OCR
Oxford Cambridge and RSA

Wednesday 6 June 2018 – 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. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

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 to 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 +15 V and –15 V
- logic circuits are run off supply rails at +5 V and 0 V.

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	$G = 1 + \frac{R_f}{R_d}$	
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	$G = -g_m R_d$	
ramp generator	$\Delta V_{out} = -V_{in}\frac{\Delta t}{RC}$	

Answer **all** the questions.

1 Fig. 1.1 shows an incomplete MOSFET amplifier circuit.

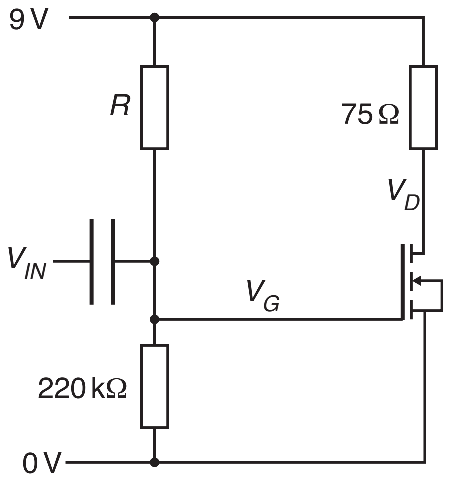


Fig. 1.1

(a) Add a component and connection to Fig. 1.1 to show how an a.c. signal can be output from the amplifier.
Label the output of the amplifier V_{OUT}. **[2]**

(b) Calculate the value of **R** to make $V_G = 3.5$ V.

R = ... kΩ **[3]**

(c) The graph in Fig. 1.2 shows how the drain current, I_{DS}, through the MOSFET depends on the voltage at V_G.

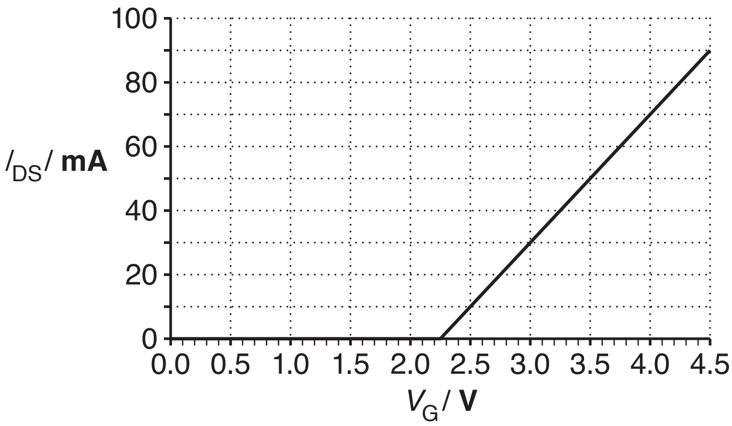


Fig. 1.2

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

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

(ii) Show that the voltage at V_D is about 5 V when V_G is 3.5 V.

[3]

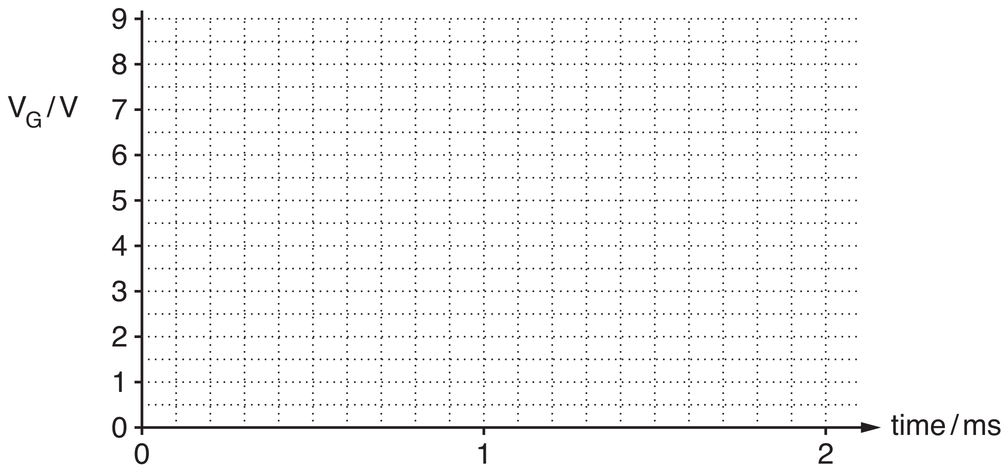
(iii) Use information from the graph to calculate the transconductance of the MOSFET.

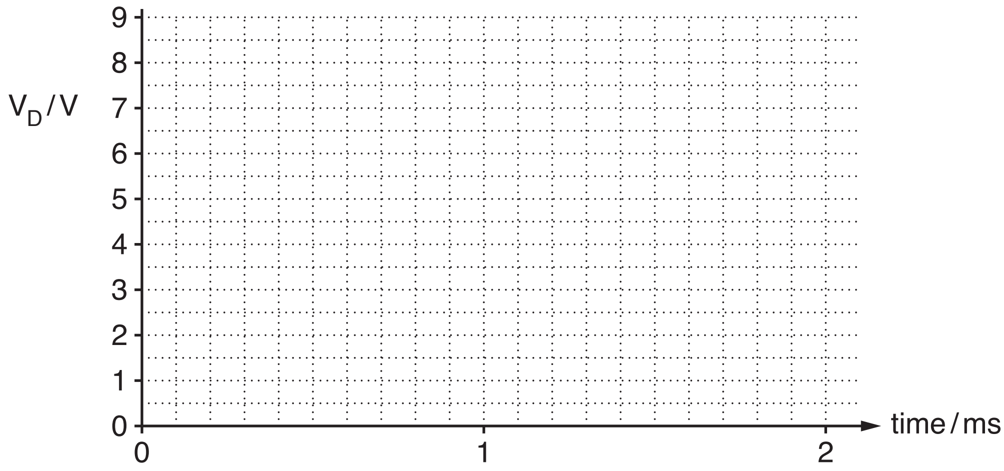
Transconductance = ... S **[3]**

(iv) Show that the gain of the amplifier is –3.

[2]

(d) A sine wave of amplitude 0.5 V and frequency 2 kHz is applied to V_{IN}.
Draw on the axes to show how the voltages $\boldsymbol{V_D}$ and $\boldsymbol{V_G}$ vary with time.





[6]

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2 The block diagram of a microcontroller is shown in Fig. 2.1. Some of the labels are missing.

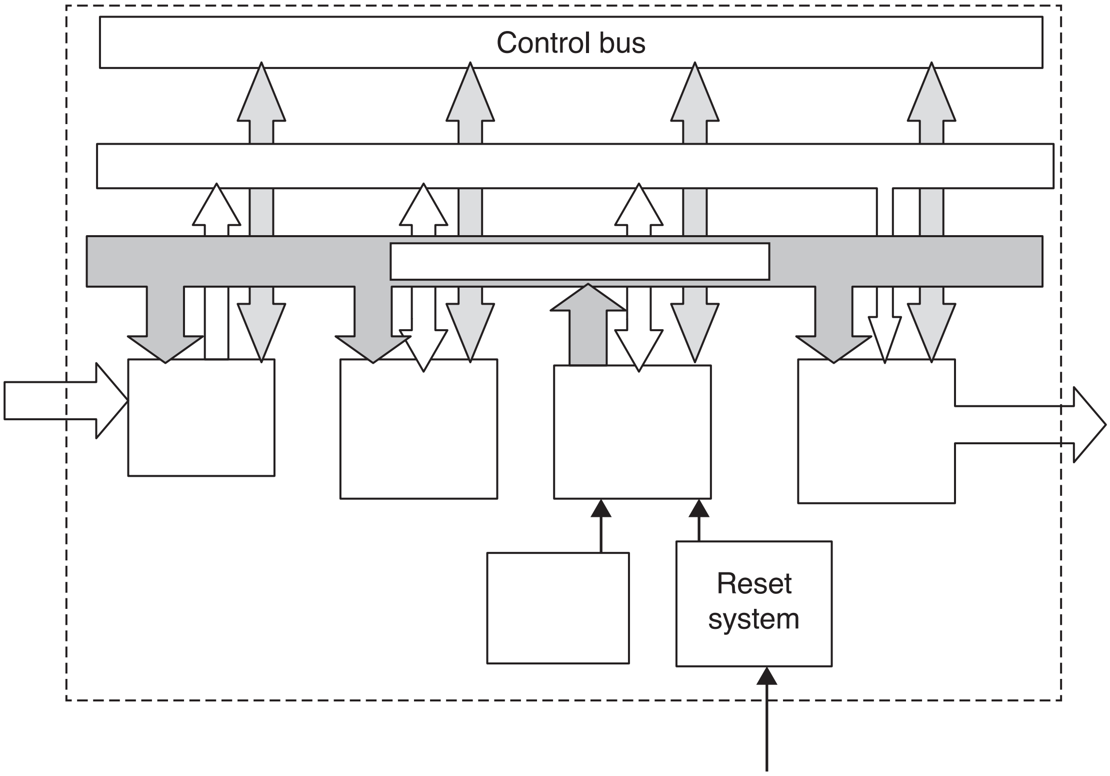

Fig. 2.1

(a) Complete the block diagram in Fig. 2.1 by writing the correct labels in the blocks and on the busses. Choose from the list below:

address bus **clock** **CPU** **data bus** **input port** **memory** **output port**

[7]

(b) Describe the address bus and explain what it is used for.

....

....

.... **[3]**

(c) Describe the program counter, state its location in a microcontroller, and explain what it is used for.

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.... **[3]**

(d) Describe what happens in the microcontroller during one machine cycle.

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.... **[5]**

3 Fig. 3.1 shows the block diagram of a switched-mode power supply.

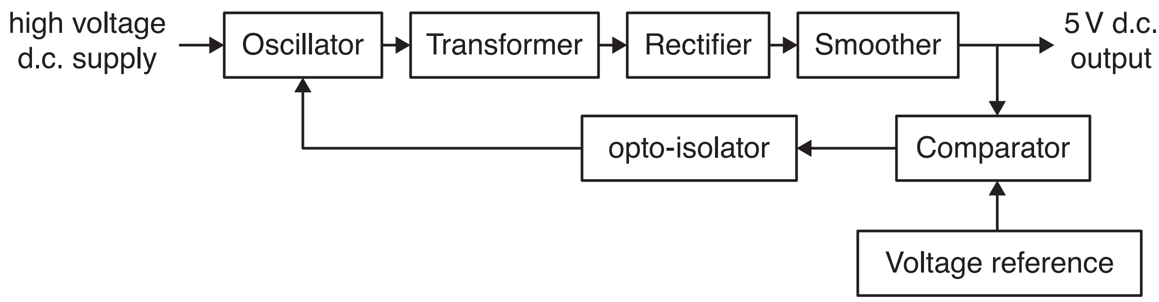

Fig. 3.1

(a) The system in Fig. 3.1 is a closed-loop control system.
State how the block diagram shows this.

....

....

.... **[1]**

(b) Explain the advantage of using a closed-loop system over an open-loop system for a power supply.

....

....

....

.... **[2]**

(c) Complete Fig. 3.2 by drawing the circuit diagram of the rectifier and smoother part of the switched-mode power supply.

[3]

Fig. 3.2

(d) Explain how an opto-isolator works by referring to the two components that it contains.

....

....

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....

....

.... **[4]**

(e) Fig. 3.3 shows an incomplete circuit diagram of the comparator in a switched-mode power supply.

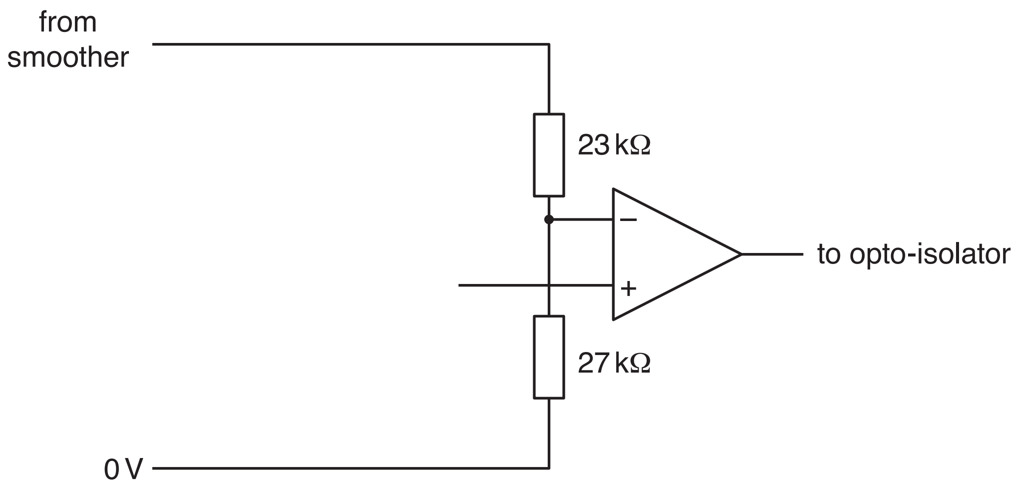


Fig. 3.3

(i) On Fig. 3.3 add the voltage reference circuit using a 2.7 V zener diode and any other components and connections needed. **[4]**

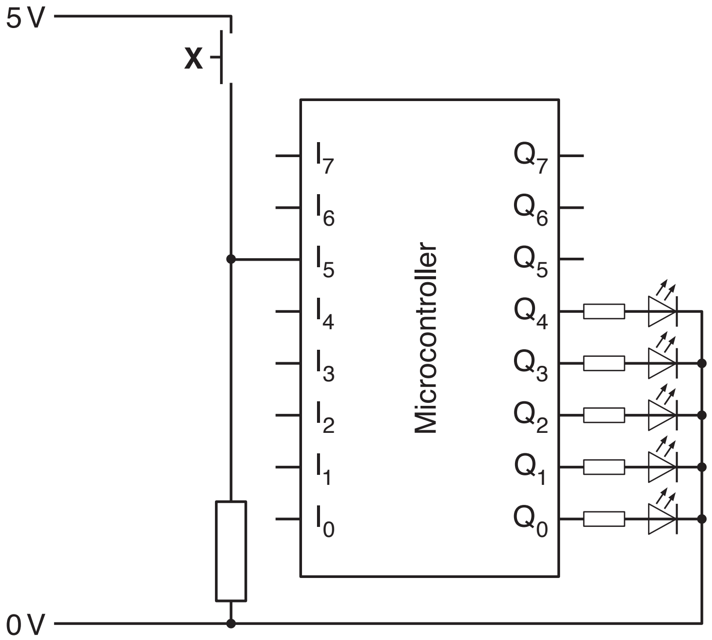
(ii) Suggest why a 5 V zener diode was not used in the voltage reference circuit.

....

....

.... **[2]**

4 A rear bicycle light circuit is shown in Fig. 4.1. The LEDs in the light can be made to illuminate in different ways using switch **X**. The main program for the microcontroller is also shown in Fig. 4.1, but the subroutines are not included.



Main program

```
        MOVI   S1, 20
loop1:  RCALL  off
        IN     S2, I
        AND    S2, S1
        JZ     loop1
        RCALL  rel
loop2:  RCALL  on
        IN     S2, I
        AND    S2, S1
        JZ     loop2
        RCALL  rel
loop3:  RCALL  flash
        IN     S2, I
        AND    S2, S1
        JZ     loop3
        RCALL  rel
loop4:  RCALL  run
        IN     S2, I
        AND    S2, S1
        JZ     loop4
        JP     loop1
```

Fig. 4.1

(a) The subroutine `rel` waits for switch **X** to be released before returning to the main program. Write the code for the subroutine `rel`.

`rel:` ....

....

....

.... **[4]**

(b) The subroutine `on` makes all of the LEDs glow. Write the code for the subroutine `on`.

`on:` ....

....

.... **[4]**

(c) The subroutine `flash` is shown below. Subroutine `flash` turns on all of the LEDs for 125 ms and then turns them off for 125 ms before returning to the main program.

Write the code for the subroutine `wait125ms`.
The subroutine `wait1ms` produces a delay of 1 ms. Use the subroutine `wait1ms` in your code.

wait125ms: ....

```
flash: RCALL on
       RCALL wait125ms
       RCALL off
       RCALL wait125ms
       RET
```

....

....

....

.... **[4]**

(d) The subroutine `run` turns on the LEDs one at a time for 125 ms in the pattern shown in Fig. 4.2.

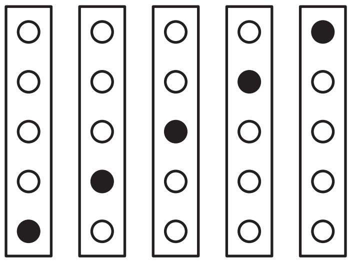


Fig. 4.2

Write the code for the subroutine `run`.

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.... **[5]**

5 Part of a circuit for controlling the temperature of an oven is shown in Fig. 5.1.

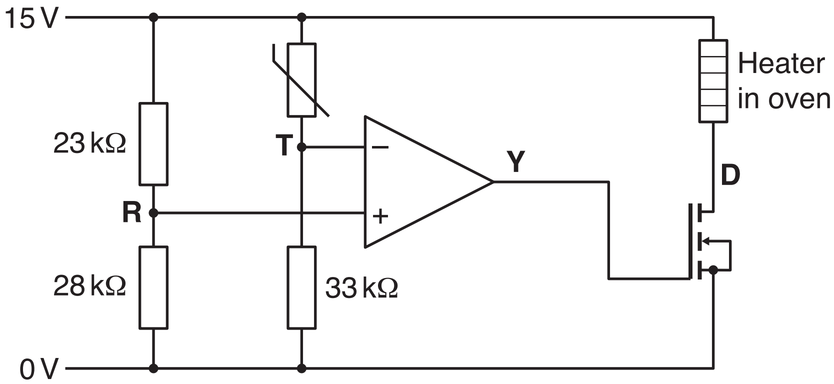


Fig. 5.1

(a) The circuit uses a thermistor to sense the temperature of the oven.
State the electrical properties of a thermistor.

....

.... **[1]**

(b) Show that the voltage at **R** is about 8 V.

[3]

(c) When the oven is cold the voltage at **T** is 5 V.
Explain why the heater is on. Refer to the voltages at **R**, **T**, **Y** and **D** in your answer.

....

....

....

....

.... **[4]**

(d) (i) Explain why the temperature of the oven reaches a constant **average** value but never stops changing.

....

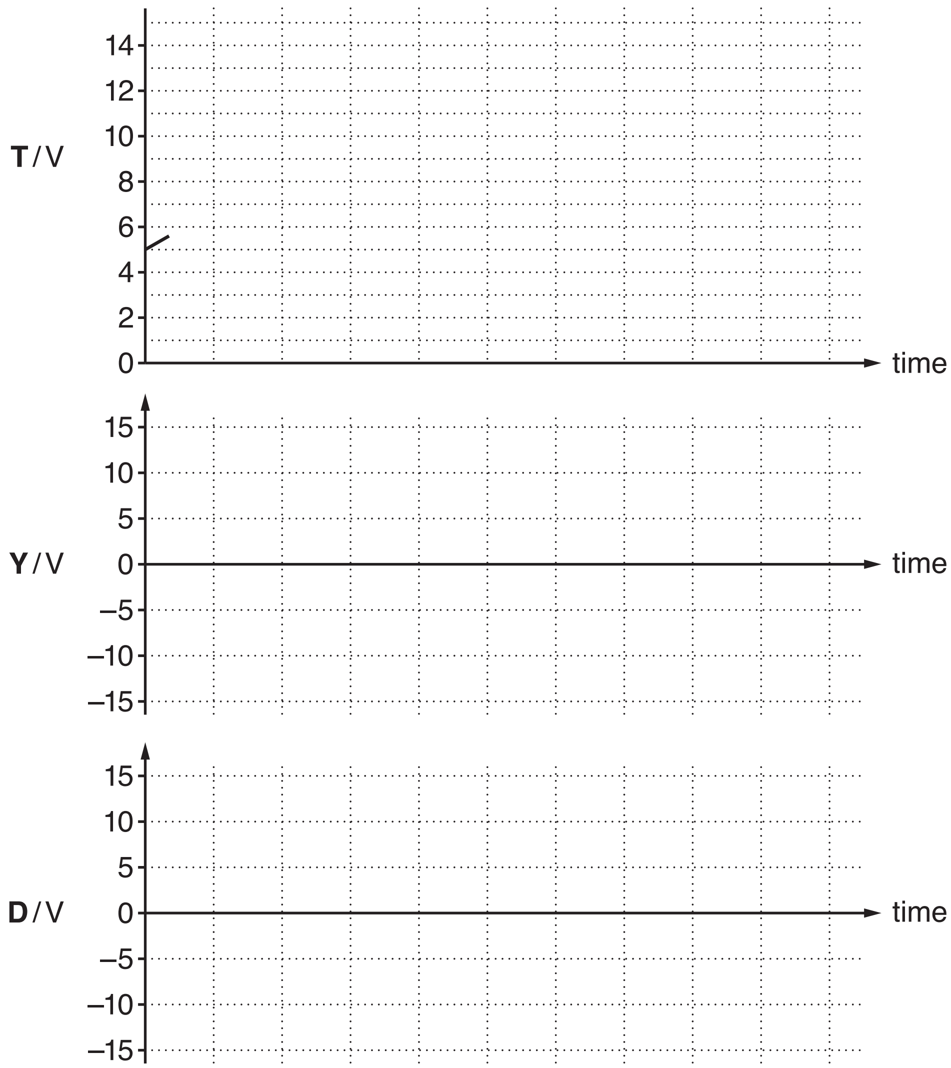
....

....

....

.... **[4]**

(ii) Complete the voltage-time graphs for **T**, **Y** and **D** to illustrate your answer to **(d)(i)**. Assume the graph starts when the oven is switched on from cold.



[6]

6 Fig. 6.1 shows a memory module.

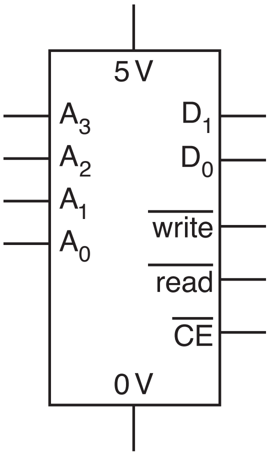


Fig. 6.1

(a) Calculate the number of memory locations in the memory module.

Number of memory locations = ... **[1]**

(b) State the largest decimal number that each memory location can hold.

Largest decimal number = ... **[1]**

(c) State the voltages on each address line and each control line when memory address 02 is being read.

A_3 = ...V A_2 = ...V A_1 = ...V A_0 = ...V

$\overline{\text{CE}}$ = ...V $\overline{\text{Read}}$ = ...V $\overline{\text{Write}}$ = ...V

[5]

(d) Describe the sequence of signals required to store the decimal number 3 at memory location 07.

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....

.... **[5]**

(e) Fig. 6.2 shows a larger memory module.

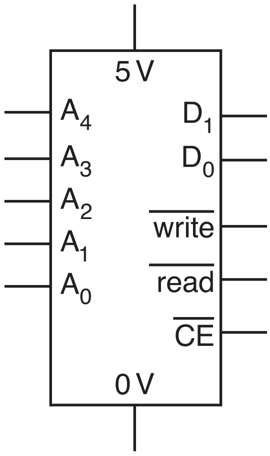
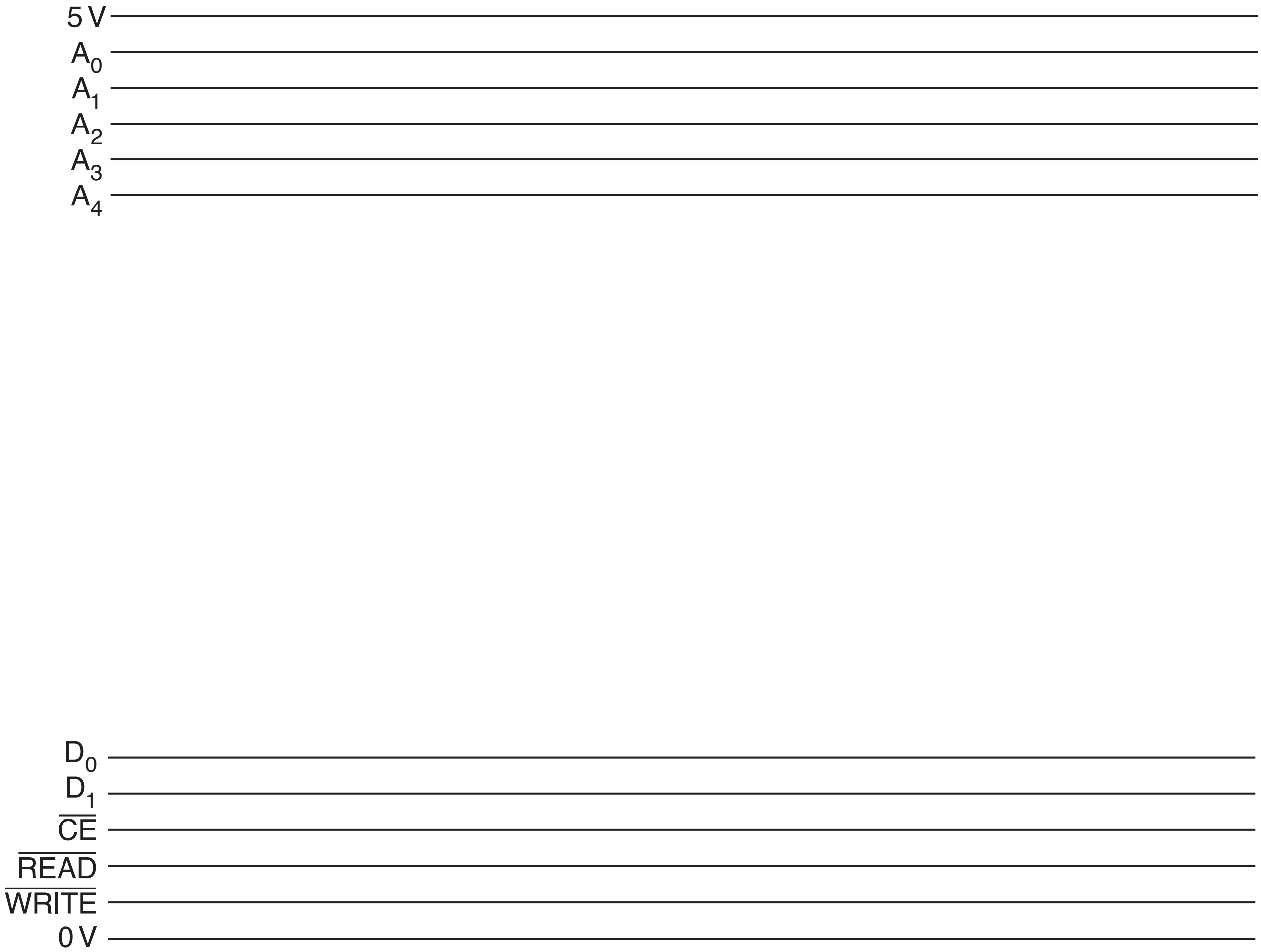


Fig. 6.2

Complete the circuit diagram below to show how the larger memory module can be made from memory modules which are the same as Fig. 6.1, and logic gates.



[6]

Quality of written response [3]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).