

1 (a) State three characteristics of an ideal operational amplifier (op-amp).

1. ....
2. ....
3. .... [3]

(b) An amplifier circuit for a microphone is shown in Fig. 8.1.

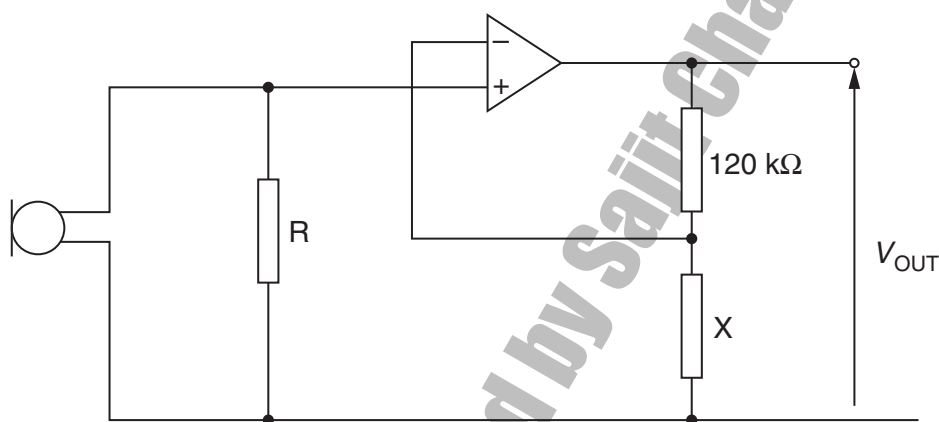


Fig. 8.1

(i) Name the type of feedback used with this op-amp.

..... [1]

(ii) The output potential difference  $V_{OUT}$  is 5.8V for a potential difference across the resistor R of 69mV. Calculate

1. the gain of the amplifier circuit,

gain = ..... [1]

2. the resistance of resistor X.

resistance = .....  $\Omega$  [2]

(iii) State one effect on the amplifier output of reducing the resistance of resistor X.

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

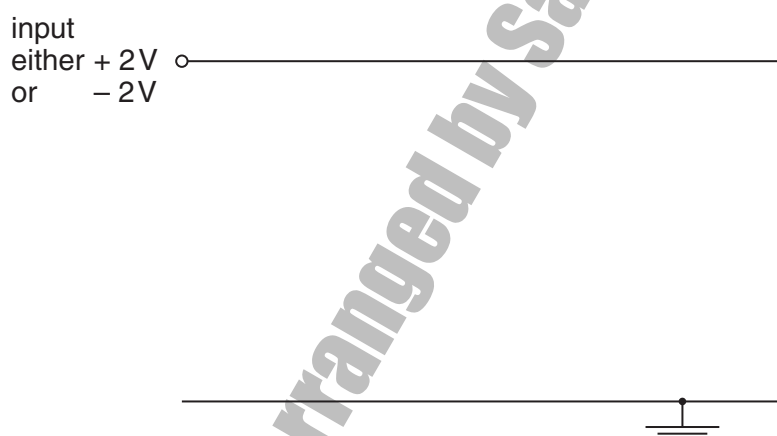
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- 2 A block diagram for an electronic sensor is shown in Fig. 9.1.



**Fig. 9.1**

- (a) Complete Fig. 9.1 by labelling the remaining boxes. [2]
- (b) A device is to be built that will emit a red light when its input is at +2 V. When the input is at -2V, the light emitted is to be green.
- (i) On Fig. 9.2, draw a circuit diagram of the device.



**Fig. 9.2**

[2]

- (ii) Explain briefly the action of this device.

.....

..... [1]

- 3 (a) By reference to an amplifier, explain what is meant by *negative feedback*.

.....

.....

..... [2]

- (b) An amplifier circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.1.

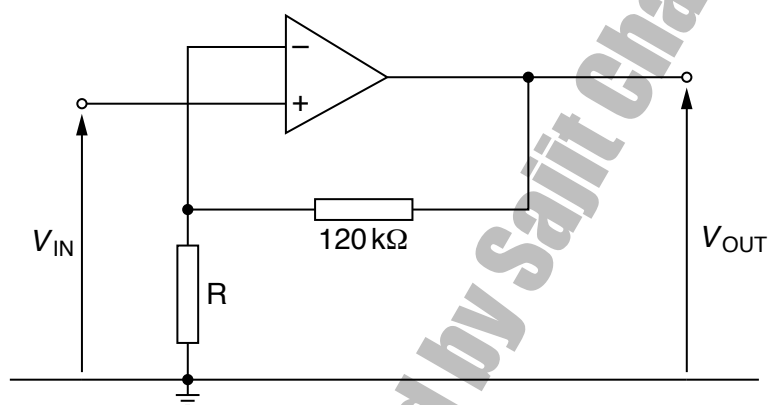


Fig. 10.1

The supply for the op-amp is  $\pm 9.0\text{V}$ .  
The amplifier circuit is to have a gain of 25.

Calculate the resistance of resistor R.

resistance = .....  $\Omega$  [2]

- (c) State the value of the output voltage  $V_{\text{OUT}}$  of the amplifier in (b) for input voltages  $V_{\text{IN}}$  of

(i)  $-0.08\text{V}$ ,

$V_{\text{OUT}} = \dots\dots\dots \text{V}$  [1]

(ii)  $+0.4\text{V}$ .

$V_{\text{OUT}} = \dots\dots\dots \text{V}$  [1]

4 (a) Fig. 8.1 shows a circuit incorporating an ideal operational amplifier (op-amp).

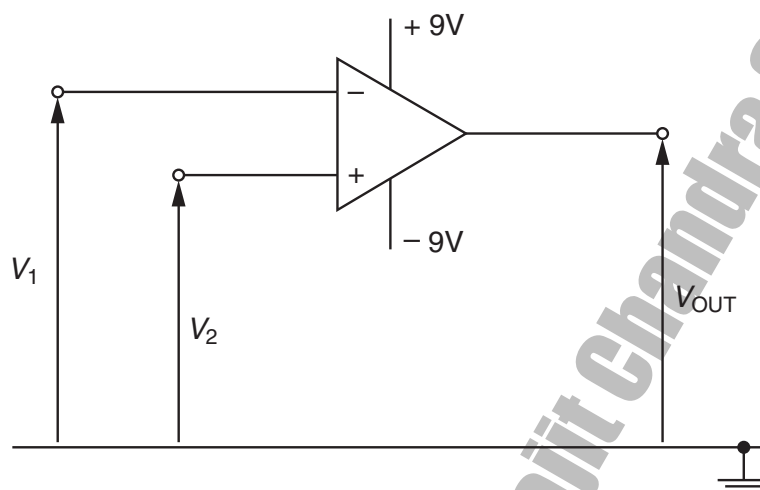


Fig. 8.1

The voltages applied to the inverting and the non-inverting inputs are  $V_1$  and  $V_2$  respectively.

State the value of the output voltage  $V_{OUT}$  when

(i)  $V_1 > V_2$ ,

$V_{OUT} = \dots\dots\dots$  V

(ii)  $V_1 < V_2$ .

$V_{OUT} = \dots\dots\dots$  V  
[1]

(b) The circuit of Fig. 8.2 is used to monitor the input voltage  $V_{IN}$ .

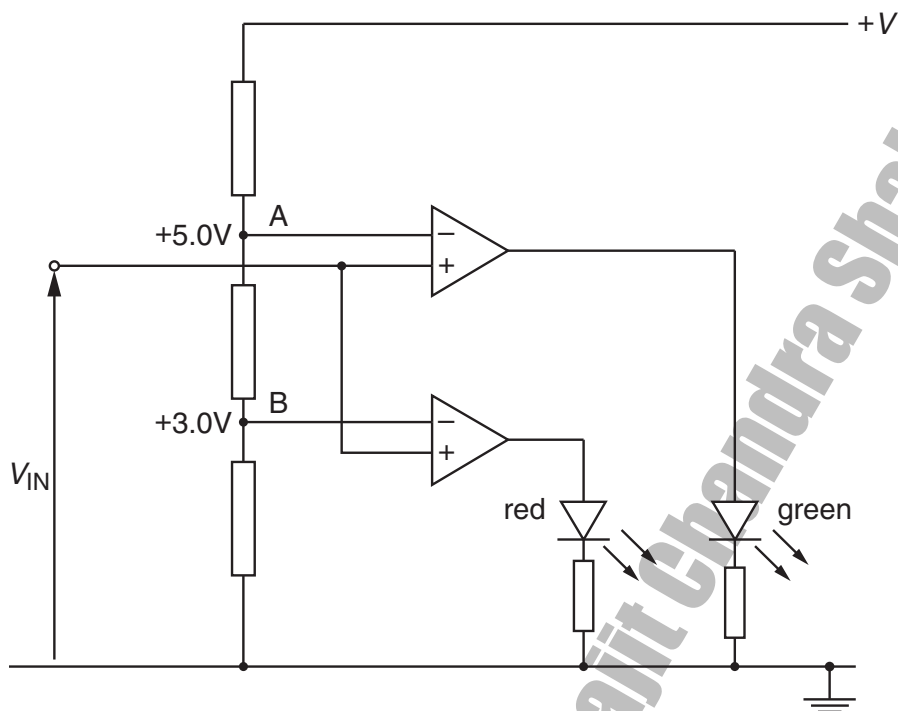


Fig. 8.2

At point A, a potential of 5.0V is maintained. At point B, a potential of 3.0V is maintained.

Complete Fig. 8.3 by indicating with a tick (✓) the light-emitting diodes (LEDs) that are conducting for the input voltages  $V_{IN}$  shown. Also, mark with a cross (✗) those LEDs that are not conducting.

$V_{IN} / V$	red LED	green LED
+2.0		
+4.0		
+6.0		

[3]

Fig. 8.3

(c) The input voltage  $V_{IN}$  in (b) is provided by a sensor circuit.

- (i) Complete Fig. 8.4 to show a sensor circuit that will provide a voltage output that increases as the temperature of the sensor decreases. Show clearly the output connections from the circuit. [2]

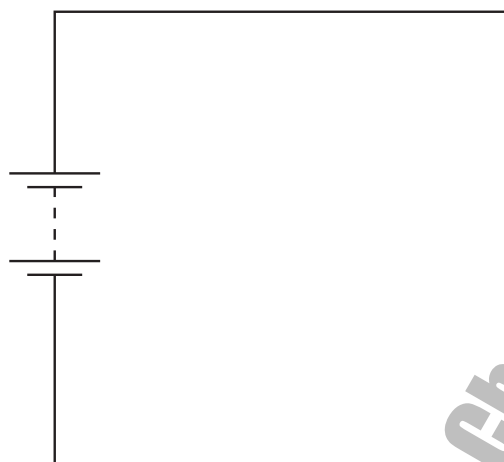


Fig. 8.4

- (ii) Explain the operation of the sensor circuit.

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..... [3]

- 5 (a) The circuit for an amplifier incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.1.

For  
Examiner's  
Use

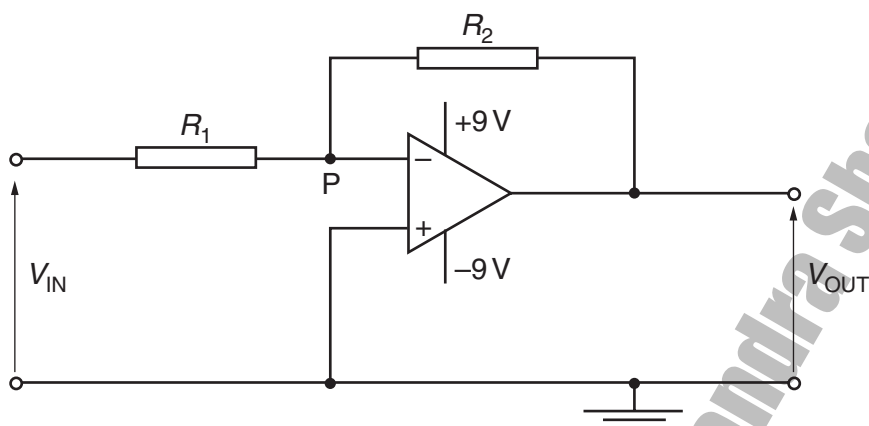


Fig. 10.1

- (i) State

1. the name of this type of amplifier circuit,

..... [1]

2. why the point P is referred to as a *virtual earth*.

.....  
 .....  
 .....  
 ..... [3]

- (ii) Show that the gain  $G$  of this amplifier circuit is given by the expression

$$G = -\frac{R_2}{R_1}.$$

Explain your working.

[4]



- (b) The circuit of Fig. 10.1 is modified by connecting a light-dependent resistor (LDR) as shown in Fig. 10.2.

For  
Examiner's  
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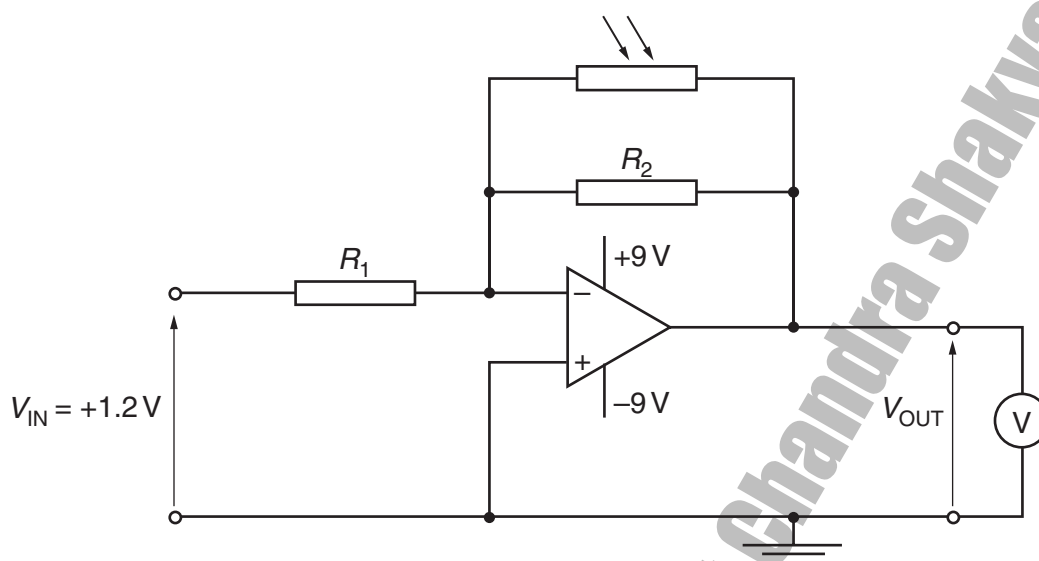


Fig. 10.2

The resistances  $R_1$  and  $R_2$  are  $5.0\text{ k}\Omega$  and  $50\text{ k}\Omega$  respectively. The input voltage  $V_{\text{IN}}$  is  $+1.2\text{ V}$ . A high-resistance voltmeter measures the output  $V_{\text{OUT}}$ . The circuit is used to monitor low light intensities.

- (i) Determine the voltmeter reading for light intensities such that the LDR has a resistance of

1.  $100\text{ k}\Omega$ ,

reading = ..... V [3]

2.  $10\text{ k}\Omega$ .

reading = ..... V [2]

- (ii) The light incident on the LDR is provided by a single lamp. Use your answers in (i) to describe and explain qualitatively the variation of the voltmeter reading as the lamp is moved away from the LDR.

For  
Examiner's  
Use

.....

.....

.....

.....

.....

..... [3]

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- 6 A metal wire strain gauge is firmly fixed across a crack in a wall, as shown in Fig. 9.1, so that the growth of the crack may be monitored.

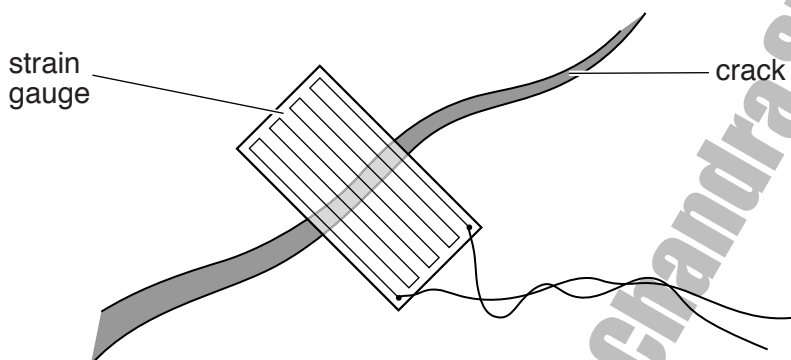


Fig. 9.1

- (a) Explain why, as the crack becomes wider, the resistance of the strain gauge increases.

.....  
 .....  
 .....  
 ..... [3]

- (b) The strain gauge has an initial resistance of  $143.0\ \Omega$  and, after being fixed in position across the crack for several weeks, the resistance is found to be  $146.2\ \Omega$ .

The change in the area of cross-section of the strain gauge wire is negligible.

Calculate the percentage increase in the width of the crack. Explain your working.

increase = ..... % [3]

- 7 The circuit of Fig. 10.1 may be used to indicate temperature change.

For  
Examiner's  
Use

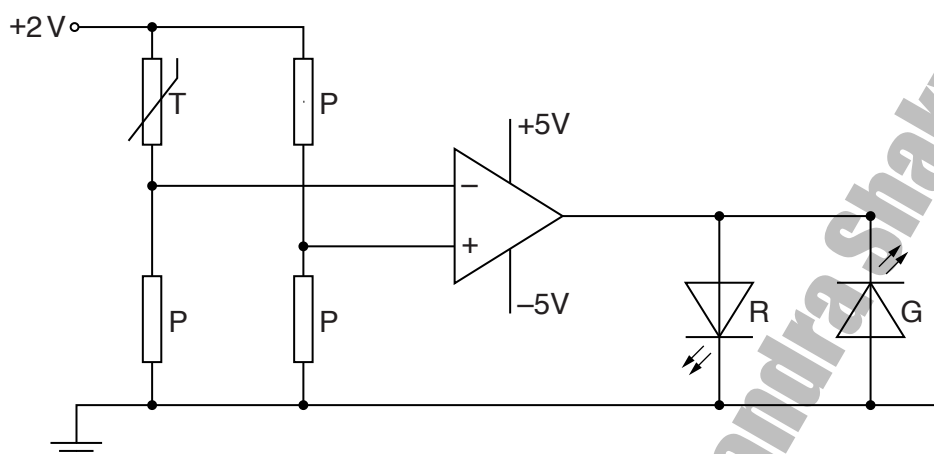


Fig. 10.1

The resistance of the thermistor T at  $16^{\circ}\text{C}$  is  $2100\ \Omega$  and at  $18^{\circ}\text{C}$ , the resistance is  $1900\ \Omega$ . Each resistor P has a resistance of  $2000\ \Omega$ .

Determine the change in the states of the light-emitting diodes R and G as the temperature of the thermistor changes from  $16^{\circ}\text{C}$  to  $18^{\circ}\text{C}$ .

.....  
 ..... [4]

- 8 An amplifier incorporating an operational amplifier (op-amp) has three inputs A, B and C, as shown in Fig. 9.1.

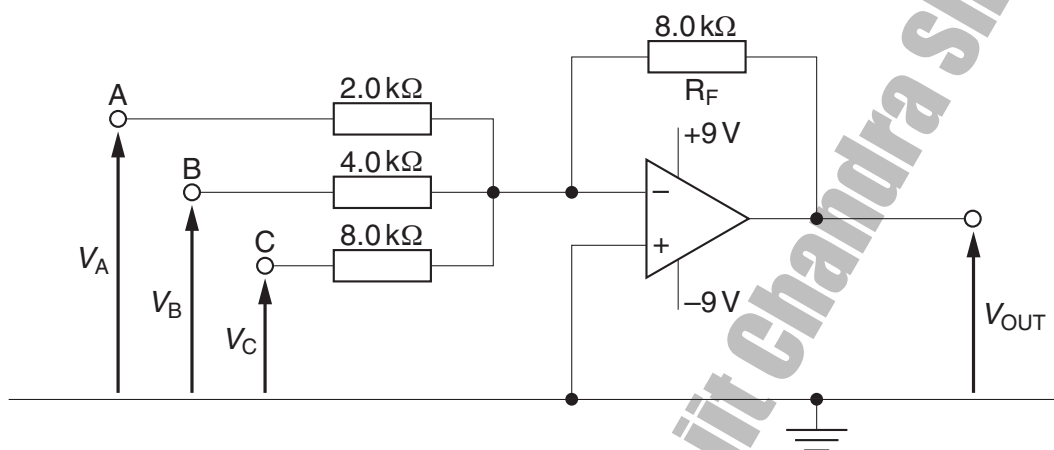


Fig. 9.1

Negative feedback is provided by the resistor  $R_F$  of resistance  $8.0\text{ k}\Omega$ .

For each of the inputs A, B and C, the amplifier may be considered as a single input amplifier. That is, each input is independent of the other two.

When the amplifier is not saturated, the output potential  $V_{\text{OUT}}$  is given by the expression

$$V_{\text{OUT}} = -(4V_A + GV_B + V_C),$$

where  $V_A$ ,  $V_B$  and  $V_C$  are the input potentials of the inputs A, B and C respectively and  $G$  is a constant.

- (a) State two effects of negative feedback on an amplifier.

1. ....  
.....
2. ....  
.....

[2]

- (b) In the expression for the output potential  $V_{\text{OUT}}$ , the constant  $G$  is the gain associated with input B. Show that the numerical value of  $G$  is 2.

For  
Examiner's  
Use

[1]

- (c) The input potentials  $V_A$ ,  $V_B$  and  $V_C$  are either zero or 1.0V.

The magnitudes of some output potentials for different combinations of  $V_A$ ,  $V_B$  and  $V_C$  are shown in Fig. 9.2.

$V_A/V$	$V_B/V$	$V_C/V$	$V_{\text{OUT}}/V$
0	0	1	1
0	1	0	.....
1	0	0	4
1	0	1	5
1	1	0	.....
1	1	1	.....

Fig. 9.2

- (i) Complete Fig. 9.2 for the three remaining values of  $V_{\text{OUT}}$ . [1]
- (ii) Suggest a use for this circuit.

..... [1]

9 (a) Negative feedback may be used in amplifier circuits. State

(i) what is meant by *negative feedback*,

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

(ii) two effects of negative feedback on an amplifier incorporating an operational amplifier (op-amp).

1. ....  
 .....  
 2. ....  
 ..... [2]

(b) Fig. 9.1 is a circuit for an amplifier that is used with a microphone.

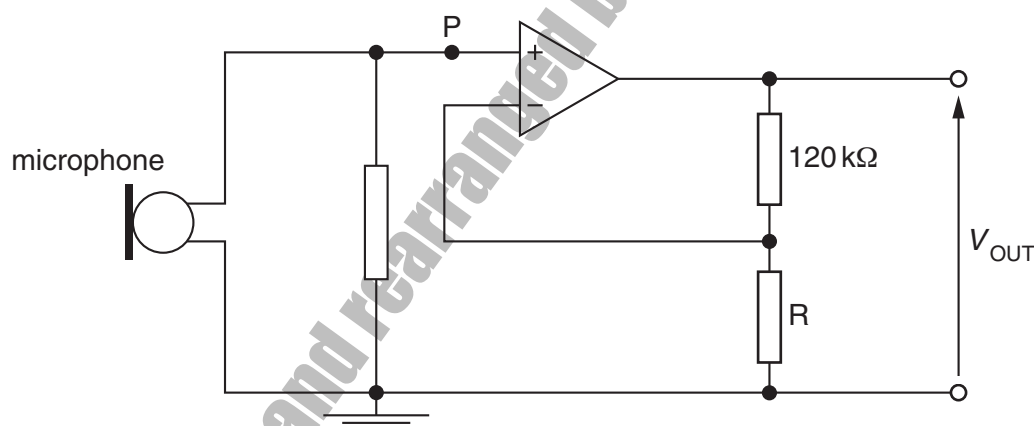


Fig. 9.1

The output potential difference  $V_{OUT}$  is 4.4V when the potential at point P is 62 mV.

Determine

(i) the gain of the amplifier,

gain = ..... [1]

(ii) the resistance of the resistor R.

resistance = .....  $\Omega$  [2]

(c) The maximum potential produced by the microphone at point P on Fig. 9.1 is 95 mV.  
The power supply for the operational amplifier may be either  $\pm 5$  V or  $\pm 9$  V.

State which power supply should be used. Justify your answer quantitatively.

.....  
.....  
.....  
..... [3]

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10 (a) State the name of an electrical sensing device that will respond to changes in

(i) length,

..... [1]

(ii) pressure.

..... [1]

(b) A relay is sometimes used as the output of a sensing circuit.

The output of a particular sensing circuit is either +2V or -2V.

On Fig. 10.1, draw symbols for a relay and any other necessary component so that the external circuit is switched on only when the output from the sensing circuit is +2V.



Fig. 10.1

[4]

- 11 The circuit diagram of Fig. 9.1 is an amplifier circuit incorporating an operational amplifier (op-amp).

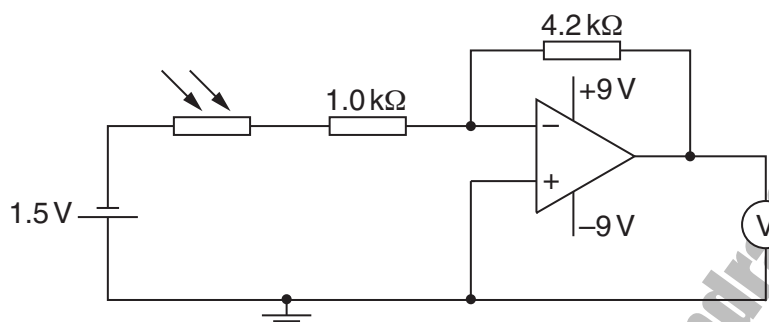


Fig. 9.1

- (a) (i) On Fig. 9.1, mark, with the letter X, the virtual earth. [1]

- (ii) Explain what is meant by a *virtual earth*.

.....

.....

.....

..... [3]

- (b) In bright sunlight, the light-dependent resistor (LDR) has resistance  $200\ \Omega$ .

- (i) Calculate, for the LDR in bright sunlight, the voltmeter reading.

reading = ..... V [3]

- (ii) The sunlight incident on the LDR becomes less bright.  
State and explain the effect on the voltmeter reading of this decrease in brightness.

For  
Examiner's  
Use

.....

.....

.....

..... [3]

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## Section B

Answer **all** the questions in the spaces provided.

For  
Examiner's  
Use

- 9 An amplifier circuit incorporating an operational amplifier (op-amp) is shown in Fig. 9.1.

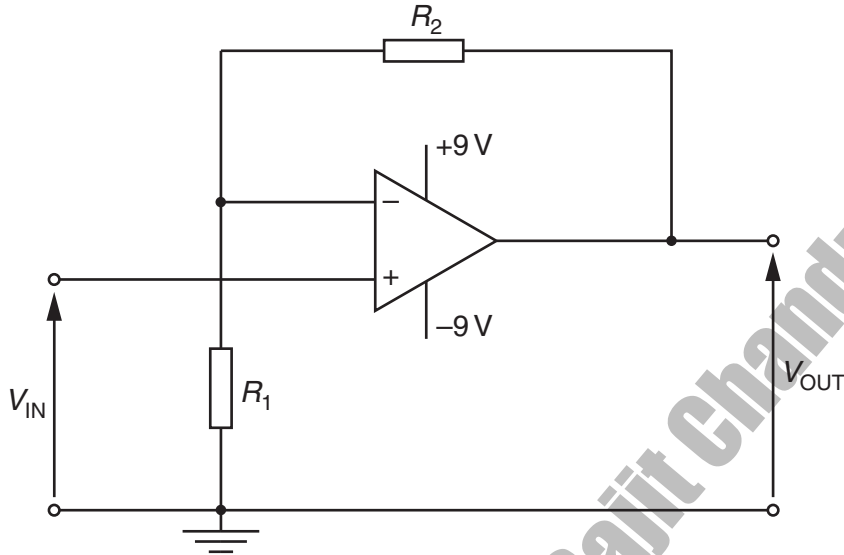


Fig. 9.1

(a) State

- (i) the name of this type of amplifier circuit,

..... [1]

- (ii) the gain  $G$  in terms of resistances  $R_1$  and  $R_2$ .

..... [1]

- (b) The value of  $R_1$  is  $820\ \Omega$ . The resistor of resistance  $R_2$  is replaced with a light-dependent resistor (LDR).

The input potential difference  $V_{IN}$  is 15 mV.

Calculate the output potential difference  $V_{OUT}$  for the LDR having a resistance of

- (i)  $100\ \Omega$  (the LDR is in sunlight),

$$V_{OUT} = \dots\dots\dots V \text{ [2]}$$

- (ii)  $1.0\ \text{M}\Omega$  (the LDR is in darkness).

$$V_{OUT} = \dots\dots\dots V \text{ [1]}$$

For  
Examiner's  
Use

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10 (a) State three properties of an ideal operational amplifier (op-amp).

1. ....
2. ....
3. ....

[3]

(b) A circuit incorporating an ideal op-amp is to be used to indicate whether a door is open or closed.  
Resistors, each of resistance  $R$ , are connected to the inputs of the op-amp, as shown in Fig. 10.1.

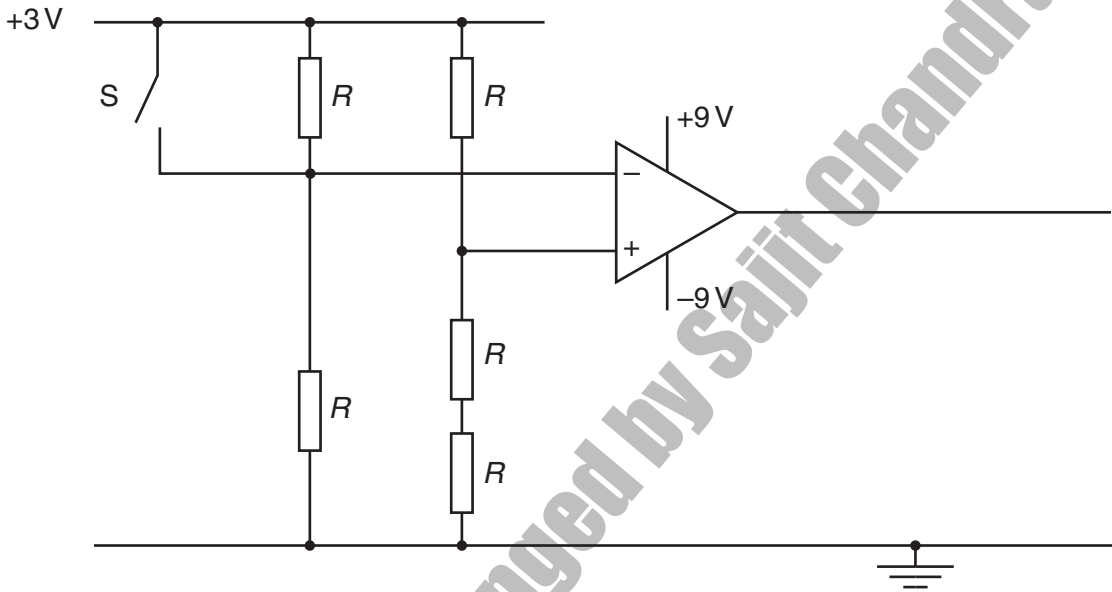


Fig. 10.1

The switch S is attached to the door so that, when the door is open, the switch is open. The switch closes when the door is closed.

- (i) Explain why the polarity of the output of the op-amp changes when the switch closes.

.....

.....

.....

..... [3]

- (ii) A red light-emitting diode (LED) is to be used to indicate when the door is open. A green LED is to indicate when the door is closed.

On Fig. 10.1,

- 1. draw symbols for the LEDs to show how they are connected to the output of the op-amp, [1]
- 2. identify the green LED with the letter G. [1]

**Please turn over for Question 11.**

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## Section B

Answer **all** the questions in the spaces provided.

For  
Examiner's  
Use

- 9 (a) An operational amplifier (op-amp) may be used as a comparator.  
State the function of a comparator.

.....

.....

..... [2]

- (b) The variation with temperature  $\theta$  of the resistance  $R$  of a thermistor is shown in Fig. 9.1.

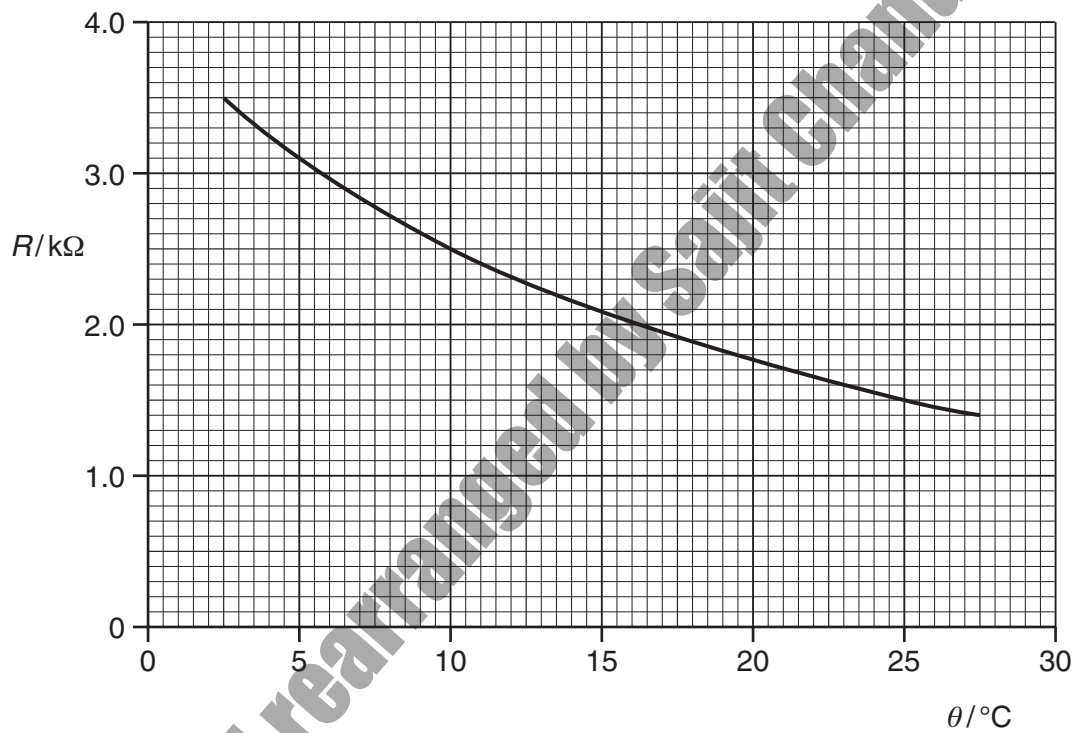


Fig. 9.1



The thermistor is connected into the circuit of Fig. 9.2.

For  
Examiner's  
Use

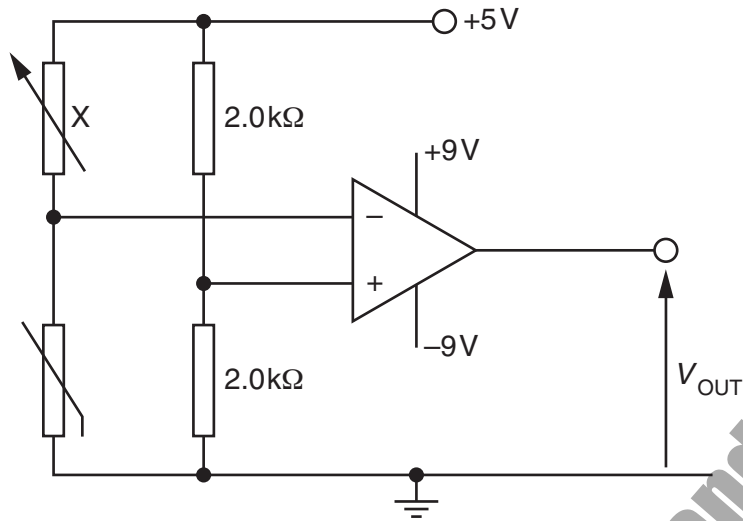


Fig. 9.2

The op-amp may be considered to be ideal.

- (i) The temperature of the thermistor is 10 °C. Determine the resistance of the variable resistor X such that the output potential  $V_{OUT}$  is zero.

resistance = ..... Ω [2]

- (ii) The resistance of the resistor X is now held constant at the value calculated in (i). Describe the change in the output potential  $V_{OUT}$  as the temperature of the thermistor is changed from 5 °C to 20 °C.

.....

.....

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.....

.....

..... [4]

Section B

Answer **all** the questions in the spaces provided.

For  
Examiner's  
Use

- 9 (a) Describe the structure of a metal wire strain gauge. You may draw a diagram if you wish.

.....

.....

.....

..... [3]

- (b) A strain gauge S is connected into the circuit of Fig. 9.1.

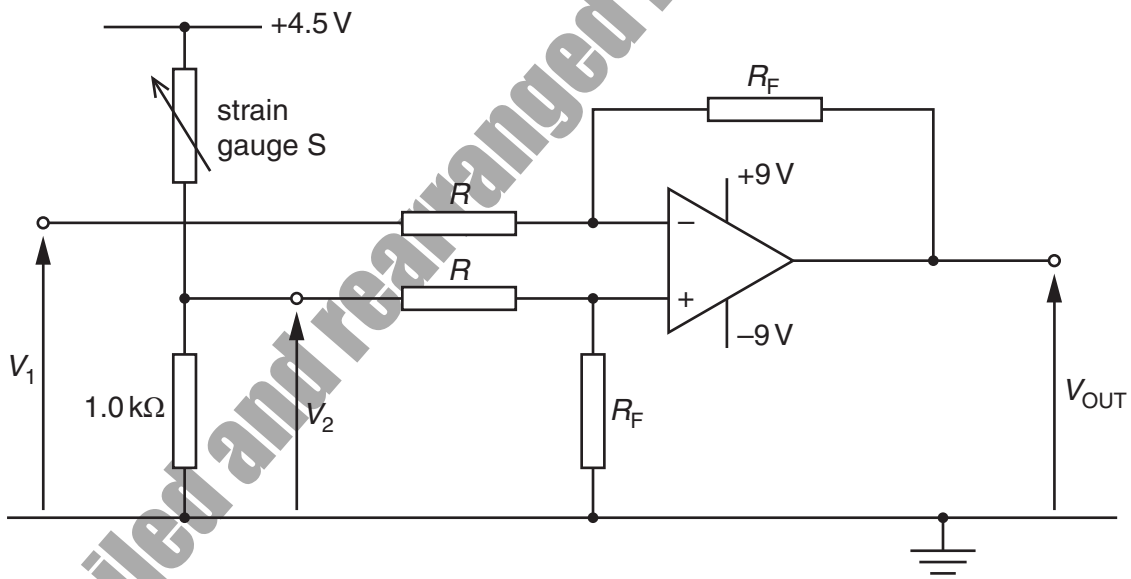


Fig. 9.1

The operational amplifier (op-amp) is ideal.  
The output potential  $V_{OUT}$  of the circuit is given by the expression

$$V_{OUT} = \frac{R_F}{R} \times (V_2 - V_1).$$

- (i) State the name given to the ratio  $\frac{R_F}{R}$ .

..... [1]

- (ii) The strain gauge S has resistance  $125 \Omega$  when not under strain. Calculate the magnitude of  $V_1$  such that, when the strain gauge S is not strained, the output  $V_{OUT}$  is zero.

For  
Examiner's  
Use

$$V_1 = \dots\dots\dots \text{ V [3]}$$

- (iii) In a particular test, the resistance of S increases to  $128 \Omega$ .  $V_1$  is unchanged. The ratio  $\frac{R_F}{R}$  is 12. Calculate the magnitude of  $V_{OUT}$ .

$$V_{OUT} = \dots\dots\dots \text{ V [2]}$$

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