Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1145/01

ELECTRONICS – ET5

A.M. WEDNESDAY, 11 June 2014

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**6**	
2.	**6**	
3.	**8**	
4.	**8**	
5.	**5**	
6.	**7**	
7.	**8**	
8.	**6**	
9.	**11**	
10.	**5**	
Total	**70**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 70.

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

INFORMATION FOR THE USE OF CANDIDATES

Preferred Values for resistors

The figures shown below and their decade multiples and sub-multiples are the E24 series of preferred values.

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91.

Standard Multipliers

Prefix	Multiplier
T	$\times 10^{12}$
G	$\times 10^{9}$
M	$\times 10^{6}$
k	$\times 10^{3}$

Prefix	Multiplier
m	$\times 10^{-3}$
μ	$\times 10^{-6}$
n	$\times 10^{-9}$
p	$\times 10^{-12}$

Alternating Voltages $V_o = V_{rms}\sqrt{2}$

Silicon Diode $V_F \approx 0{\cdot}7\,V$

Operational amplifier

$G = -\dfrac{R_F}{R_{IN}}$ Inverting amplifier

$G = 1 + \dfrac{R_F}{R_1}$ Non-inverting amplifier

$V_{OUT} = V_{DIFF}\left(\dfrac{R_F}{R_1}\right)$ Difference amplifier

$V_{OUT} = -R_F\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}\right)$ Summing amplifier

$V_L \approx V_Z\left(1 + \dfrac{R_F}{R_1}\right)$ Stabilised power supply

Emitter follower $V_{OUT} = V_{IN} - 0{\cdot}7\,V$

Filters

$f_b = \dfrac{1}{2\pi RC}$ Break frequency for high pass and low pass filters

$X_C = \dfrac{1}{2\pi fC}$ Capacitive reactance

Thyristor phase control

$\phi = \tan^{-1}\dfrac{R}{X_C}$

$\tan\phi = \dfrac{R}{X_C}$

Signal conversion $\text{resolution} = \dfrac{\text{i/p voltage range}}{2^n}$ ADC

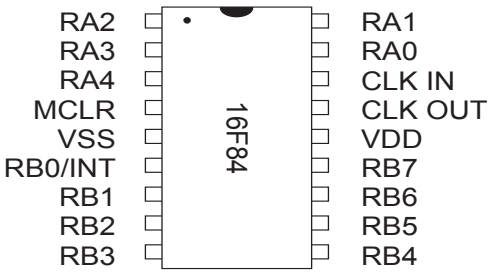
Power amplifier $P_{MAX} = \dfrac{V_S^2}{8R_L}$ where V_S is the rail-to-rail voltage

PIC Information

The PIC programs include 'equate' statements that define the following labels:

Label	Description
PORTA	input / output port A
PORTB	input / output port B
TRISA	the control register for port A
TRISB	the control register for port B
STATUS	the status register
INTCON	the interrupt control register
W	the working register (= h '0')
F	the file register (= h '1')
RP0	the register page selection bit 0
Z	the zero flag status bit
GIE	the global interrupt controller bit
INTE	the external interrupt enable bit

Pinout for 16F84 PIC IC:



List of commands:

Mnemonic	Operands	Description
bcf	f, b	Clear bit b of file f
bsf	f, b	Set bit b of file f
btfss	f, b	Test bit b of file f, skip next instruction if bit is set
call	k	Call subroutine k
clrf	f	Clear file f
goto	k	Branch to label k
movf	f, d	Move file f (to itself if d = 1, or to working register if d = 0)
movlw	k	Move literal k to working register
movwf	f	Move working register to file f
retfie		Return from interrupt service routine and set global interrupt enable bit GIE

Comparison of TASM and MPASM languages:

Version		TASM	MPASM
Number system notation	Decimal	153	d'153'
	Hex	$2B	h'2B' or 0x2B
	Binary	%10010110	b'10010110'
Opcode Notation		.equ	equ
		.org	org
		.end	end
		label:	label

Structure of the INTCON register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	EEIE	TOIE	INTE	RBIE	TOIF	INTF	RBIF

Structure of the STATUS register

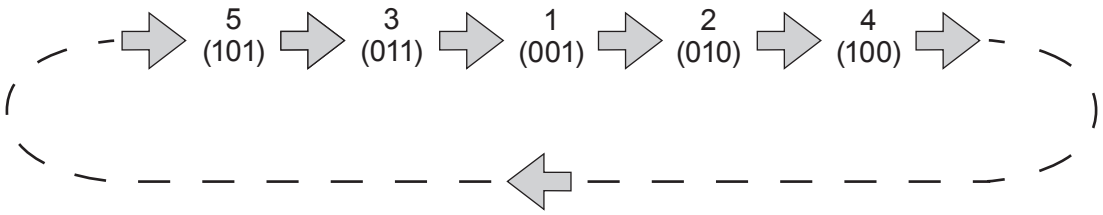
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IRP	RP1	RP0	TO	PD	Z	DC	C

Turn over.

Examiner only

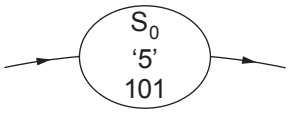
1. *(a)* A sequence generator is used to select questions at random in a quiz.

It outputs the following sequence of numbers repeatedly at high speed, in binary. (The binary equivalents are given in brackets.)



The sequence freezes when a contestant presses a switch, to interrupt the flow of clock pulses to the sequence generator.

Complete the state diagram for this system, **including any unused states**. [3]



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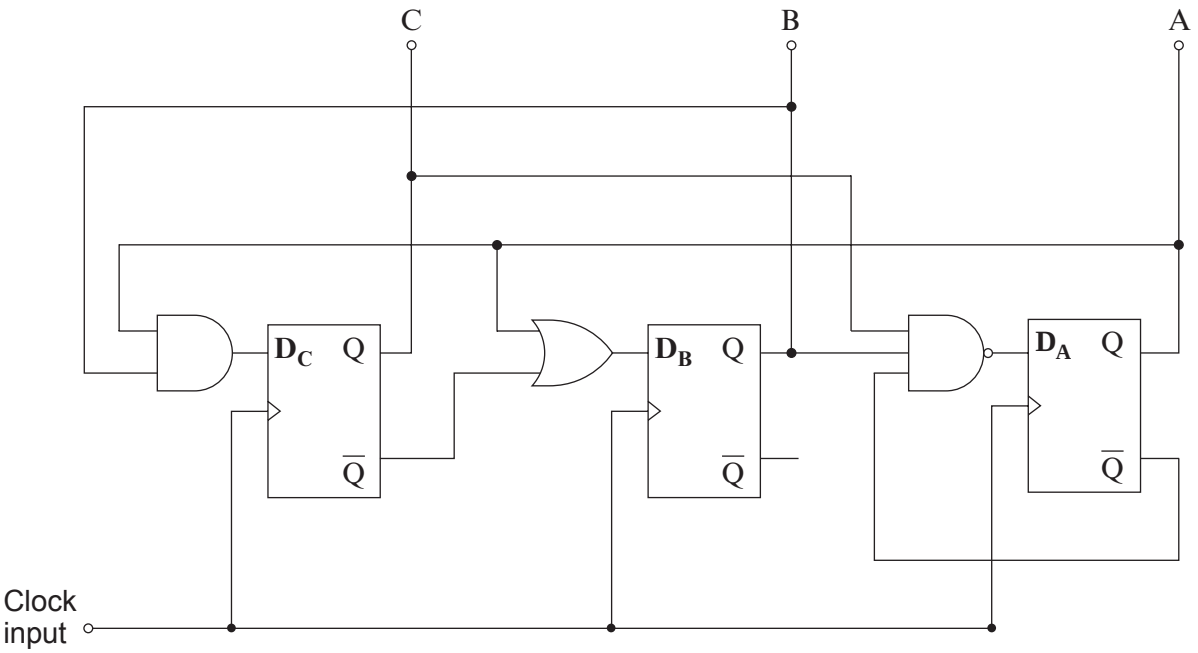
(b) The diagram below shows the circuit for a synchronous counter.



Complete the Boolean expressions linking inputs $\mathbf{D_A}$, $\mathbf{D_B}$ and $\mathbf{D_C}$ to the outputs A, B and C. [3]

$\mathbf{D_C}$ = ...

$\mathbf{D_B}$ = ...

$\mathbf{D_A}$ = ...

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2. The following Boolean expressions control a sequence generator:

$D_C = \overline{B}$

$D_B = A \oplus C$

$D_A = \overline{B + C}$

(a) Complete the table for **all eight** possible output combinations for this sequence generator. [3]

Current Outputs				Next Outputs		
State	**C**	**B**	**A**	D_C	D_B	D_A
0	0	0	0			
1						
2						
3						
4						
5						
6						
7						

(b) Write down all of the unused states. [2]

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(c) Are there any stuck states? If so, identify them. [1]

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3. A PIC microcontroller is used in a lift control system.

The main program uses sensors attached to Port A to control the lift motor, which is linked to Port B bit 3.

The interrupt uses a temperature sensor attached to Port B bit 0 which is used to monitor the lift motor. When the motor overheats, this sensor causes an interrupt, which uses a buzzer attached to PORT B bit 2, and a LED on PORT B bit 1.

A switch unit connected to Port A bit 0 outputs a logic 1 signal when pressed, and a logic 0 signal when not pressed.

(a) Complete the coding to define all the bits of Port A as inputs, and the bits of Port B as described above. [2]

```
bsf     STATUS,RP0
movlw   b '_ _ _ _ _'
movwf   TRISA
movlw   b '_ _ _ _ _ _ _ _'
movwf   TRISB
bcf     STATUS,RP0
```

(b) Parts of the program stored in the microcontroller are given below:

Address	Operator	Operand
00	goto	start
04	goto	alarm

The Interrupt Service Routine is given below. It includes a subroutine called twosec, which causes a two second delay.

```
Label          Operator     Operand
……..           movwf        Wstore;
               bcf          INTCON,1;
loop           movlw        b'00000110';
               movwf        PORTB;
               call         twosec;
               movlw        b'00000100';
               movwf        PORTB;
               call         twosec;
               btfss        PORTA,0;
               goto         loop;
               clrf         PORTB;
               movf         Wstore;
               retfie;
```

(i) What label should be used at the beginning of the Interrupt Service Routine? [1]

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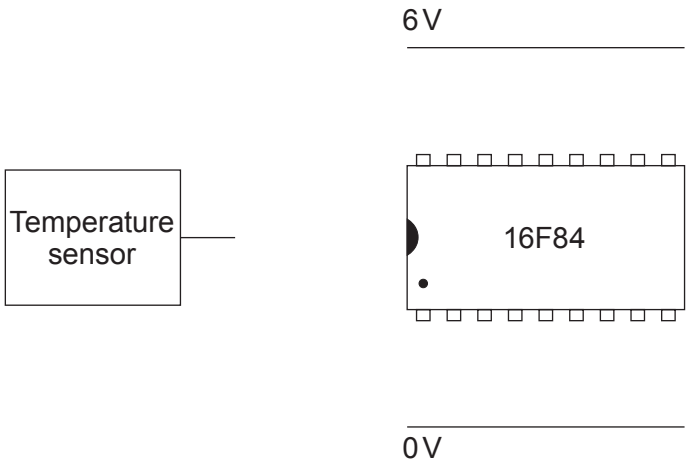
Examiner only

(ii) The pinout for the PIC microcontroller is given in the Information Sheet on page 3.

An interrupt is triggered when the temperature sensor outputs a logic 0 signal. Show how this sensor is connected to the PIC microcontroller. [1]



(iii) What is the effect of the instruction “bcf INTCON,1”? [1]

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(iv) Explain what happens to the buzzer and LED when an interrupt is called. [3]

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4. Here is part of the specification for a bench power supply.

Load regulation	0.01% for 90% load change
Line regulation	0.05% for 10% line voltage change
Ripple regulation	<3 mV rms

(a) What is meant by the terms:

(i) *Load regulation?* [1]

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(ii) *Line regulation?* [1]

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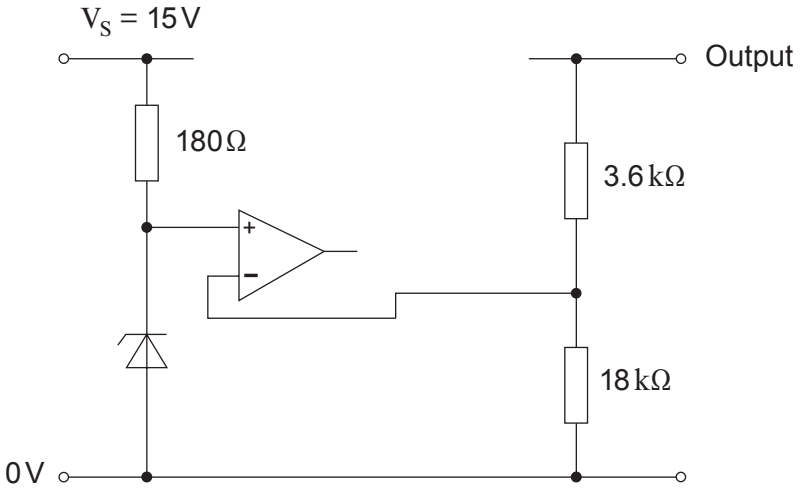
(b) The diagram shows part of a voltage regulator circuit, that uses a 10 V zener diode.



(i) Write down the voltage at the non-inverting input of the op-amp. [1]

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(ii) Complete the circuit diagram by adding an emitter follower to drive the output. [2]

(iii) Calculate the output voltage of the voltage regulator. [1]

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Examiner only

(iv) The supply voltage V_S increases to 15.5 V. Describe any resulting changes: [2]

- to the output;

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- within the circuit.

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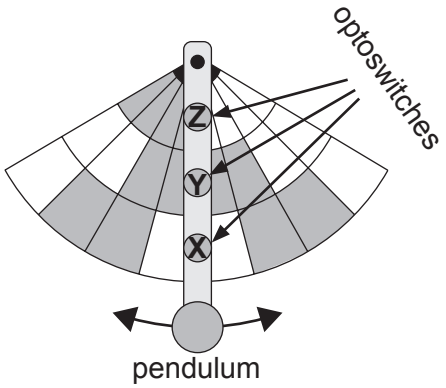
Examiner only

5. A Gray code encoded disc is used as part of a system to warn a 4 x 4 off-road enthusiast when the vehicle has tipped to a dangerous angle. As the vehicle tips, the pendulum swings, taking the optoswitches over different segments of the encoded disc.



(a) (i) What is the difference between Gray code and binary code? [1]

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(ii) What is the disadvantage of using binary code rather than Gray code in this application? [1]

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Examiner only

(b) The following table shows the behaviour of the system.

- Normally a green LED, **G**, lights, showing that the vehicle is safe.
- The amber LED, **A**, indicates that the vehicle tilt is risky.
- The red LED, **R**, comes on when it is dangerous.

Optoswitch output			**LEDs**		
Z	**Y**	**X**	**G**	**A**	**R**
0	0	0	0	0	1
0	0	1	0	1	0
0	1	1	1	0	0
0	1	0	1	0	0
1	1	0	1	0	0
1	1	1	1	0	0
1	0	1	0	1	0
1	0	0	0	0	1

Complete the following Boolean expressions to show the relationships between the outputs **Z**, **Y** and **X**, of the optoswitches and the LEDs: [3]

G = ...

A = ...

R = ...

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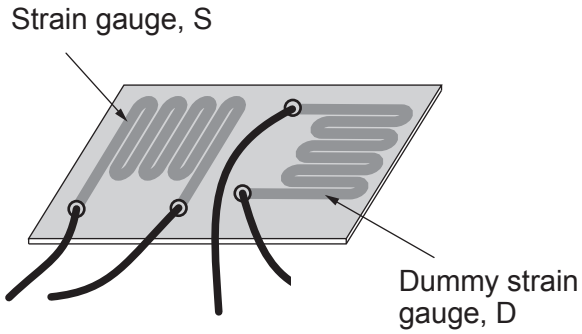
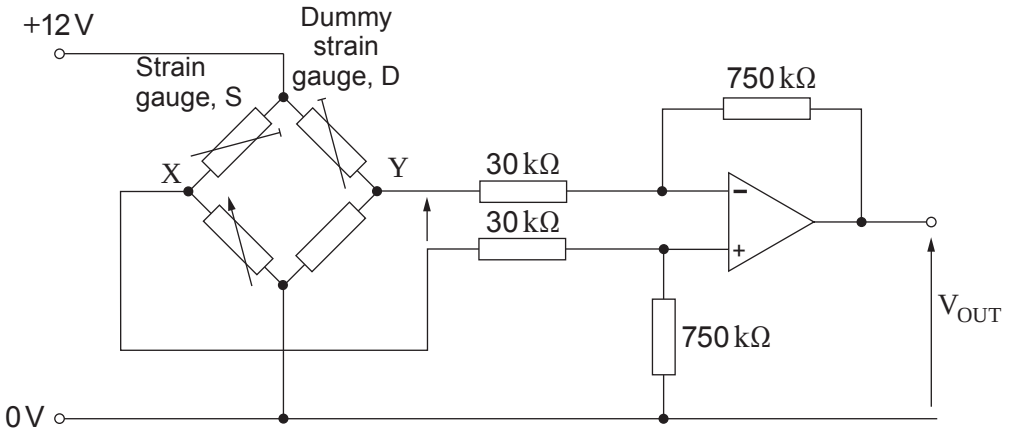
6. The diagram shows a strain gauge module.



It is used in the circuit shown below to monitor movement in a wall in an old building.



(a) The sun starts to shine on the module raising its temperature. As a result, the resistance of the strain gauge and dummy strain gauge both increase.
What happens to the voltage:

(i) at X? ..... [1]

(ii) at Y? ..... [1]

(b) The wall moves slightly, causing the resistance of strain gauge S to **increase**.
What happens to the voltage:

(i) at X? ..... [1]

(ii) at Y? ..... [1]

Examiner only

(c) The circuit has a high Common-Mode Rejection Ratio (CMRR). Why is this important in this application? [1]

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(d) Calculate the output voltage (to two decimal places) when the voltage at X = 5.87 V and the voltage at Y = 5.82 V. [2]

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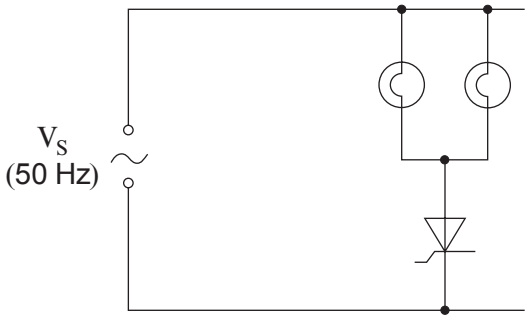
7. The diagram shows part of the circuit for a light dimmer.



(a) Complete the diagram by adding:

(i) a diac connected to improve the rise time of the signal that triggers the thyristor;

(ii) a RC network connected to vary the brightness of the bulbs using phase control. [3]

(b) (i) Calculate the phase angle between the supply voltage and the voltage across the capacitor, when $R = 2.2\ k\Omega$ and $C = 470\ nF$. [2]

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(ii) What is the relationship between this phase angle and the brightness of the bulbs? [1]

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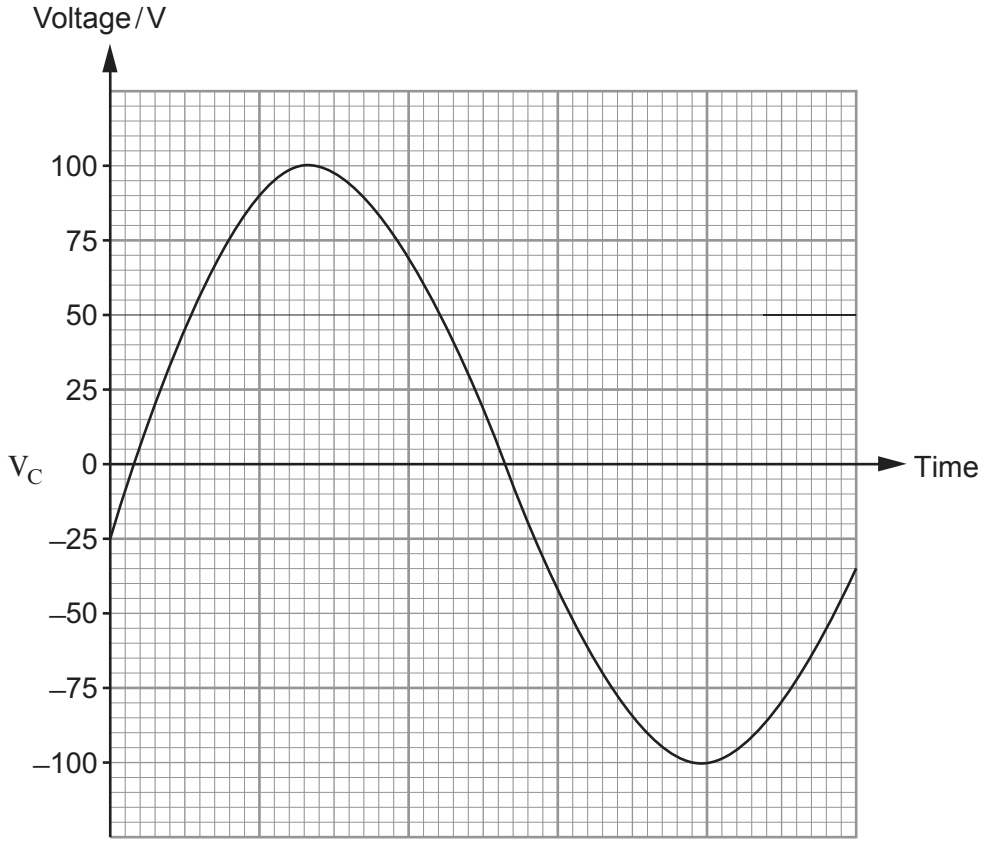
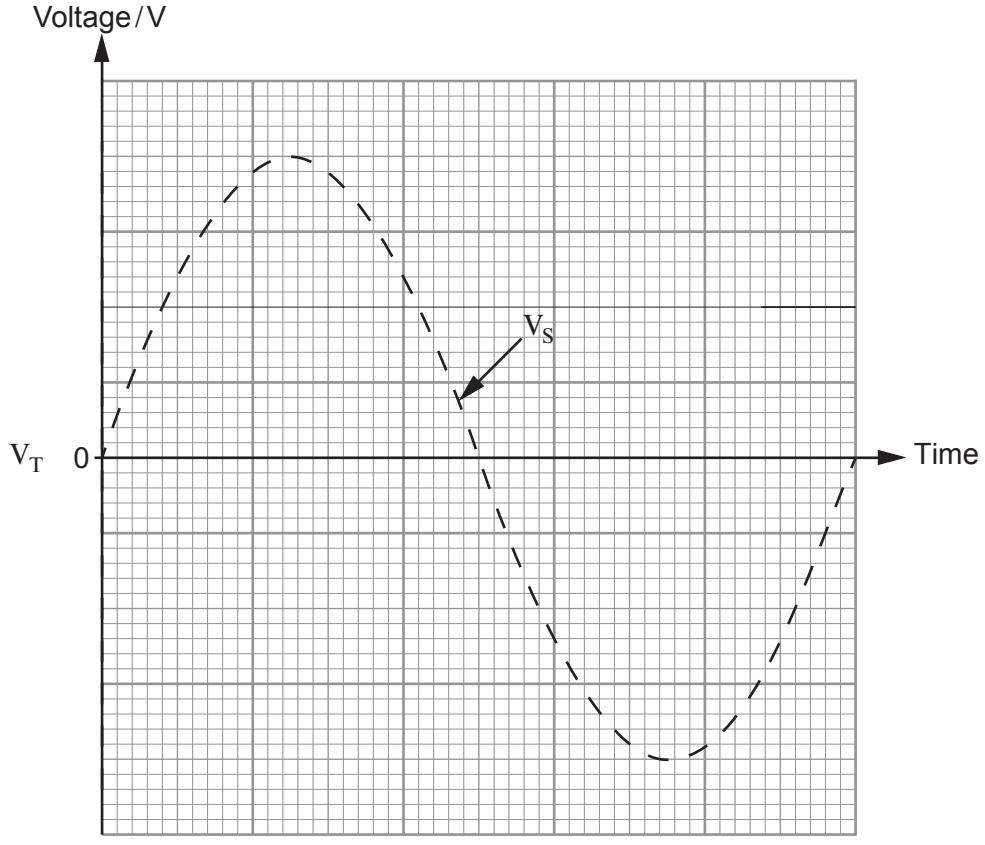
Examiner only

(c) The thyristor conducts when the voltage across the capacitor reaches 25 V. The upper graph shows the voltage, V_C, across the capacitor. Use the axes provided on the lower graph to sketch the corresponding voltage, V_T, across the thyristor. The dotted curve shows the supply voltage V_S. [2]





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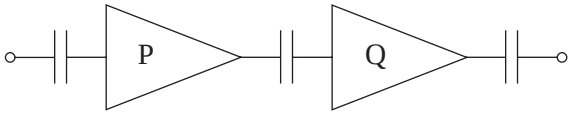
8. *(a)* A pre-amplifier uses two identical op-amps connected as a two-stage voltage amplifier.

Each op-amp has a gain-bandwidth product of 2×10^6 Hz. The two-stage amplifier has an overall voltage gain of 100.

The diagram shows this two-stage amplifier.



(i) In order to maximise bandwidth, what is the optimum voltage gain of: [2]

amplifier P; .....

amplifier Q? .....

(ii) Calculate the bandwidth of the two-stage amplifier. [1]

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(iii) What is the purpose of the three capacitors in this system? [1]

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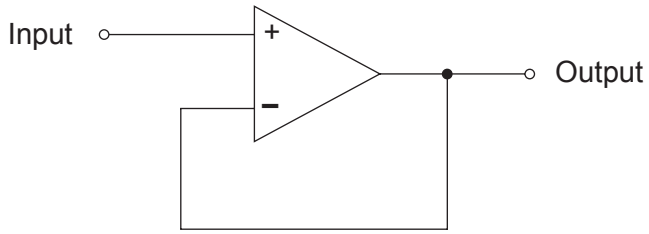
(b) The output of a pre-amplifier includes the following sub-system:



(i) What is the voltage gain of this sub-system? [1]

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(ii) What is its purpose in the pre-amplifier? [1]

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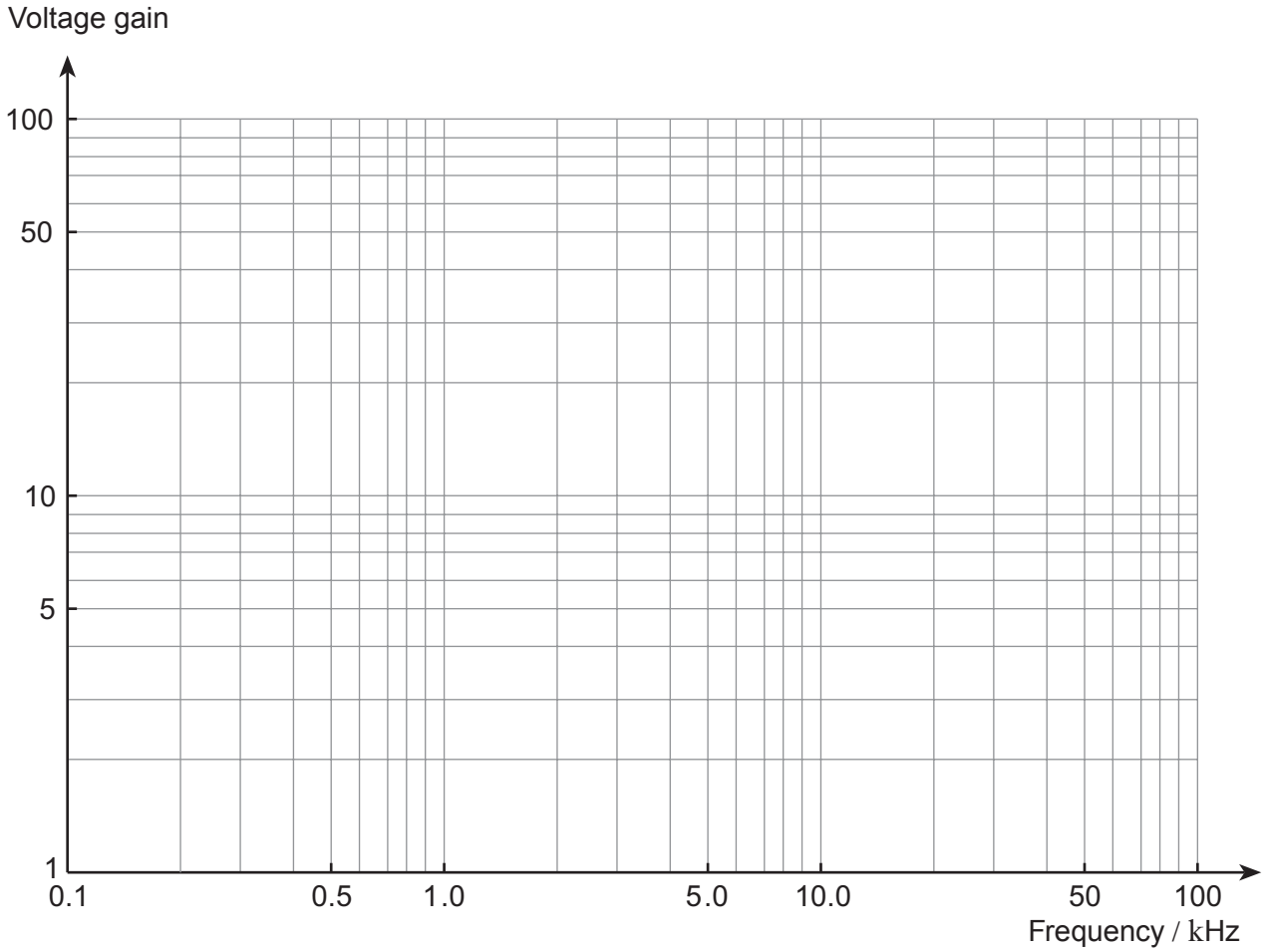
9. An audio system requires an active treble-cut filter with the following specification:

- low frequency voltage gain = 20;
- break frequency = 10 kHz.

(a) Use the axes provided to sketch the frequency response for the specified filter. [3]



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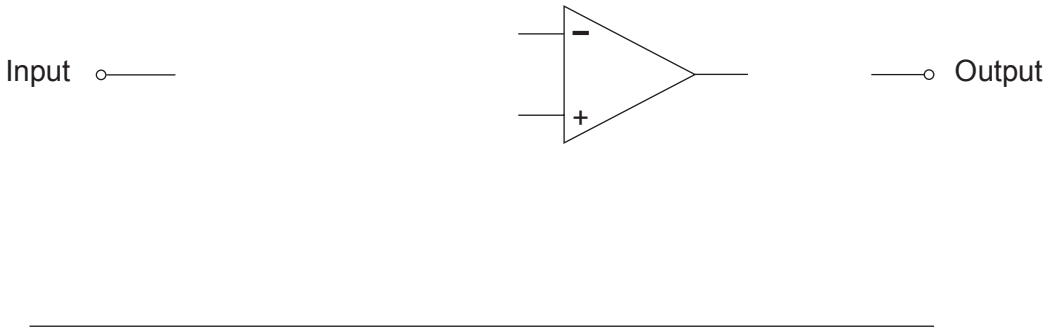
(b) (i) Design a filter with these characteristics, incorporating an op-amp, a 7.5 kΩ resistor, a 150 kΩ resistor and a capacitor. Complete the following template with your design. [3]



(ii) Which of these capacitors offers a break frequency closest to 10 kHz? (Justify your choice with a calculation.) [2]

0.1 nF 0.47 nF 1 nF 2 nF 4.7 nF 10 nF

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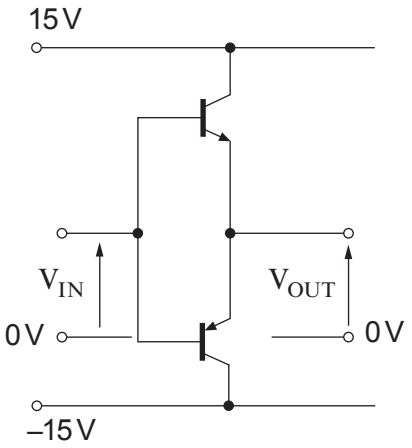
(c) The audio system uses the sub-system, shown in the following circuit diagram to drive a loudspeaker.



(i) The input voltage V_{IN} = –1.9 V.

What is the corresponding output voltage V_{OUT}? [1]

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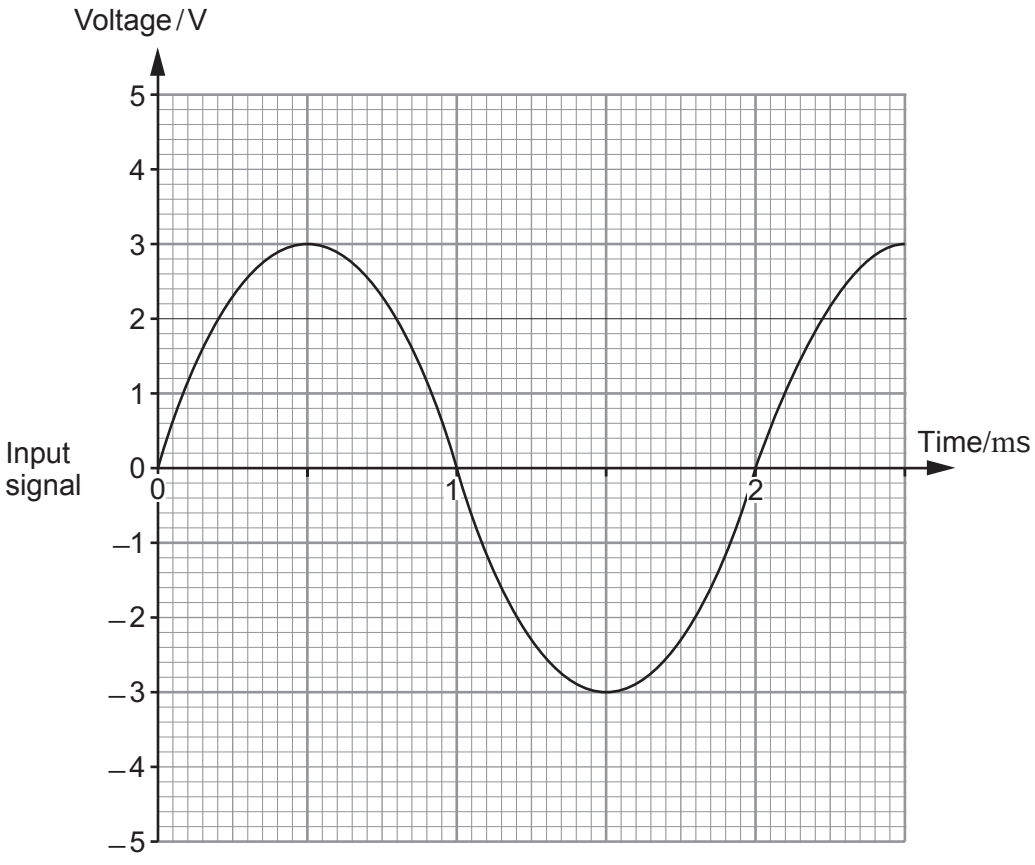
(ii) This sub-system suffers from cross-over distortion. The signal shown in the graph is applied to the input of this sub-system.
Use the same axes to draw the signal at the output of the sub-system. [2]



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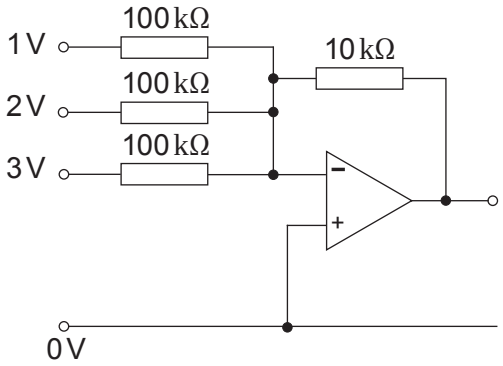
10. A summing amplifier circuit can be used as the basis for an audio mixer, or for a digital-to-analogue converter (DAC).

(a) The diagram that follows shows a summing amplifier used as part of an audio mixer. The output of the op-amp saturates at ±10 V. It is tested using the DC input voltages shown in the diagram.



Calculate the expected output voltage, V_{OUT}. [1]

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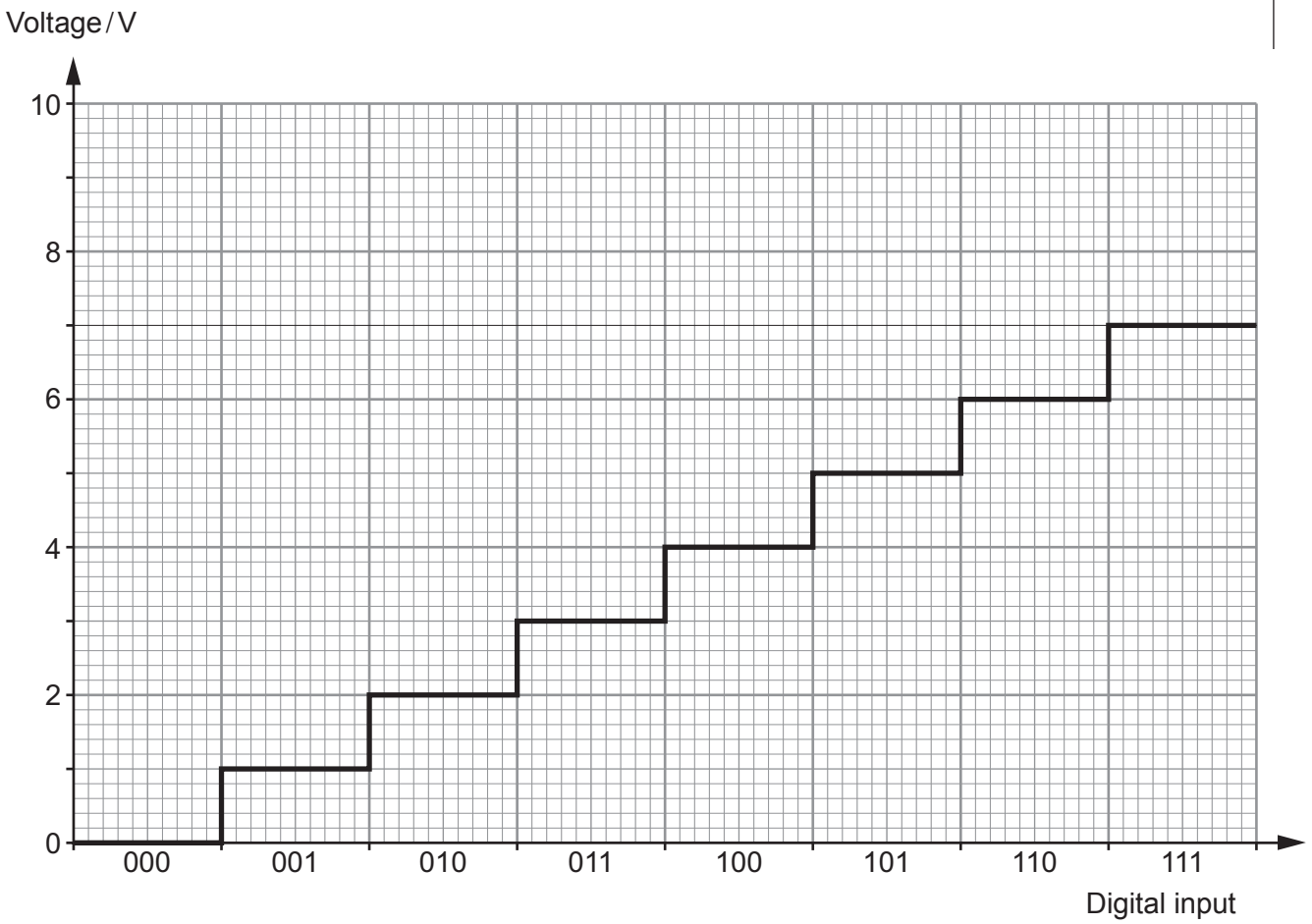
(b) A 3-bit DAC is required to produce an output signal defined by the following graph:



A 3-bit binary number, CBA is applied to the input. Bit A is the least-significant bit (LSB). Logic 1 signals are encoded as a 10 V signal and logic 0 signals as 0 V.

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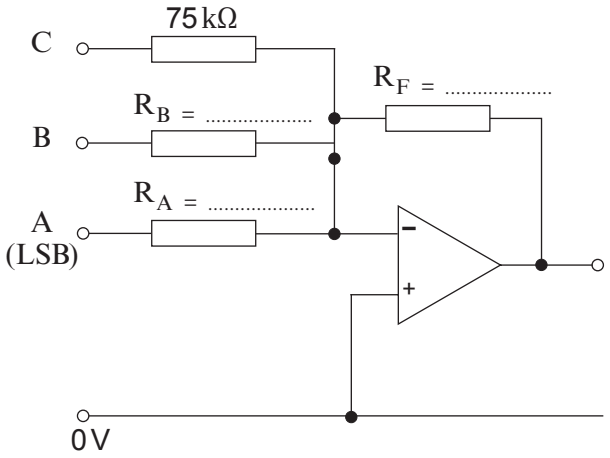
(i) The following diagram shows the first part of the circuit for the DAC:



Calculate suitable values for resistors and add them to the diagram. [2]

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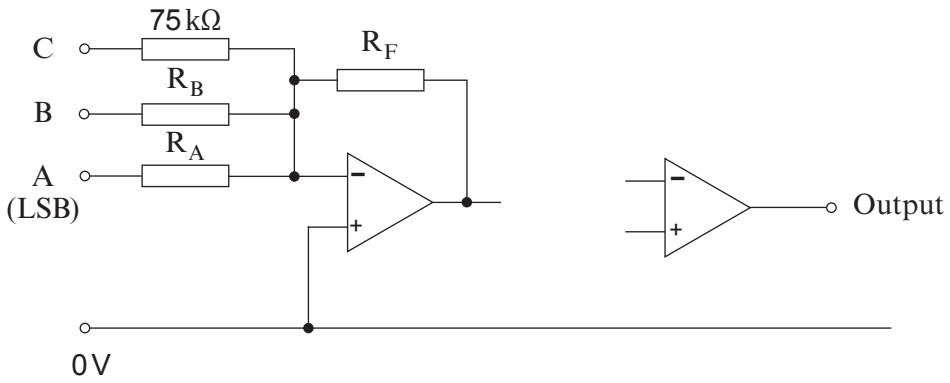
(ii) A second op-amp is added to the circuit in order to invert the signal without changing its gain.



Add all necessary components to the second op-amp and label them with suitable values. [2]

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