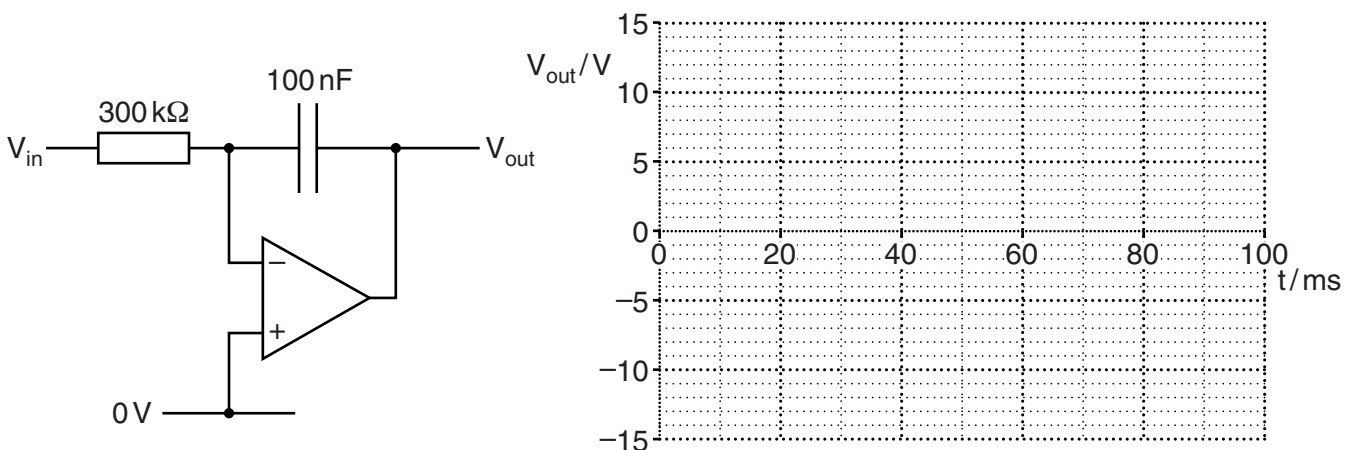


Fig. 5.3

[4]

[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.

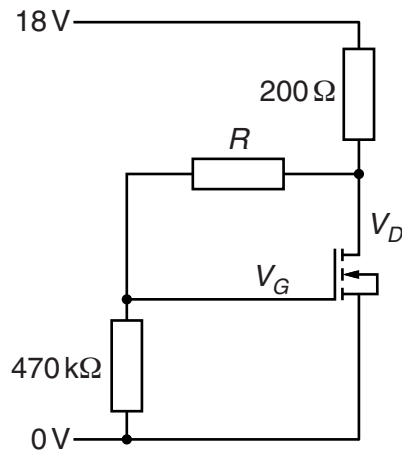


Fig. 7.1

- (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.

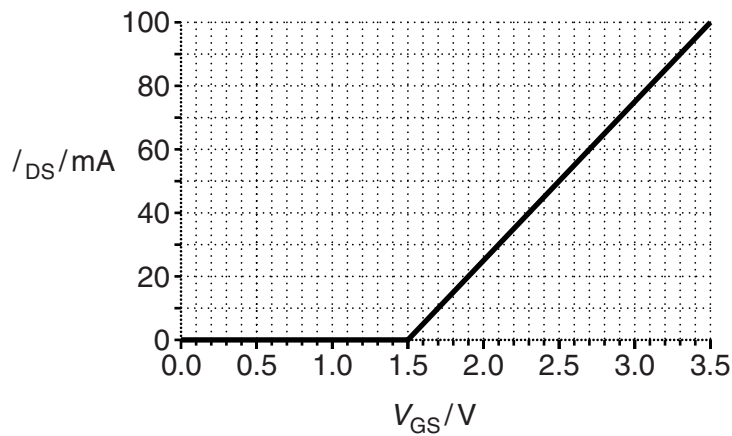


Fig. 7.2

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

gain = [3]

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

R = $M\Omega$ [6]

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

.....
.....
.....
..... [2]

[Total: 14]

18

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

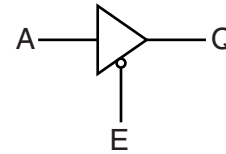


Fig. 8.1

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

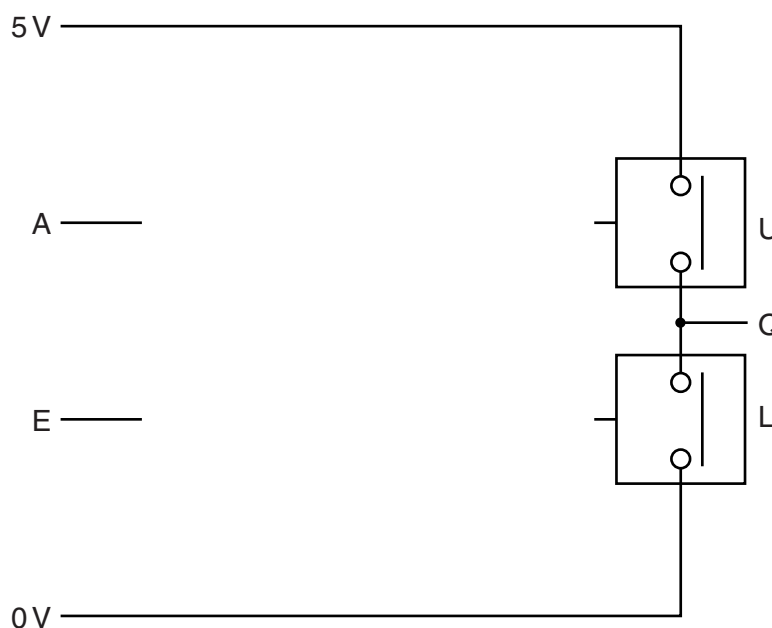


Fig. 8.2

(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.

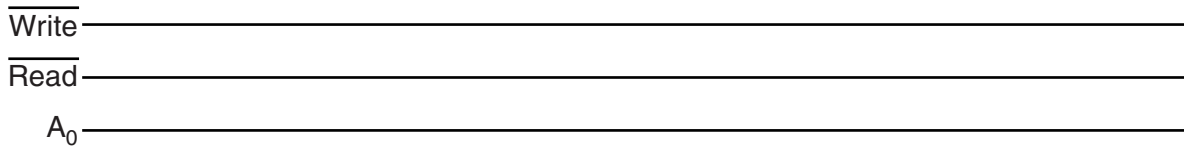
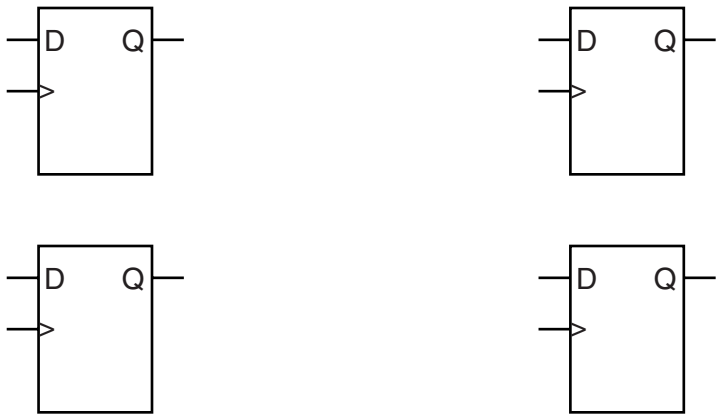
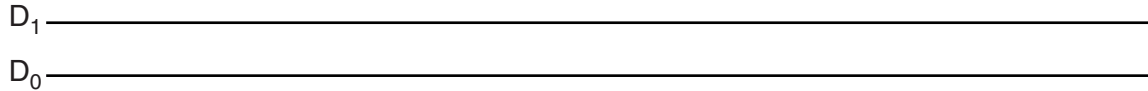


Fig. 8.3

[6]

(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

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