OCR
Oxford Cambridge and RSA

# Wednesday 7 June 2017 – 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**

| | | |
|---|---|---|
| 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** the questions.

**1** Fig. 1.1 shows a MOSFET circuit.

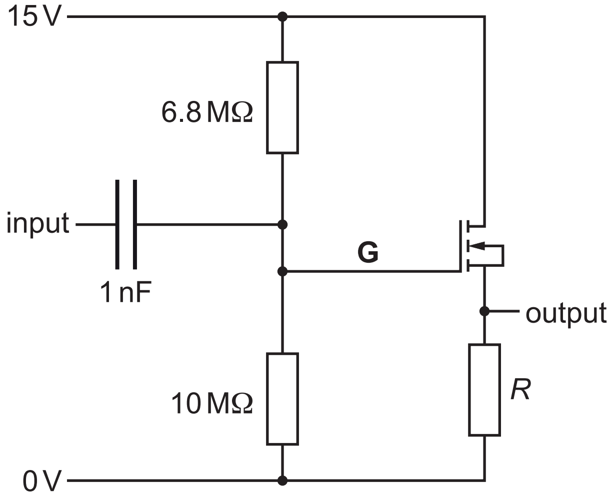


**Fig. 1.1**

**(a)** Show that the voltage at **G** is about 9 V.

**[2]**

**(b)** Fig. 1.2 shows the behaviour of the MOSFET in Fig. 1.1.

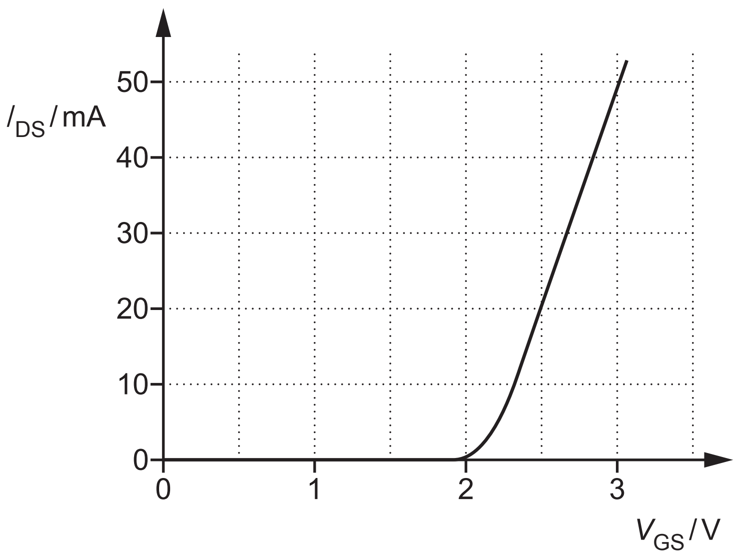


**Fig. 1.2**

**(i)** State the threshold voltage of the MOSFET in Fig. 1.1.

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

**(ii)** When there is no signal at the input the current through *R* is 20 mA.
Calculate the voltage at the output when there is no signal at the input.

voltage at output = ...................................................... V **[2]**

**(iii)** Calculate the value of the resistor *R*.

*R* = ...................................................... Ω **[1]**

**(iv)** Fig. 1.3 shows how the voltage at the input changes with time.
Draw on Fig. 1.3 to show how the voltage at the output changes with time.

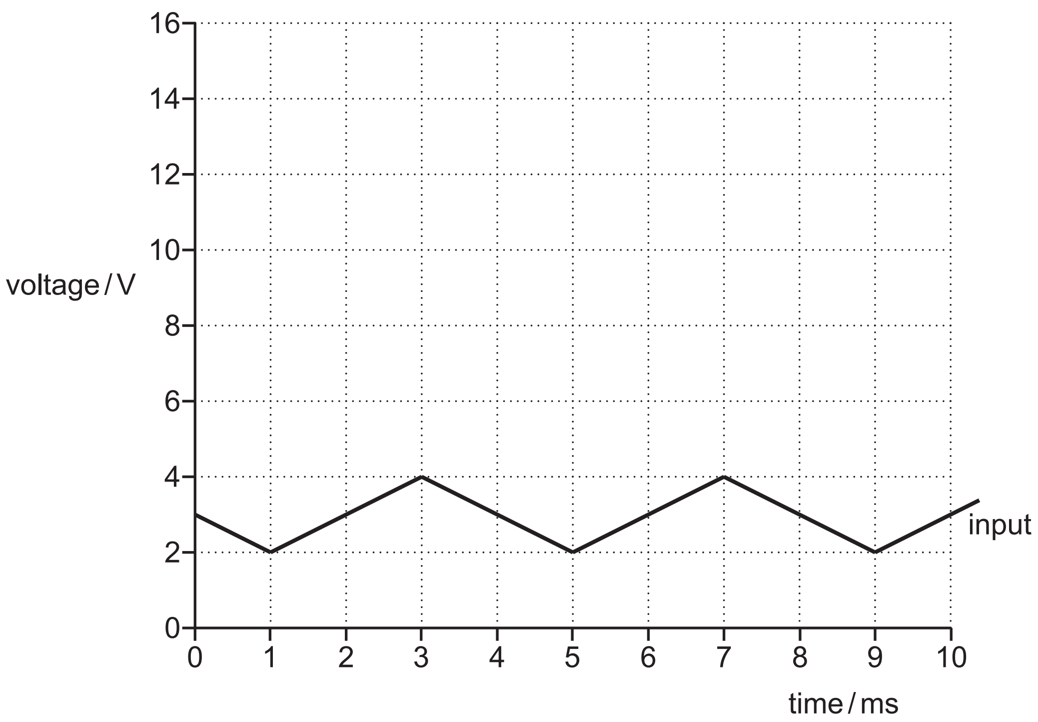


**Fig. 1.3**

**[4]**

**(c)** Explain why the circuit in Fig. 1.1 is useful.

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**2** This question is about microcontrollers.

**(a)** State the function of the clock in a microcontroller.

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**(b)** Explain the purpose of the reset pin on a microcontroller.
In your answer include the effect of activating the reset pin on any registers.

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**(c)** Programs for microcontrollers are sometimes written in assembler.
Describe how programs written in assembler are converted to a form that the microcontroller can read.
State where programs are stored in the microcontroller.

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**(d)** Explain how a microcontroller carries out the instructions in a program by describing a single machine cycle. Make reference to registers in your answer.

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**3** Fig. 3.1 shows the incomplete block diagram of a 4 x 4 bit *volatile* memory module.

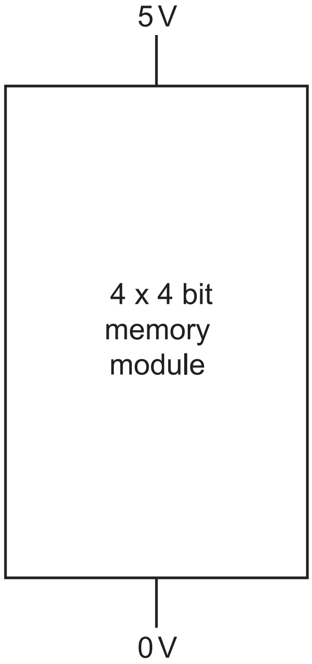


**Fig. 3.1**

**(a)** State what is meant by *volatile* when referring to volatile memory.

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**(b)** Complete the block diagram of the 4 x 4 bit memory in Fig. 3.1 by adding labelled connections for each of the address lines, data lines and control lines.

**[6]**

**(c)** The memory module is constructed from a number of memory cells.
Calculate the number of memory cells in the memory module.

number of memory cells = ......................................................... **[1]**

**(d)** Draw a circuit diagram in the space below to show how a memory cell can be made from a D-type flip-flop and a tristate.


**[5]**

**(e)** Give **two** reasons why a tristate is needed in a memory cell.

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4 A MOSFET amplifier circuit is shown in Fig. 4.1.

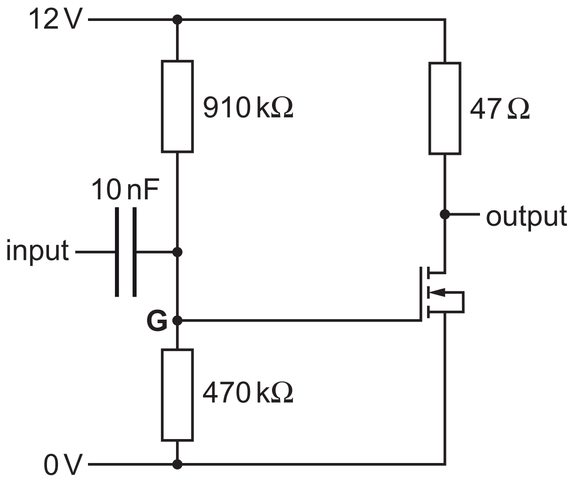


**Fig. 4.1**

**(a)** Explain the purpose of the two resistors 910 kΩ and 470 kΩ in the amplifier circuit.

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**(b)** The graphs in Fig. 4.2 show how the output voltage depends on the signal at the input. Explain how these graphs show that the a.c. gain of the amplifier is about –7.

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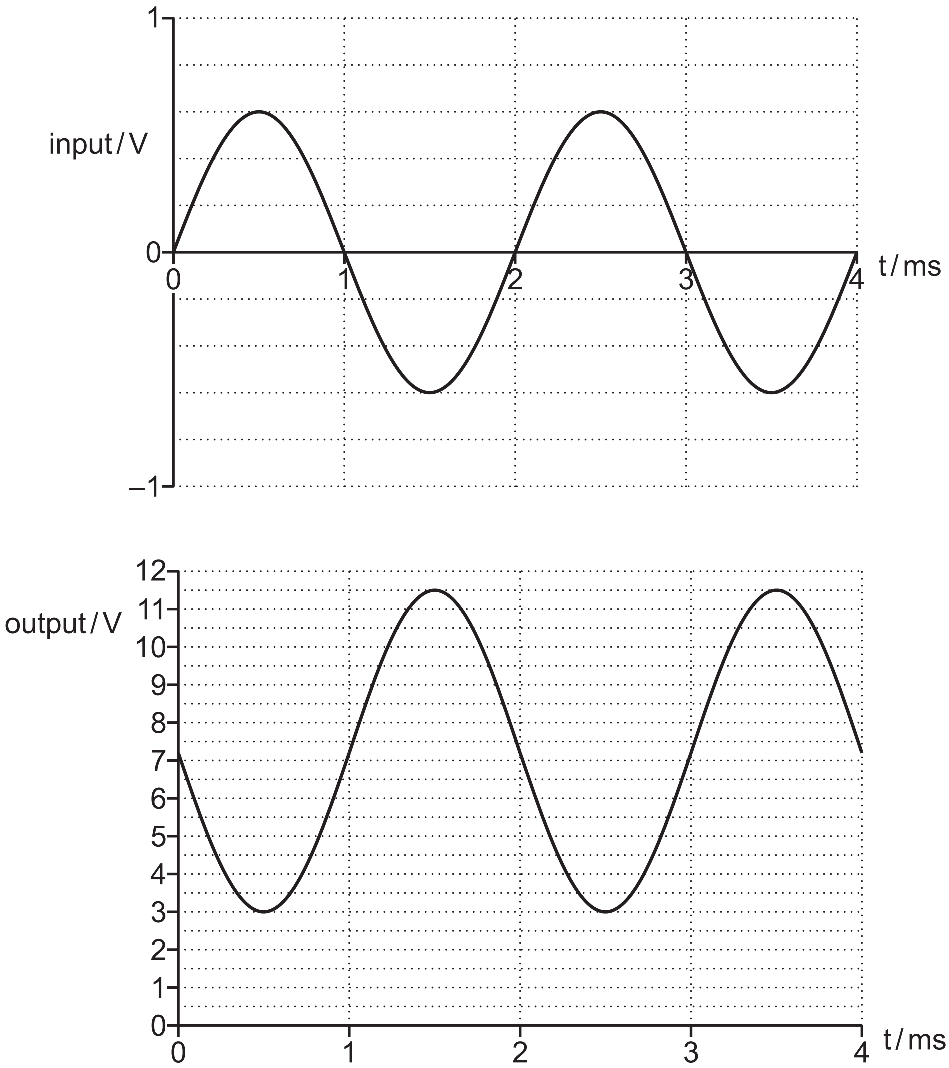



**Fig. 4.2**

**(c)** Calculate the transconductance of the MOSFET in Fig. 4.1.

transconductance = ...................................................... S **[3]**

**(d)** Calculate the threshold voltage of the MOSFET in Fig. 4.1.

threshold voltage = ...................................................... V **[4]**

**5** This question is about a system that automatically keeps the temperature in a biology experiment constant.

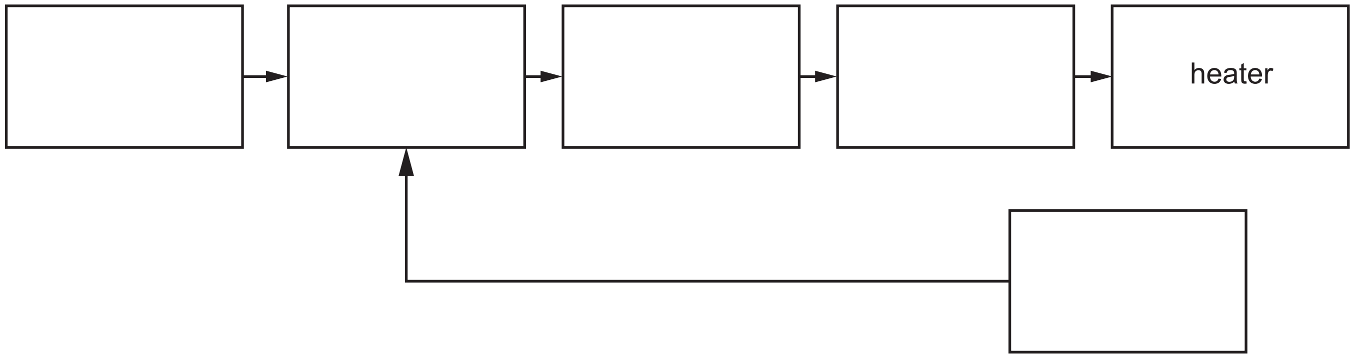



**Fig. 5.1**

**(a)** Use some of the terms below to complete the block diagram in Fig. 5.1 of a proportional control system for temperature.

**AND gate** **difference amplifier** **opto-isolator** **power amplifier**

**ramp generator** **reference** **temperature sensor** **tristate**

**[5]**

**(b)** Draw the circuit diagram of a ramp generator in Fig. 5.2 below. Label the component values to make the output $V_{out}$ change at –1 V/ms when the input voltage $V_{in}$ is 2 V.

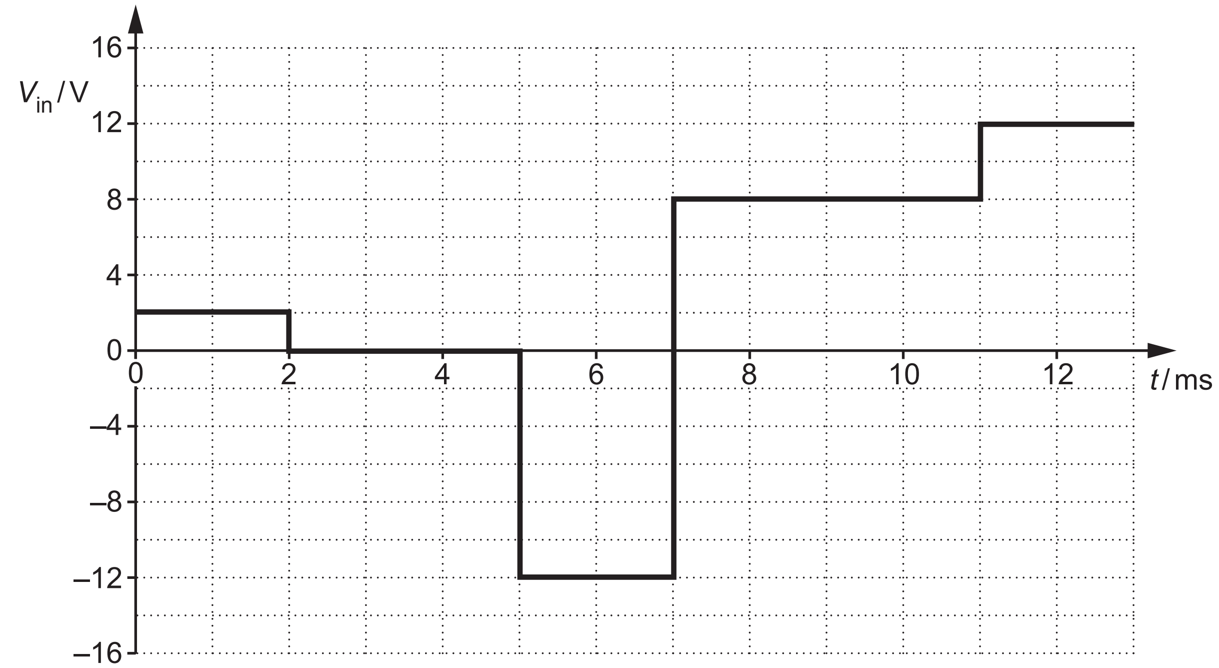
Justify your component values with a calculation.

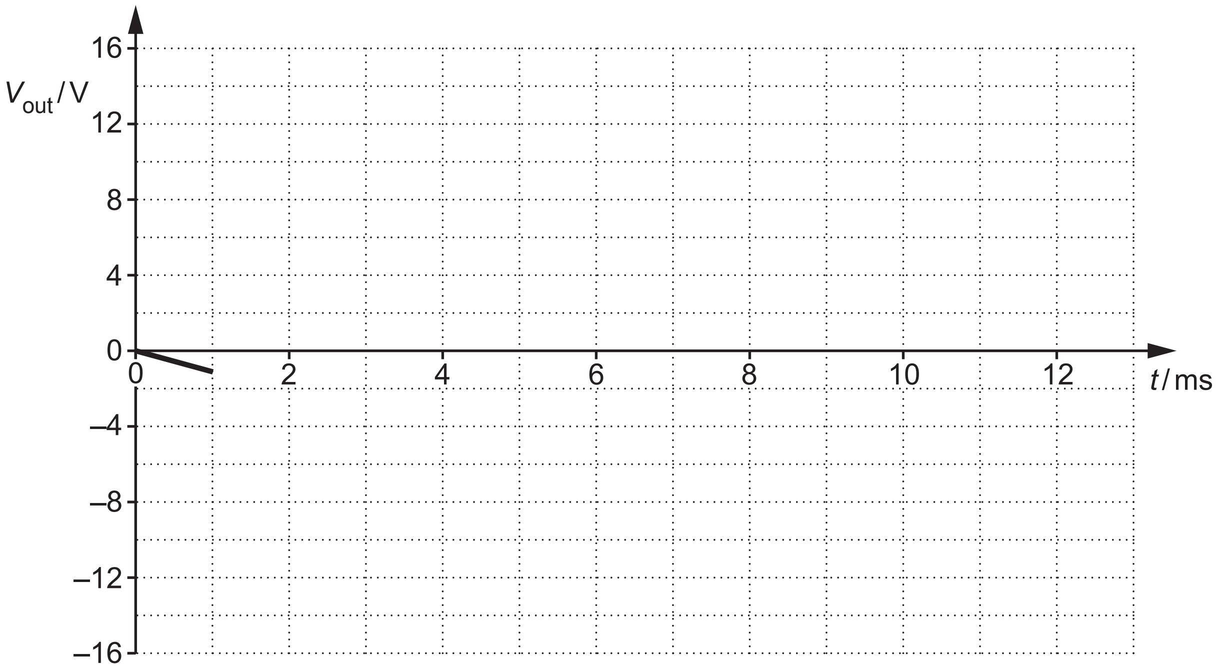

**Fig. 5.2**

**[6]**

**(c)** The graph below shows how the input voltage $V_{in}$ of the ramp generator in Fig. 5.2 varies with time.

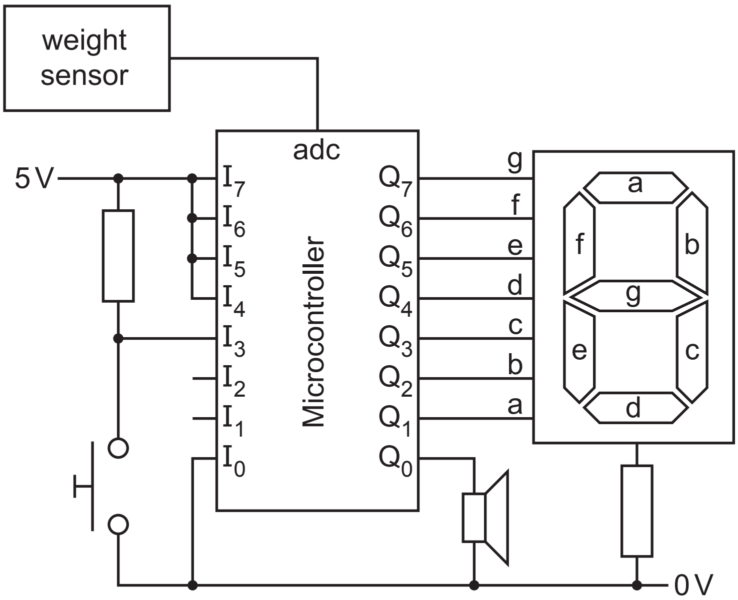
Complete the graph to show how the output voltage $V_{out}$ varies with time. $V_{out}$ starts at 0V.




**[6]**

**6** Fig. 6.1 shows the circuit and part of the program for scales used in a sweet factory to help the operator fill a bag with the correct weight of sweets.




```
strt: RCALL wgh
      RCALL disp
JP    strt

wgh:  RCALL readadc
      MOV   S7, S0
      RCALL wait180ms
      RCALL readadc
      SUB   S7, S0
      JNZ   wgh
      RET
```

**Fig. 6.1**

**(a)** Write the subroutine `wait180ms` to wait for 180 ms before returning. You should use the subroutine `wait1ms` which waits for 1 millisecond in your subroutine.

`wait180ms:` ..................................................

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**(b)** The subroutine `low` displays L on the display and the subroutine `high` displays H on the display in Fig. 6.1. The subroutines do not operate the speaker.
Write the subroutines `low` and `high`.

low: ..................................................................

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high: ..................................................................

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**[4]**

**(c)** Describe the effect of the subroutine `corr` on the output devices in Fig. 6.1.

```
corr: MOVI  S2, 01
      MOVI  S3, 40
      MOVI  S4, 90
bck:  OUT   Q, S4
      RCALL wait1ms
      RCALL wait1ms
      EOR   S4, S2
      DEC   S3
      JNZ   bck
      RET
```

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**(d)** Explain how the contents of the register affect what the subroutine `disp` does to the output devices in Fig. 6.1.

```
disp: MOVI  S5, 80
      AND   S5, S0
      JNZ   nxt1
      RCALL low
      JP    end
nxt1: MOVI  S5, 7C
      AND   S5, S0
      JNZ   nxt2
      RCALL corr
      JP    end
nxt2: RCALL high
end:  RET
```

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**7** Fig. 7.1 shows the block diagram of a switched-mode power supply.

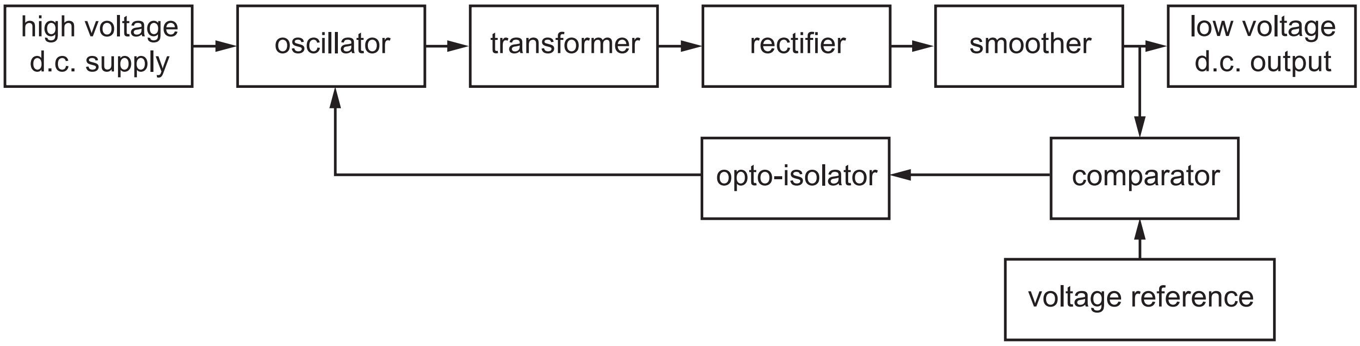


**Fig. 7.1**

**(a)** Explain why the oscillator is needed in the system in Fig. 7.1.

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.................................................................................................................................. **[1]**

**(b)** Draw the circuit for a rectifier by adding four diodes and any necessary connections to Fig. 7.2.


**Fig. 7.2**

**[2]**

**(c)** Explain why the output voltage of a switched-mode power supply does not change when the high voltage input is reduced from 230 V to 110 V.

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**(d)** State **two** other advantages of a switched-mode power supply over a power supply using just a transformer, rectifier, smoother and regulator.

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**8** Fig. 8.1 shows a 4-bit register.

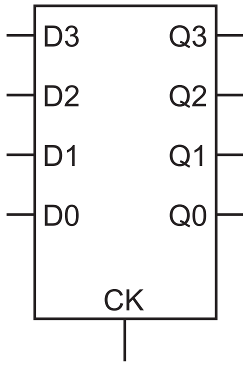


**Fig. 8.1**

**(a)** Show how the 4-bit register can be constructed from D-type flip-flops.
Label all of your connections.

**[4]**

**(b)** Write the decimal number 37 in 7-bit binary in the boxes below.

| | | | | | | |
|---|---|---|---|---|---|---|

**[1]**

**(c)** A system for adding two binary numbers together using a full adder is shown in Fig. 8.2. Complete the diagram by filling in the empty boxes.

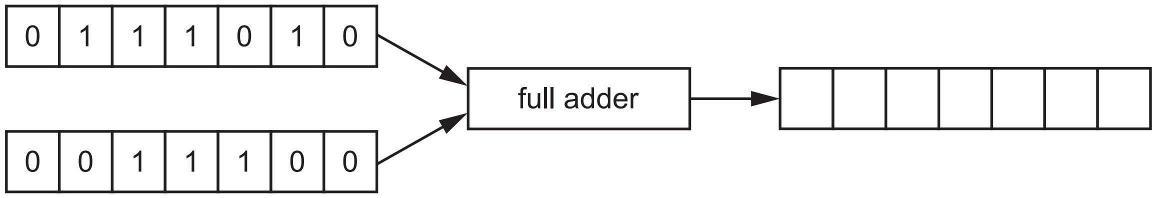


**Fig. 8.2**

**[2]**

**(d)** Two's complement is used in digital systems to represent negative numbers. Show how you would represent the number -73 using two's complement.

Explain your working by first representing 73 as a binary number and then showing each step with a comment.

**[4]**

**(e)** Complete the block diagram in Fig. 8.3 of a system for subtracting one number from another below. Use a full adder and a two's complement processor in your design.


**Fig. 8.3**

**[2]**

**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).