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Tuesday 14 June 2016 – Morning**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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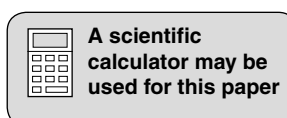
Centre number						Candidate number				
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INSTRUCTIONS TO CANDIDATES

- 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. 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 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 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	$\Delta V_{out} = -V_{in} \frac{\Delta t}{RC}$	

4

Answer **all** questions.

- 1 Fig. 1.1 shows an incomplete MOSFET amplifier circuit.

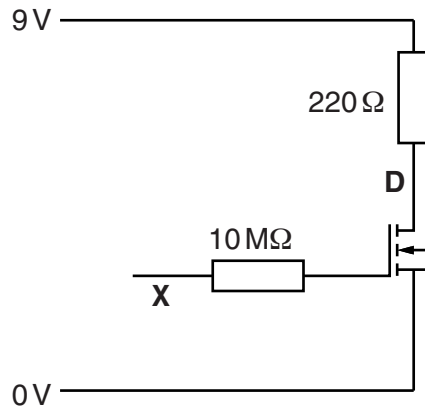
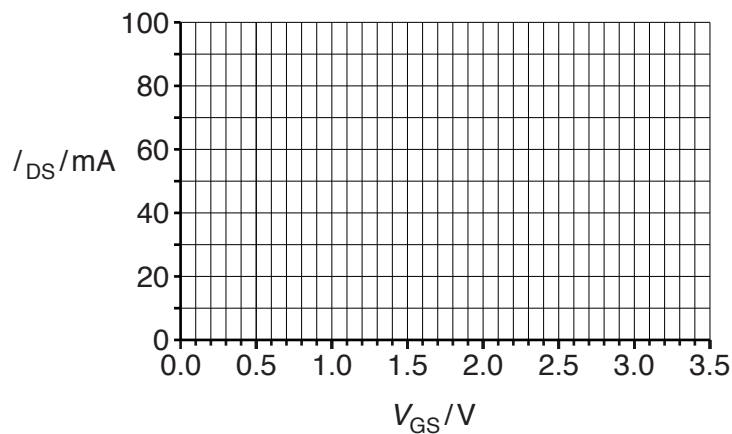


Fig. 1.1

- (a) Calculate the values of resistors required in the circuit of Fig. 1.1 to make the point **X** at 2.9V. Draw and label these resistors with their values on Fig. 1.1. [2]
- (b) Add components and connections to Fig. 1.1 to show how an a.c. signal can be input and output from the amplifier. Label the input and the output of the amplifier. [3]
- (c) The MOSFET has a threshold voltage of 2.8V and a transconductance of 0.20S.
- (i) Draw on the axes below to show the variation of the drain current I_{DS} with the gate-source voltage, V_{GS} .



[3]

(ii) Calculate the a.c. voltage gain of the amplifier.

gain = [2]

(d) The circuit has been designed to have a voltage of 5V at **D** when there is no a.c. signal at the input.

(i) Explain why the circuit has been designed in this way.

.....

 [2]

(ii) Calculate the drain current I_{DS} when there is no signal at the input of the amplifier.

I_{DS} = mA [2]

(e) Fig. 1.2 shows a graph of the drain current, I_{DS} , against the drain-source voltage, V_{DS} , for a gate-source voltage, V_{GS} , of 5V. Sketch another line on the graph for a gate-source voltage of 4V.

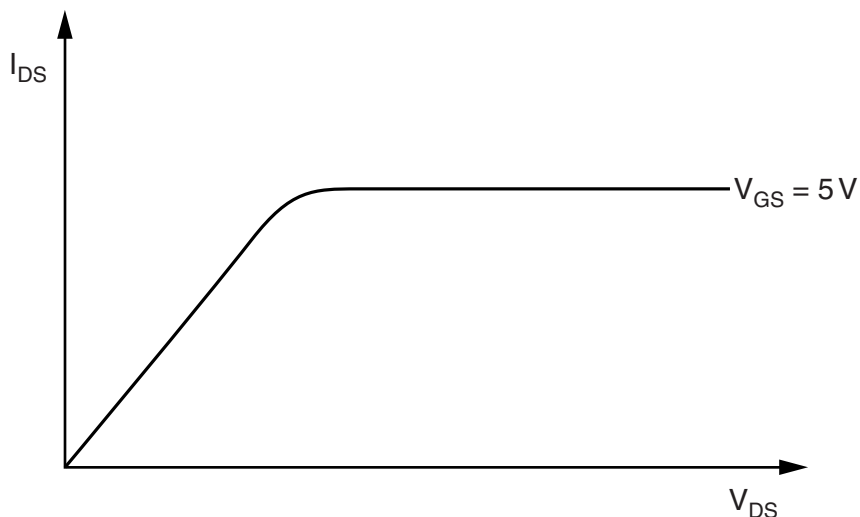


Fig. 1.2

[3]

2 The circuit of Fig. 2.1 is an on-off feedback system to control the temperature of a fish tank.

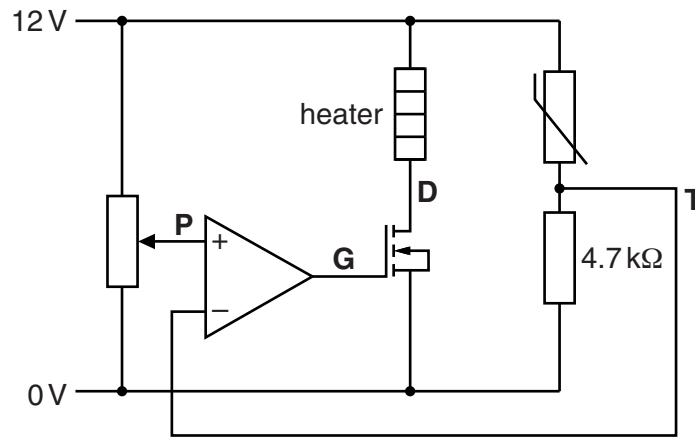


Fig. 2.1

(a) State the function of the potentiometer in the circuit.

..... [1]

(b) Explain how the circuit in Fig. 2.1 works to control temperature.

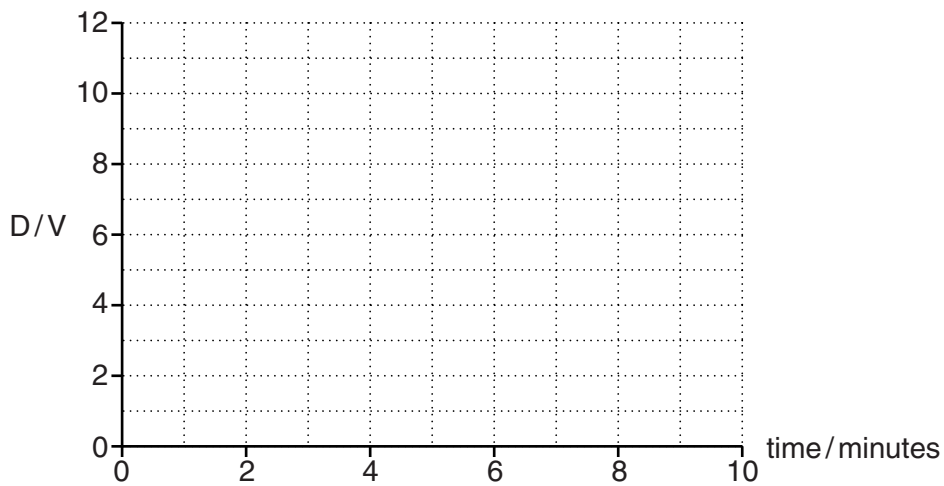
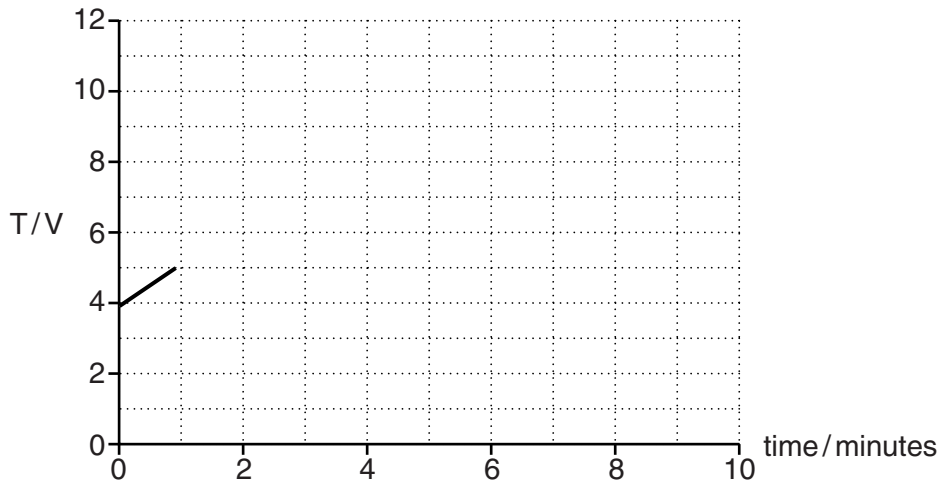
.....

 [6]

(c) When the circuit is first turned on, the voltage at the inverting terminal of the op-amp is 4V. Calculate the resistance of the thermistor when the circuit is first turned on.

resistance =kΩ [2]

- (d) The potentiometer is set to make the voltage at **P** = 7V.
 Draw on the axes below to show how the voltage at **T** and **D** vary with time.



[5]

- (e) Another system to control the temperature of a fish tank uses proportional feedback.
 State and explain **one** advantage of each feedback system.

Advantage of proportional feedback with reason:

.....

.....

.....

Advantage of on-off feedback with reason:

.....

.....

..... [4]

3 The block diagram of a switched-mode power supply is shown in Fig. 3.1.

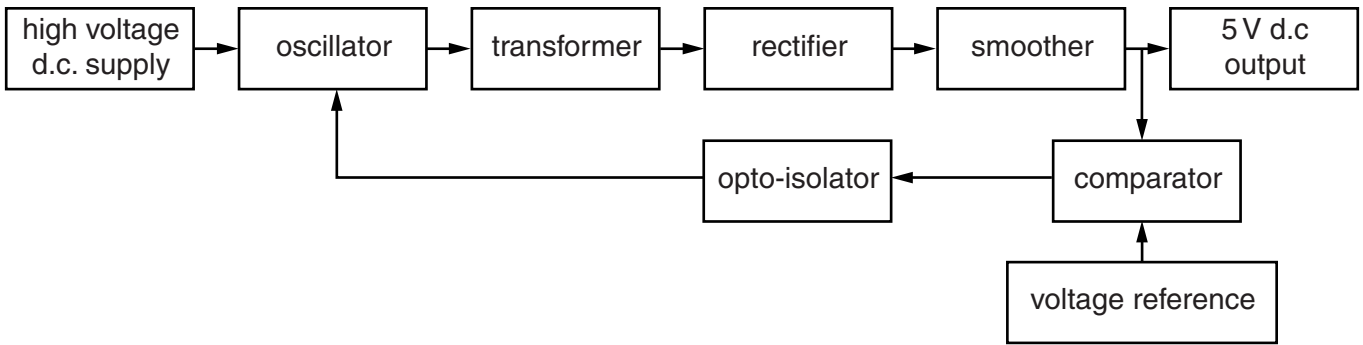


Fig. 3.1

(a) Explain how the switched-mode power supply responds when the output falls from just above 5V to just under 5V d.c.

.....

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.....

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.....

.....

..... [4]

(b) The rectifier circuit is shown in Fig. 3.2 and Fig. 3.3 shows how the voltage at V_{in} varies with time.

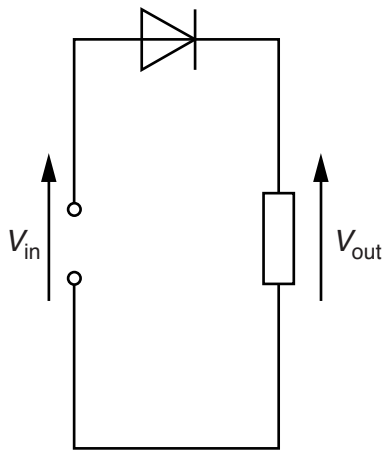


Fig. 3.2

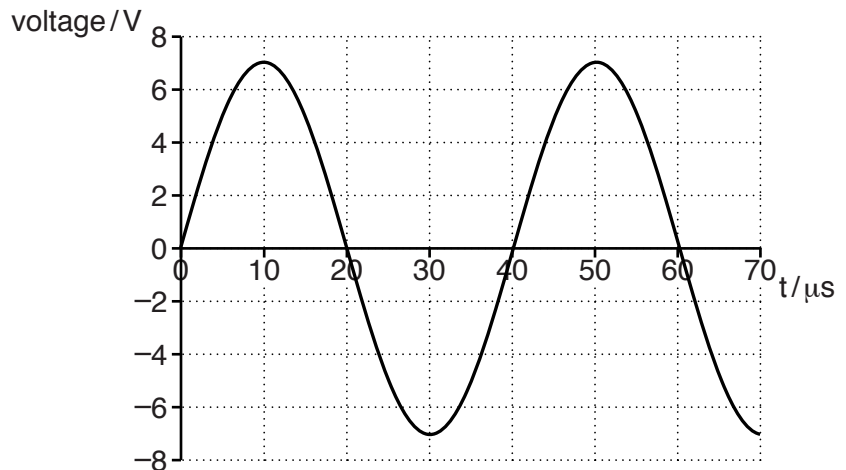


Fig. 3.3

(i) Draw a graph on the axes to show how V_{out} varies with time.

[3]

(ii) Calculate the frequency of V_{in} from Fig. 3.3.

frequency = Hz [2]

(c) The circuit diagram of the reference, comparator and opto-isolator from Fig. 3.1 is shown in Fig. 3.4. The comparator operates from supply rails at 5V and 0V.

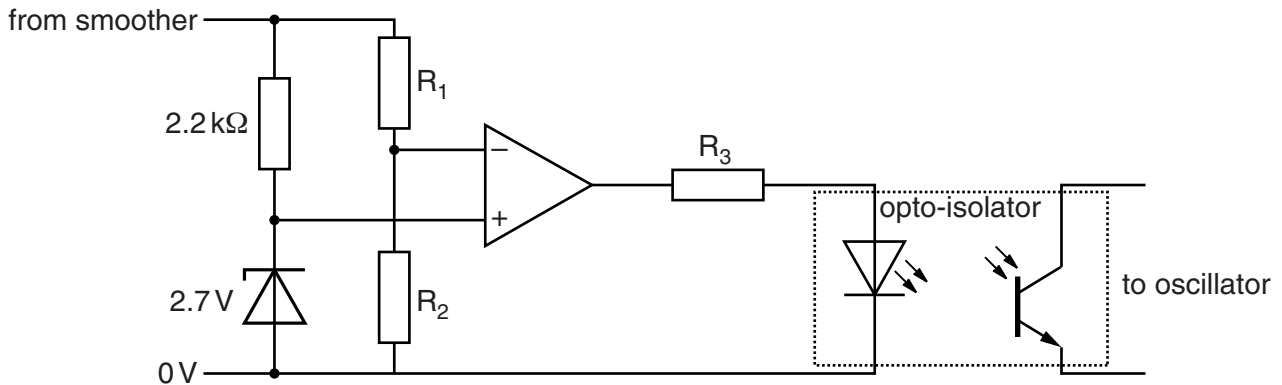


Fig. 3.4

(i) Put a ring around the reference part of the circuit. [1]

(ii) Calculate values for R_1 and R_2 to make the system produce a 5V output.

$R_1 = \dots\dots\dots \Omega$, $R_2 = \dots\dots\dots \Omega$ [2]

(iii) The LED in the opto-isolator is designed to work at 1.7V, 8 mA. Calculate a suitable value for R_3 . State what you have to assume.

$R_3 = \dots\dots\dots \Omega$

Assumption: [2]

4 The block diagram of a light control system is shown in Fig. 4.1.

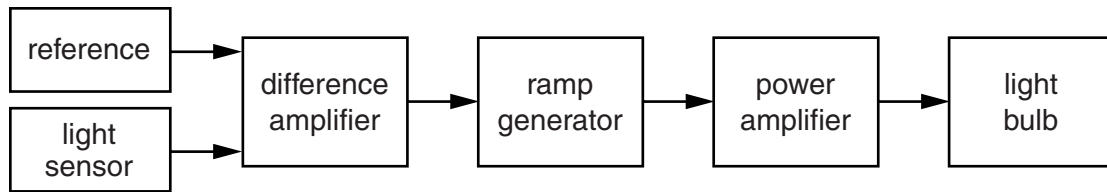


Fig. 4.1

(a) (i) Put a ring around the type of system shown in Fig. 4.1.

- on-off control open-loop control proportional control switched-mode control

[1]

(ii) Give a reason for your answer.

.....
 [1]

(b) The circuit of the difference amplifier is shown in Fig. 4.2.

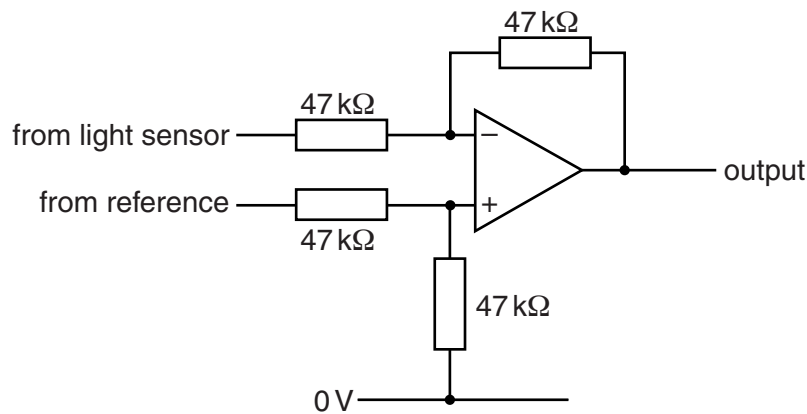


Fig. 4.2

(i) Calculate the output voltage of the difference amplifier when the light sensor voltage is 6V and the reference voltage is 4V.

output voltage = V [1]

(ii) Calculate the voltage at the inverting terminal of the op-amp when the light sensor voltage is 6V and the reference voltage is 4V.

voltage at inverting terminal = V [1]

- (c) The circuit of the ramp generator sub-system is shown in Fig. 4.3.

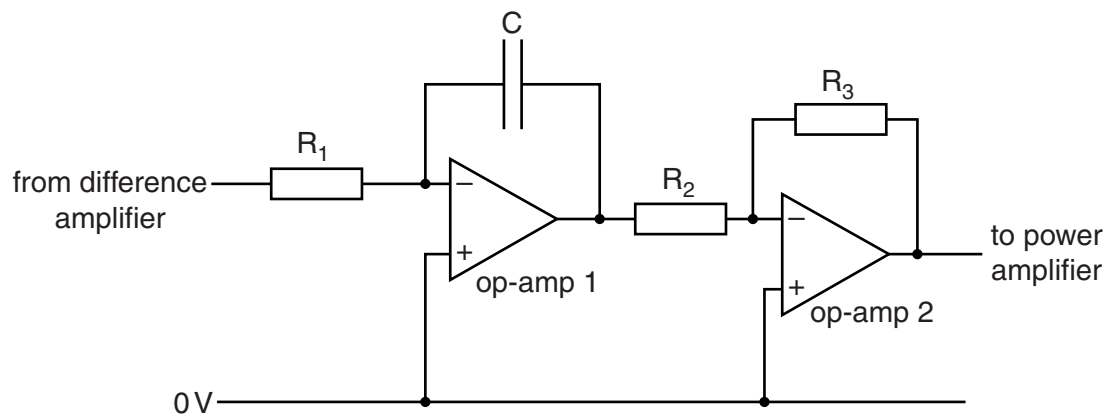


Fig. 4.3

The ramp generator output changes at a rate 0.33V/s when the voltage from the difference amplifier is $+2.5\text{V}$. Calculate the values of all of the components in the circuit.

$$C = \dots\dots\dots \mu\text{F}, \quad R_1 = \dots\dots\dots \text{k}\Omega, \quad R_2 = \dots\dots\dots \text{k}\Omega, \quad R_3 = \dots\dots\dots \text{k}\Omega \quad [4]$$

- (d) Explain how the system works by filling in the gaps using the words below. Each word can be used once, more than once or not at all.

decreasing increasing negative positive unchanging zero

When the circuit is first turned on, the reference voltage is greater than the voltage from the light sensor. The output from the difference amplifier is so the voltage at the ramp generator output is, the power amplifier output voltage is and the brightness of the bulb is

When the voltages from the light sensor and reference are the same, the difference amplifier output is so the voltage at the ramp generator output is, the power amplifier output voltage is and the brightness of the bulb is [8]

- 5 A student has built the circuit in Fig. 5.1 to show how quickly a wheel is rotating. Each time a magnet on the wheel goes past a sensor, the sensor produces a high pulse.

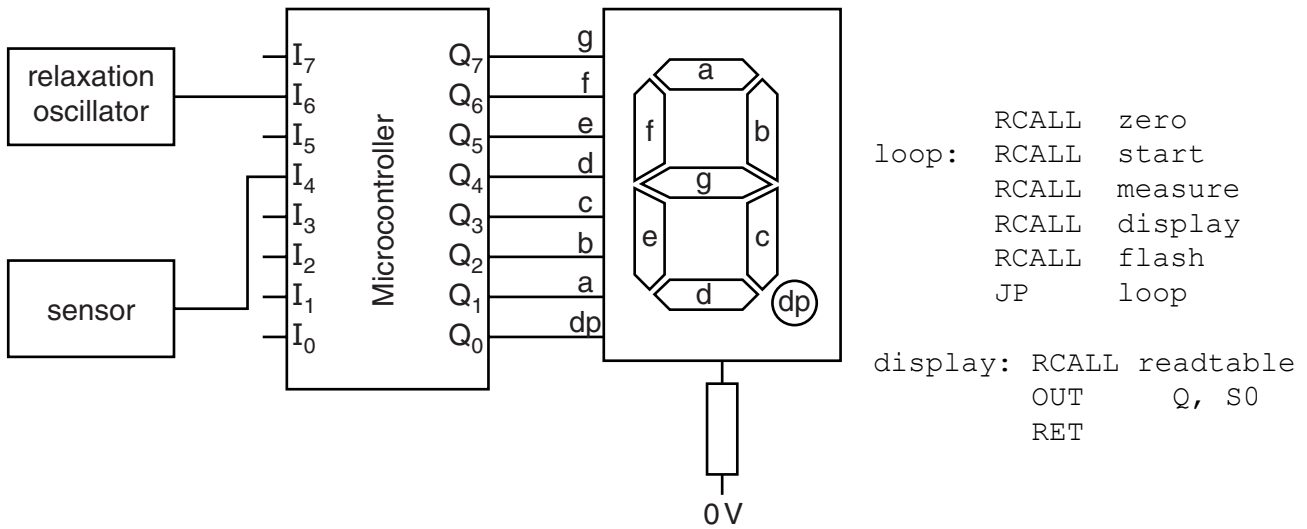


Fig. 5.1

- (a) Complete the subroutine `zero` to put a 0 on the 7-segment display with the decimal point (dp) off.

```

zero:  .....
       .....
       .....
    
```

[4]

- (b) Complete the subroutine `start` which waits for the signal from the relaxation oscillator to go high before returning to the main program.

```

start: .....
       .....
       .....

       JZ  start
       RET
    
```

[4]

- (c) The subroutine `measure` determines the number of pulses produced by the sensor while the oscillator signal is high.

```
measure:  MOVI  S7, 00
          MOVI  S2, 10
          MOVI  S4, 40
next:     IN    S3, I
          AND   S3, S2
          JZ   next
          INC  S7
again:    IN    S3, I
          AND   S3, S2
          JNZ  again
          IN    S3, I
          AND   S3, S4
          JNZ  next
          RET
```

Explain how the subroutine `measure` uses registers to respond to changes in signal from the sensor and the relaxation oscillator.

.....

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.....

.....

..... [6]

14

- (d) Write the subroutine `flash` to turn the dp light on for 200 ms and then off for 200 ms without changing the rest of the display. The dp should keep turning on and off for 10 seconds before returning to the main program.

[6]

6 Fig. 6.1 shows the incomplete circuit diagram of a non-volatile memory cell.

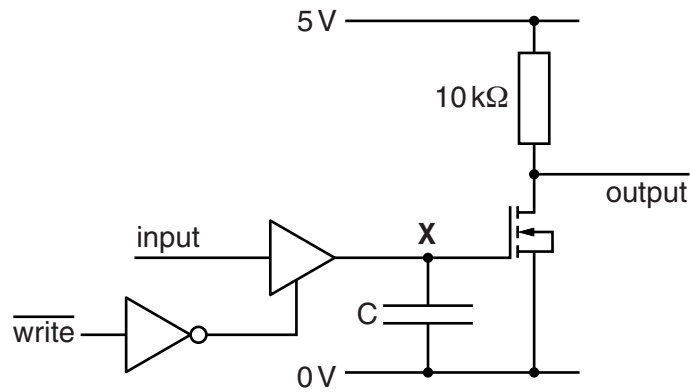


Fig. 6.1

(a) State what non-volatile means when referring to memory.

..... [1]

(b) Complete Fig. 6.2 to show how the state of the voltage at X and the output depends on the input and write voltages.

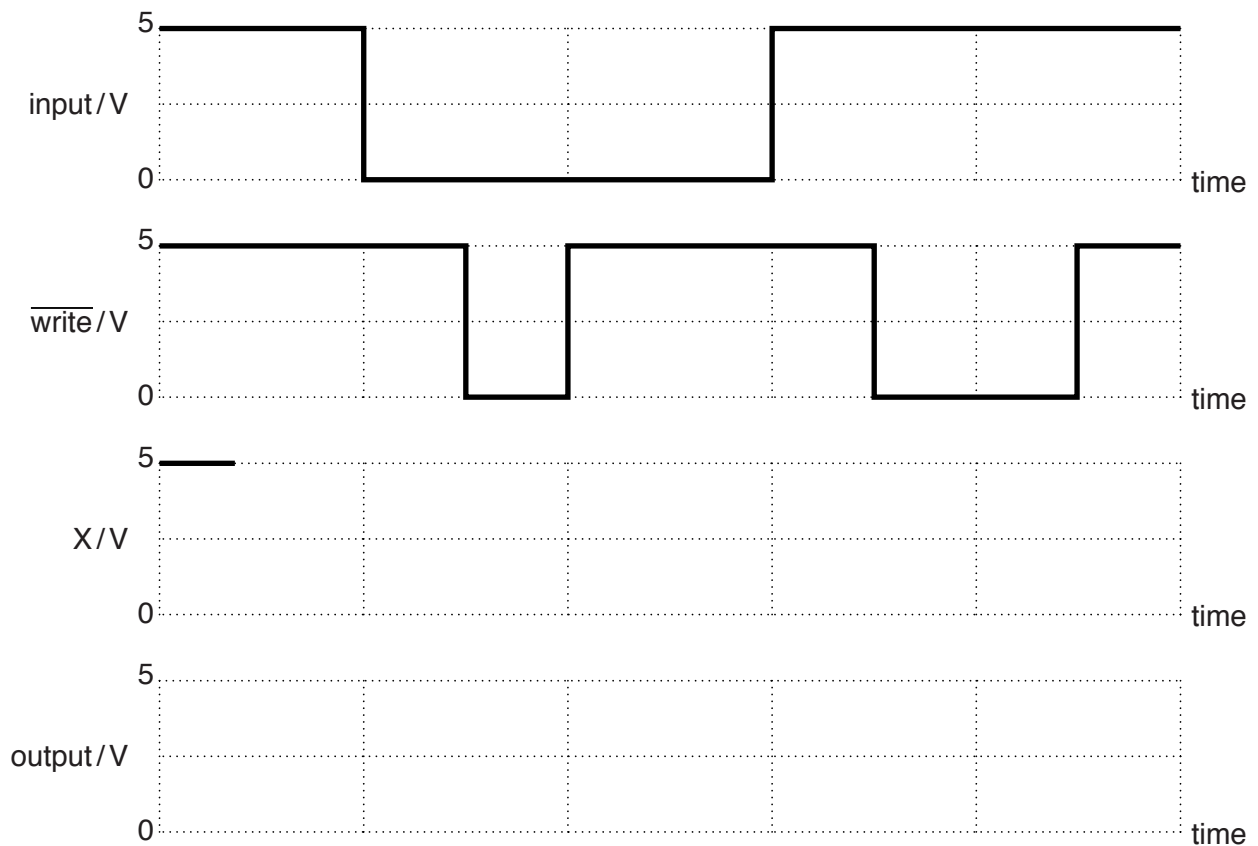


Fig. 6.2

[4]

16

- (c) Add a NOT gate and tristate to the circuit in Fig. 6.3 to show how a memory cell can be made with a bidirectional data line and $\overline{\text{read}}$ input.

Label the data and $\overline{\text{read}}$ lines.

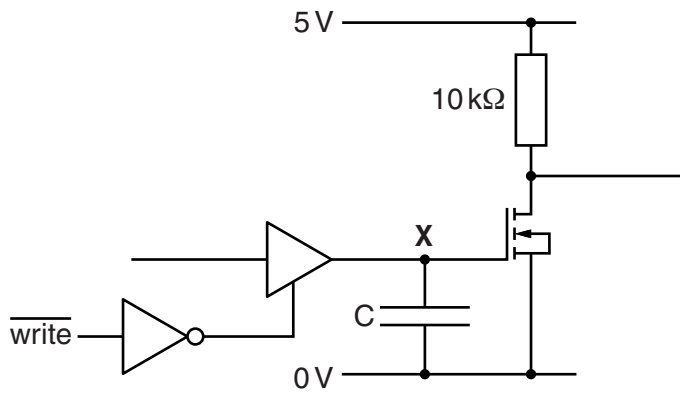


Fig. 6.3

[4]

7 This question is about microcontrollers.

(a) State the location and describe the function of the general purpose registers in a microcontroller.

Location:

Function:

.....

..... [3]

(b) Describe what the data bus is in a microcontroller and what it is used for.

Description of data bus:

.....

Purpose of data bus:

.....

.....

..... [4]

(c) Describe what happens in a microcontroller when a subroutine is called and what happens at the end of the subroutine when the RET function is executed. Refer to the contents of the registers.

.....

.....

.....

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.....

.....

.....

.....

..... [6]

Quality of written communication [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).

A large area of lined paper for writing answers. It features a vertical margin line on the left side and horizontal dotted lines for writing. The lines are evenly spaced and extend across the width of the page.

A large grid of dotted lines for writing, consisting of 20 horizontal rows and a vertical margin line on the left side.

A large area of the page is reserved for writing, featuring a vertical solid line on the left side and horizontal dotted lines extending across the page.



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