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

fraction of Vout that is sent back to the V⁻ input

[2]

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

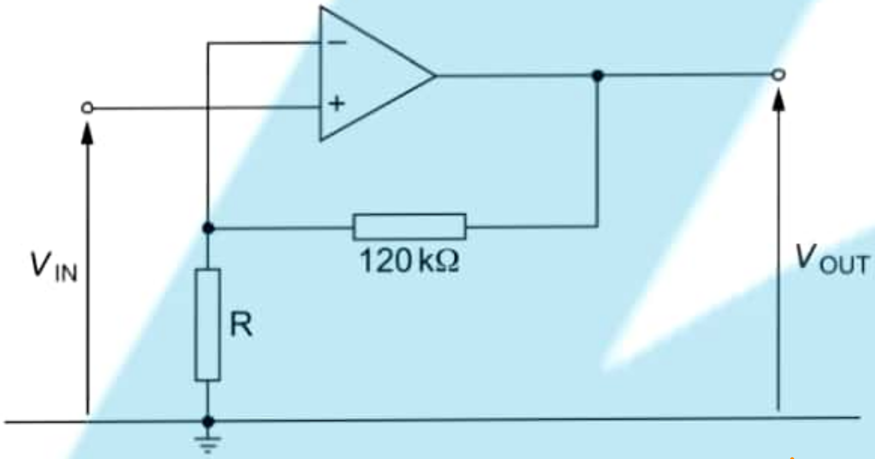


**Fig. 10.1**

The supply for the op-amp is ±9.0V. saturation voltage??
The amplifier circuit is to have a gain of 25.

Calculate the resistance of resistor R.

$1 + \frac{R_f}{R_{in}} = 25$

$1 + \frac{120}{R_{in}} = 25$

$1 - 25 = \frac{120}{R_{in}}$

$R_{in} = \frac{-120}{-24}$

$= 4.8 k\Omega$

$5 k\Omega$

resistance = ~~4800~~ 5000 Ω [2]

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

(i) −0.08V,

$25(-0.08 - 0)$

$V_{OUT}$ = −2 V [1]

(ii) +0.4V.

$25(0.4)$

$V_{OUT}$ = 9 V [1]

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

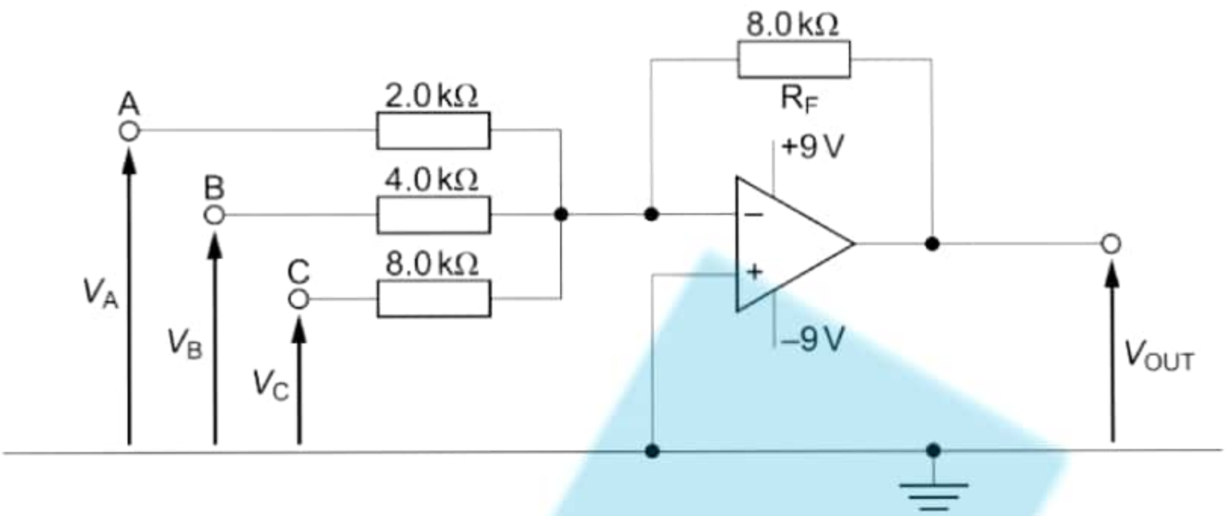


**Fig. 9.1**

Negative feedback is provided by the resistor $R_F$ of resistance 8.0 kΩ.

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 $V_{OUT}$ is given by the expression

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

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. ~~Reduces Vout, makes it less likely it would saturate~~

2. Reduced the gain greater stability

[2]

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

gain $= -\frac{R_f}{R_{in}} = \frac{8}{4} = 2$

[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 | $V_{OUT}$/V |
|---|---|---|---|
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | ...2... $-2$ |
| 1 | 0 | 0 | 4 |
| 1 | 0 | 1 | 5 |
| 1 | 1 | 0 | ...6... |
| 1 | 1 | 1 | ...7... |

**Fig. 9.2** $-(4(0)+2(1)+0)$

(i) Complete Fig. 9.2 for the three remaining values of $V_{OUT}$. [1]

(ii) Suggest a use for this circuit.

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

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

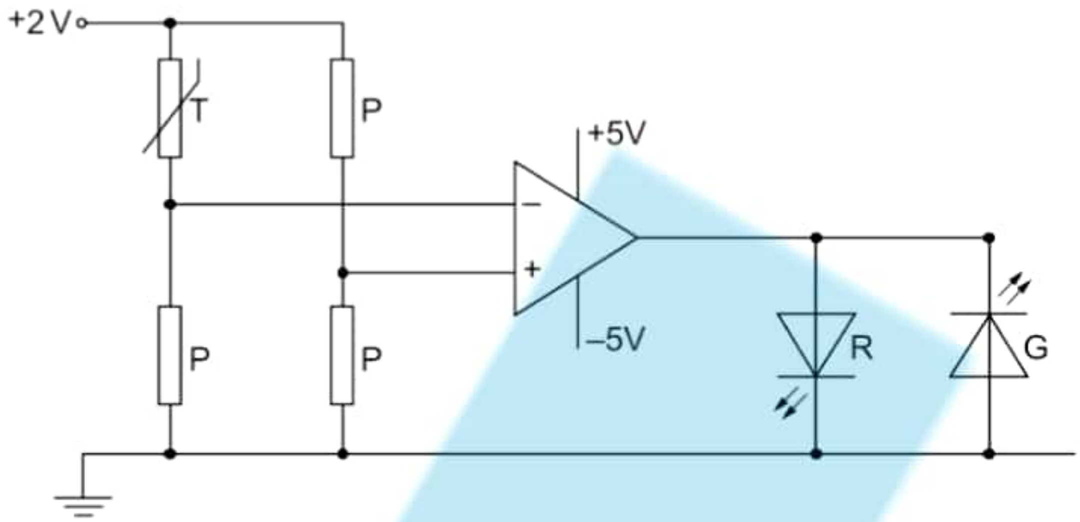


**Fig. 10.1**

The resistance of the thermistor T at 16 °C is 2100 Ω and at 18 °C, the resistance is 1900 Ω. Each resistor P has a resistance of 2000 Ω.

Determine the change in the states of the light-emitting diodes R and G as the temperature of the thermistor changes from 16 °C to 18 °C.

$V_{out}$ at 16°C $= g\left[\left(2 \times \frac{2}{2+2}\right) - \left(2 \times \frac{2}{2+2.1}\right)\right]$

$= g(1 - 0.975)$

$= +ve$

$V_{out}$ at 18°C $= g\left[\left(2 \times \frac{2}{2+2}\right) - \left(2 \times \frac{2}{2+1.9}\right)\right]$

$= g(1 - 1.025)$

$= -ve$

when 16°C, R is on, G is off, then as temp goes to 18°C, R turns off, green turns on. [4]

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

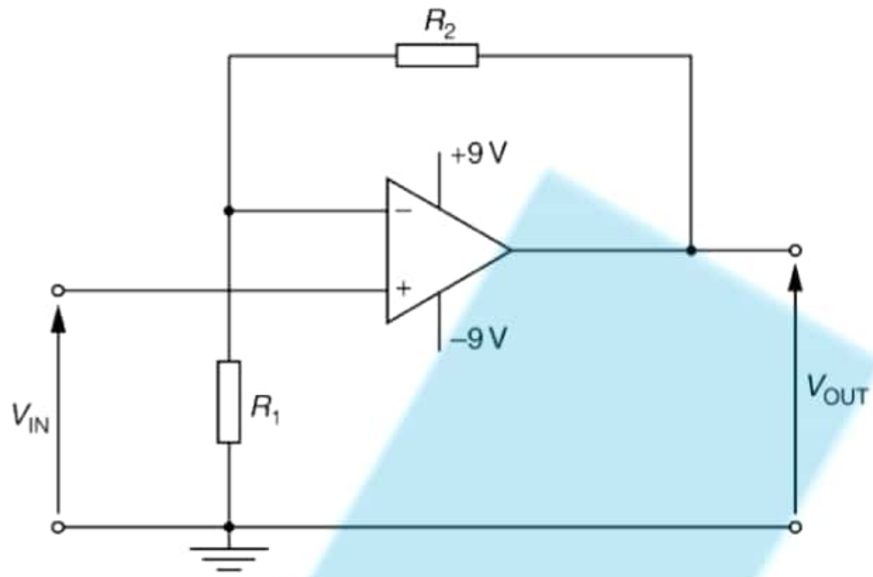


**Fig. 9.1**

**(a)** State

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

non inverting ..................................................... [1]

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

$G = 1 + \frac{R_f}{R_{in}}$ ✗ ..................................................... [1]

**(b)** The value of $R_1$ is 820 Ω. 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

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**(i)** 100 Ω (the LDR is in sunlight),

$$\text{gain} = 1 + \frac{R_f}{R_{in}} = 0.12195$$

$$V_{out} = 1.12195\,(15 \times 10^{-3} - 0)$$
$$= 0.017$$

$V_{OUT}$ = 0.017 .............................. V [2]

**(ii)** 1.0 MΩ (the LDR is in darkness).

$$\text{gain} = 1 + \frac{1 \times 10^6}{820} = 1220.5$$

$$= 1220.5\,(15 \times 10^{-3} - 0)$$

$$= 18.3\ V$$

$V_{OUT}$ = +9 .............................. V [1]

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An operational amplifier (op-amp) may be used as part of the processing unit in an electronic sensor.

**(a)** State three properties of an ideal op-amp.

1. gain ∞
2. infinite input impedine
3. zero output impedance

[3] 5

**(b)** A comparator circuit incorporating an ideal op-amp is shown in Fig. 9.1.

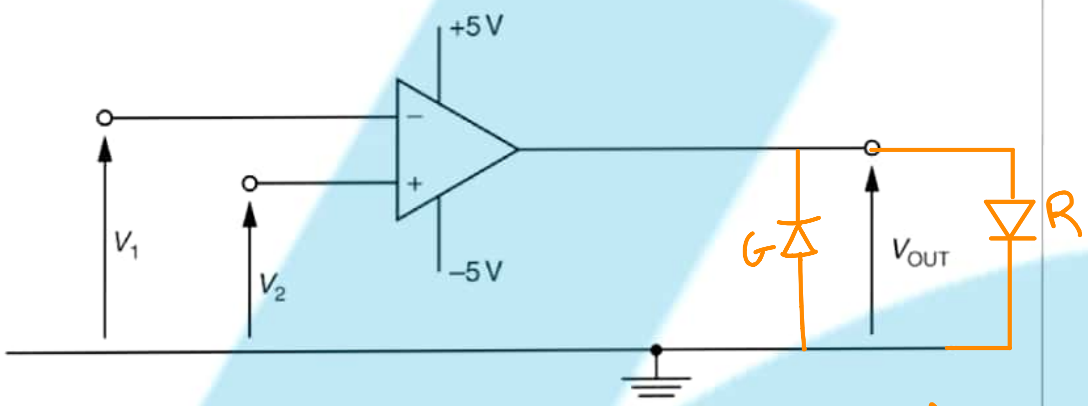


**Fig. 9.1**

$V_{out} = 2(1.5 - 1.5)$

**(i)** In one application of the comparator, $V_2$ is kept constant at +1.5 V.
The variation with time $t$ of the potential $V_1$ is shown in Fig. 9.2. The potential $V_2$ is also shown.



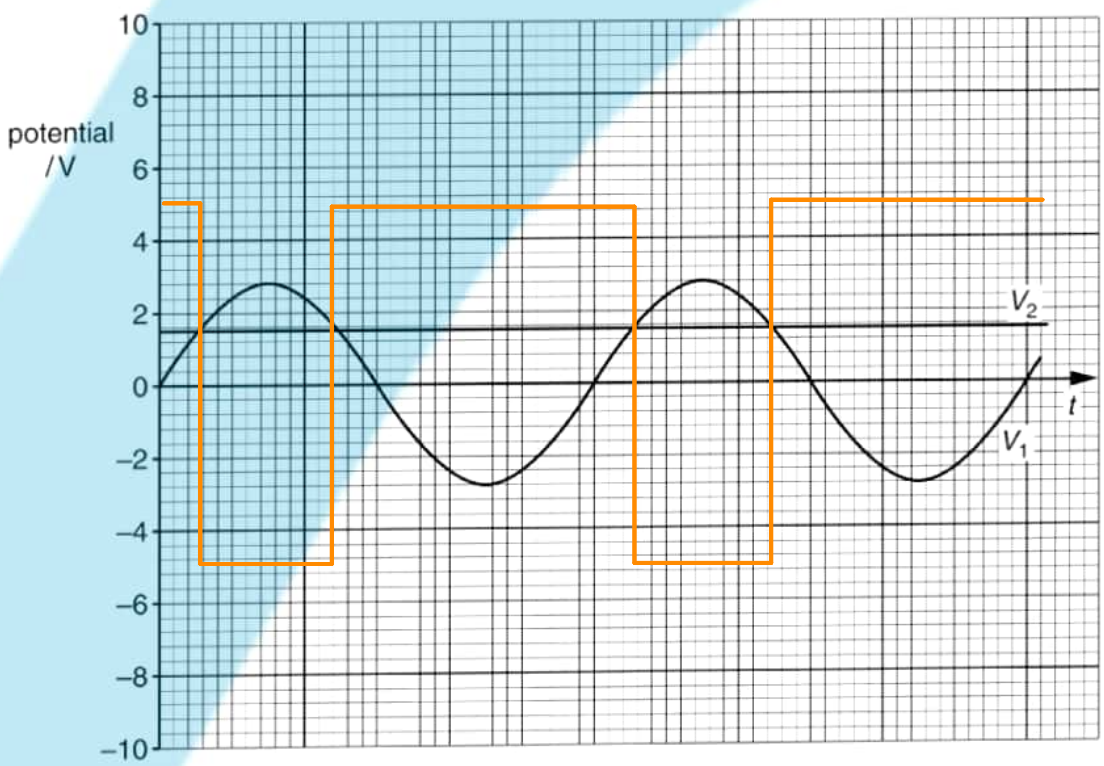


**Fig. 9.2**

On Fig. 9.2, show the variation with time $t$ of the output potential $V_{OUT}$. [4] 4

**(ii)** Two light-emitting diodes (LEDs) R and G are connected to the output of the op-amp in Fig. 9.1 such that R emits light for a longer time than G.

On Fig. 9.1, draw the symbols for the two diodes connected to the output of the op-amp and label the diodes R and G. [3]

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

1. infinite inputs impedance
2. infinite gain
3. infinite bandwidth

2 [3]

**(b)** An amplifier circuit is shown in Fig. 9.1.

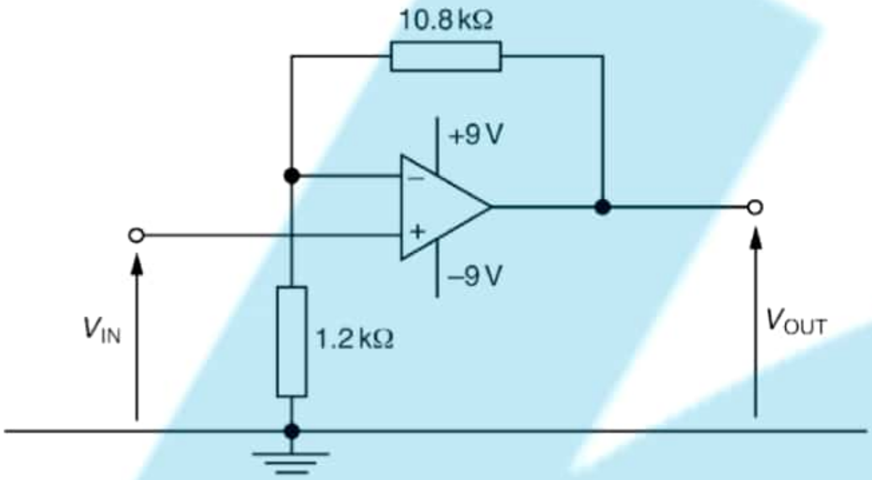


**Fig. 9.1**

**(i)** Calculate the gain of the amplifier circuit.

$1 + \frac{10.8}{1.2}$

$= 10$

gain = 10 [2]

**(ii)** The variation with time $t$ of the input potential $V_{IN}$ is shown in Fig. 9.2.

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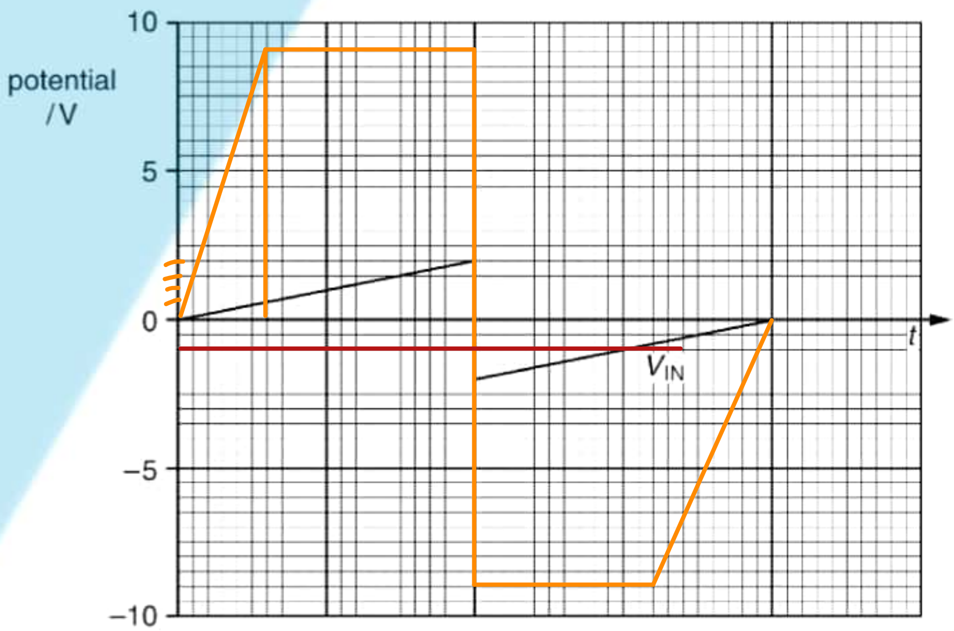


$9 = 10(x)$

$0.9$

$10(0.9) = 9$

**Fig. 9.2**

On the axes of Fig. 9.2, show the variation with time $t$ of the output potential $V_{OUT}$. [3]