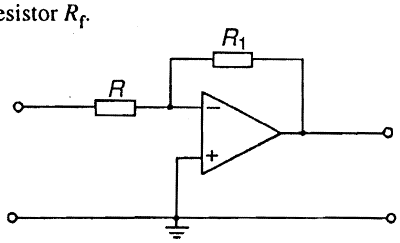
TOPIC 24 Analogue Electronics

1 The operational amplifier circuit shown below includes a feedback resistor R_f.



What may be the purpose of the resistor R_f?

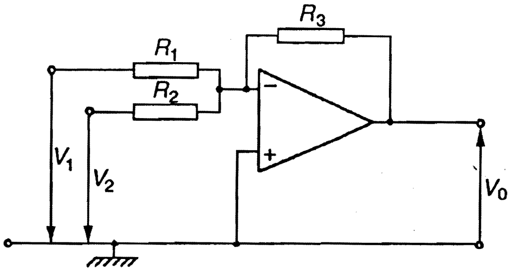
A to increase the gain
B to make the amplifier non-inverting
C to increase the bandwidth
D to block a.c. inputs
E to increase the input impedance J85/I/21

2 The process of *negative* feedback in electronics can involve returning a fraction of the output of an operational amplifier to the input. This may affect the gain and the bandwidth (the range of frequency over which the gain is constant). Which one of the following combinations of effects is correct?

	effect on gain	*effect on bandwidth*
A	increased	decreased
B	decreased	decreased
C	increased	unchanged
D	unchanged	increased
E	decreased	increased

J86/I/21; N87/I/21; J90/I/22

3 The circuit shown below includes an operational amplifier.



Which of the following expressions correctly gives the magnitude of the output voltage V_0?

A $V_1 + V_2$

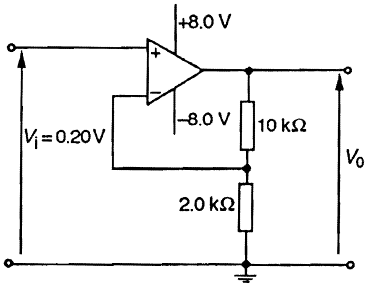
B $V_1\left(\frac{R_1}{R_3}\right) + V_2\left(\frac{R_2}{R_3}\right)$

C $V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_3}{R_2}\right)$

D $(V_1 + V_2)\left(\frac{R_3}{R_1 + R_2}\right)$

E $(V_1 + V_2)\left(\frac{R_1 + R_2}{R_3}\right)$ J88/I/22

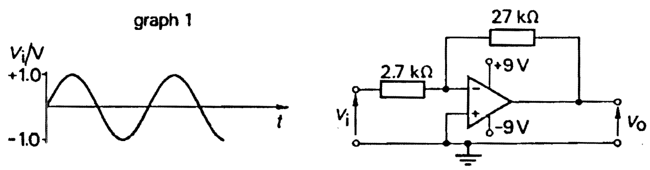
4 An input voltage V_i of 0.20 V is applied to an operation amplifier connected as shown in the diagram.



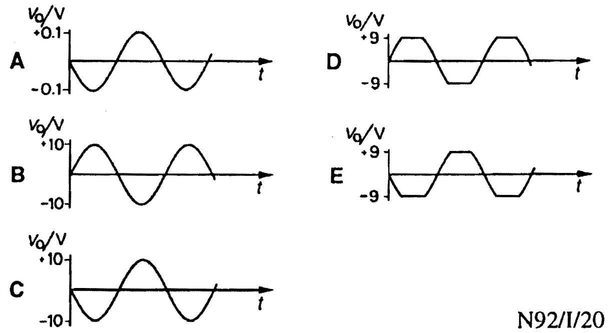
What is the output voltage V_0?

A 0.20 V B 0.80 V C 1.0 V
D 1.2 V E 8.0 V N88/I/23

5 The sinusoidal potential difference V_i shown in graph 1 is applied to the input of the operational amplifier circuit shown.

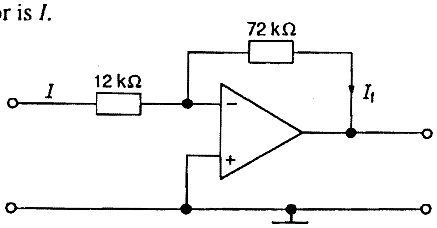


Which graph gives the correct variation of voltage with time at the output?



N92/I/20

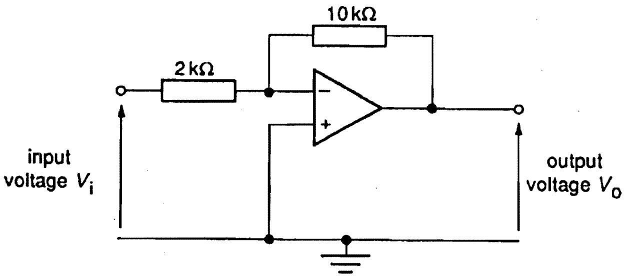
6 In the circuit shown in the diagram, the operational amplifier may be assumed to be ideal. The current in the 12 kΩ resistor is I.



What is the current I_f in the 72 kΩ resistor?

A $-6I$ B $-\frac{1}{6}I$ C $\frac{1}{6}I$ D I E $6I$
J93/I/21

7 The diagram shows an operational amplifier circuit.

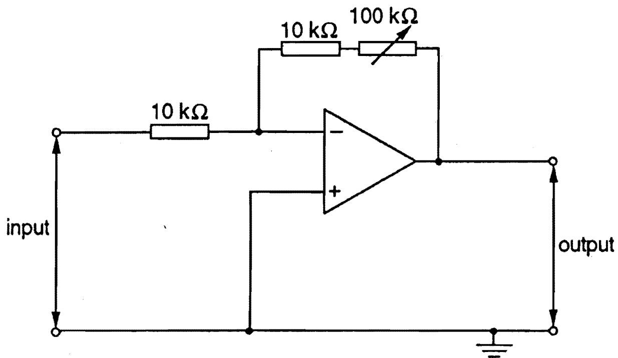


Which of the following correctly states the nature and magnitude of the amplification?

	nature	*magnitude of* $\frac{V_0}{V_i}$
A	inverting	0.2
B	inverting	5.0
C	non-inverting	0.2
D	non-inverting	5.0

N94/I/21

8 The circuit shown includes an ideal operational amplifier.



Which of the following gives the minimum and maximum values of the voltage gain of the circuit?

A 0.09 and 1.0
B 0.1 and 1.0
C 1.0 and 10
D 1.0 and 11

J95/I/21

9 Fig. 1 illustrates the circuit for a non-inverting voltage amplifier. What are the values of R_1 and R_2 such that the gain may be set at any value between 5 and 10?

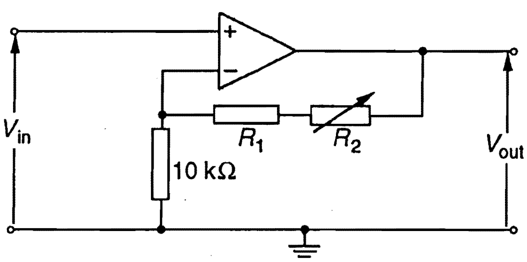


Fig. 1

N85/III/7

10 Resistors of the values shown in Fig. 2 are connected to an operational amplifier A.

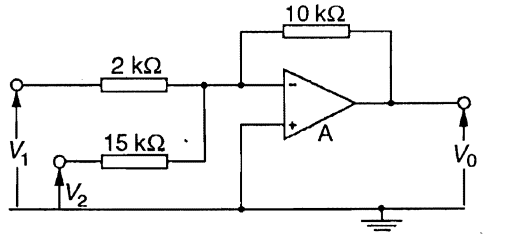


Fig. 2

If the two d.c. input signals are V_1 = 0. 1 V and V_2 = 0.6 V what is the output V_0?

J87/III/7

11 An inverting d.c. voltage amplifier with a gain of 100 is constructed using an ideal operational amplifier. The power for the amplifier is provided by two batteries, each of e.m.f. 6.0 V and negligible internal resistance (see Fig. 3).

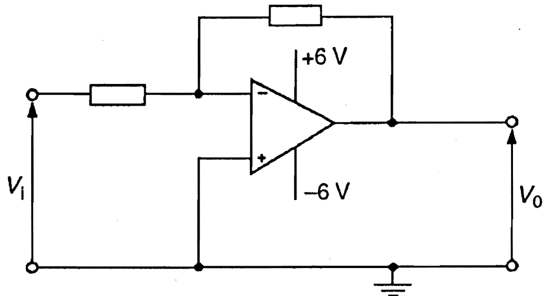


Fig. 3

Sketch a graph showing how the output voltage V_0 depends on the input voltage V_i in the range from $V_i = 0$ V to $V_i = 0.1$ V. [6]

N88/III/6

12 The circuit shown in Fig. 4 includes an ideal operational amplifier.

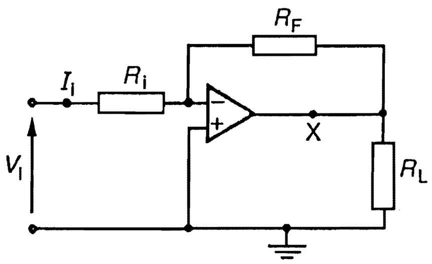


Fig. 4

For one particular input signal V_i, the current in the input resistor R_i is I_i. Sketch the circuit and indicate on your diagram the direction of

(a) I_F, the current in the feedback resistor R_F,

(b) I_L, the current in the load resistor R_L,

(c) I_X, the current at X.

Write an equation relating I_F, I_L and I_X. [5]

J89/III/7

13 In the operational amplifier circuit of Fig. 5, $V_i = +2.0$V.

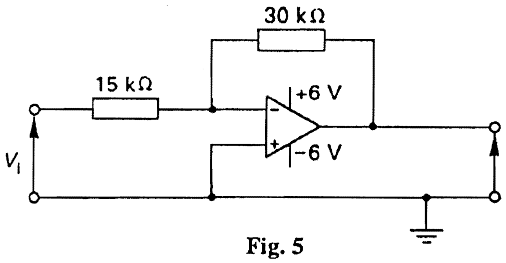


Fig. 5

(*a*) Calculate the output potential V_0. [3]

(*b*) The input signal V_i is then replaced by the signal shown in Fig. 6. Sketch on the axes of Fig. 7 below, the corresponding output potential V_0.

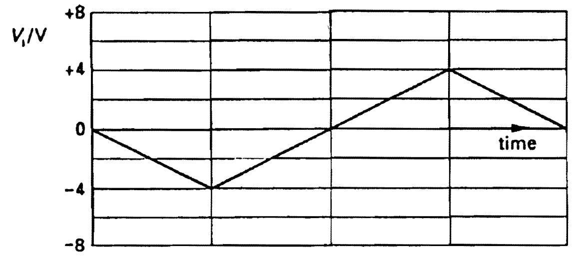


Fig. 6

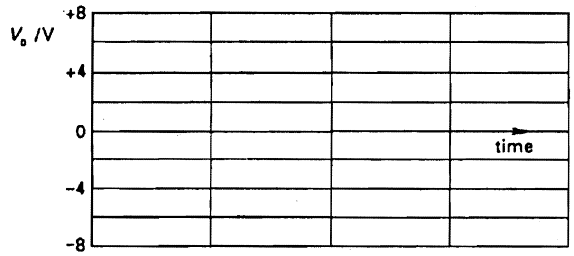


Fig. 7 [4]

J91/II/6

14 An ideal operational amplifier is used in the circuit shown in Fig. 8 with two input potentials V_1 and V_2 of +30 mV and +20 mV respectively.

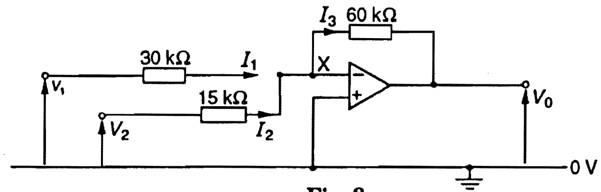


Fig. 8

(*a*) What is the potential at the point X? [1]

(*b*) Calculate the currents

(i) I_1, (ii) I_2, (iii) I_3. [3]

(*c*) What is the output potential V_0? [3]

(*d*) V_2 is then replaced by the half-wave rectified voltage of peak value 60 mV shown in Fig. 9; V_1 is unchanged. On the axes below, sketch the variation with time of the output potential V_0. Label the V_0 axis with appropriate values.

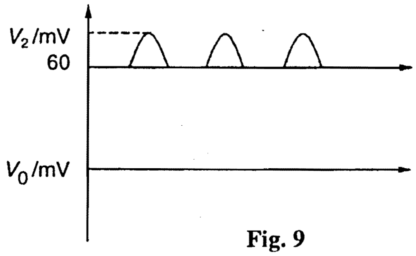


Fig. 9 [3] N91/II/3

15 (*a*) A circuit containing an ideal operational amplifier (op-amp) is shown in Fig. 10.

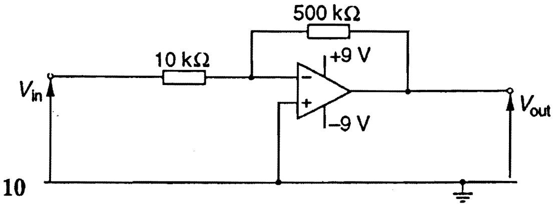


Fig. 10

(i) Calculate the gain, $\frac{V_{out}}{V_{in}}$, for this circuit. [3]

(ii) What is the maximum voltage output which this op-amp can provide? [1]

(*b*) Fig. 11 shows the variation with time of the input voltage to the circuit above.

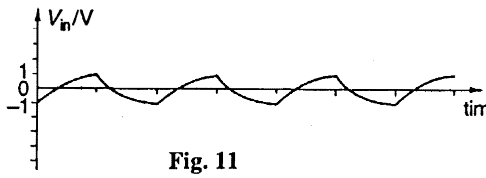


Fig. 11

(i) Sketch on the axes of Fig. 12 another graph to show the variation with time of the output voltage. Label the V_{out} axis with appropriate values.

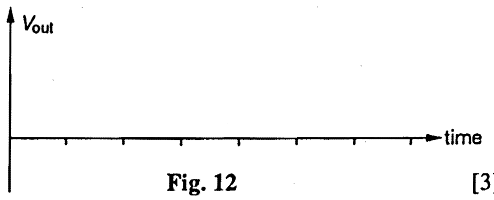


Fig. 12 [3]

(ii) Suggest a practical use for the circuit used in this way. [1] J92/II/5

16 An ideal operational amplifier is used in the circuit shown in Fig. 13 with a constant input of 0.50 V and power supplies of +6.0 V and −6.0 V.

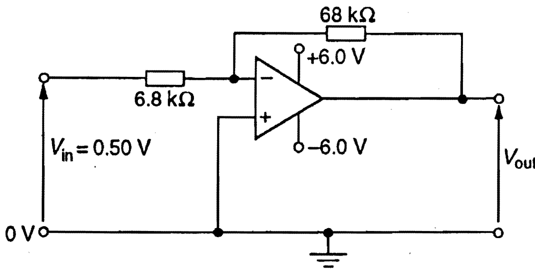


Fig. 13

(a) Calculate the gain of this amplifier circuit. [2]

(b) What is the output voltage V_{out}? [1]

(c) The constant input is then changed from 0.50 V to a sinusoidal alternating voltage of 0.50 V $_{r.m.s.}$

(i) Calculate the peak value of the input voltage. [1]

(ii) With the power supply as indicated, what are the maximum and minimum values of the output voltage? [1]

(iii) On Fig. 14, sketch a graph to show the shape of the output for this alternating input.

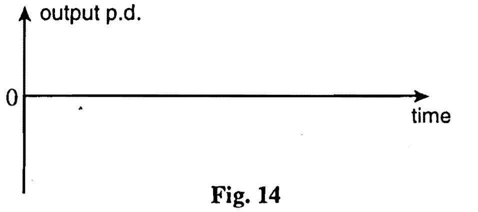


Fig. 14 [2] N93/II/5

17 In an experiment, small voltage changes are to be measured. In order to do this using an ordinary voltmeter, a student set up the circuit shown in Fig. 15.

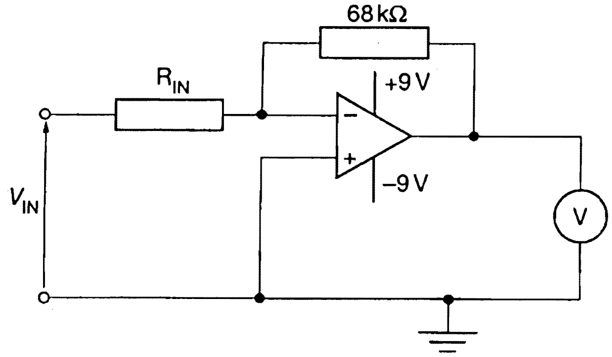


Fig. 15

When the input voltage V_{IN} is changed from 1.000 V to 1.025 V, the change in the reading of the voltmeter is to be 1.00 V.

(a) Calculate

(i) the required gain of the amplifier circuit,

(ii) the resistance of the resistor R_{IN}. [3]

(b) When the student tested the circuit, the voltmeter recorded –9.00 V both when V_{IN} was 1.000 V and when it was 1.025 V.

(i) Give an explanation for this observation.

(ii) Complete Fig. 16, by making suitable connections to B, to show how you would modify the circuit so that, when the input potential V_{IN} = 1.000 V, the voltmeter reading is zero, and when V_{IN} = 1.025 V, the voltmeter reads 1.00 V.

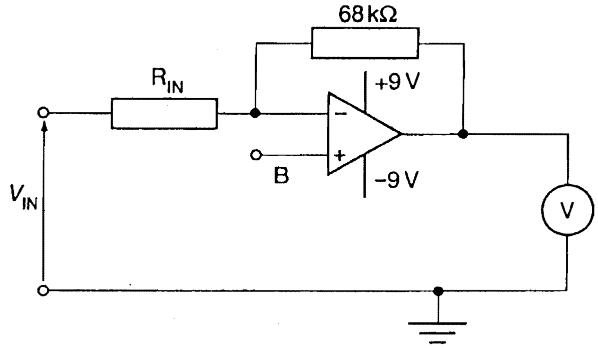


Fig. 16 [4] N96/II/5

Long Questions

18 Explain what is meant by *voltage gain* and *negative feedback* in relation to electronic circuits.

Fig. 17 shows a circuit containing an ideal operational amplifier where the point P is usually referred to as a *virtual earth*. Explain what you understand by *virtual earth* in this context and hence derive an expression for V_2 in terms of V_1 and the values of the circuit components.

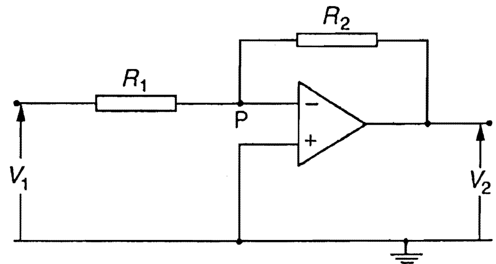


Fig. 17

The current, I, through a certain device varies with applied potential difference, V, according to the relation

$$I = I_0 e^{kV}$$

where I_0 and k are constants. If R_2 is replaced by this device, write down an expression for the feedback current in terms of V_2. Hence show that V_2 is given by the expression

$$V_2 = 1 / k \ln (V_1 / R_1 I_0).$$

What is the possible advantage of this type of amplifier over a linear amplifier when a wide range of input signal amplitudes must be displayed? J85/III/12

19 List **three** desirable features of an operational amplifier.

In almost all cases where an operational amplifier is used as a linear voltage amplifier, negative feedback is employed. State the advantages of using negative feedback.

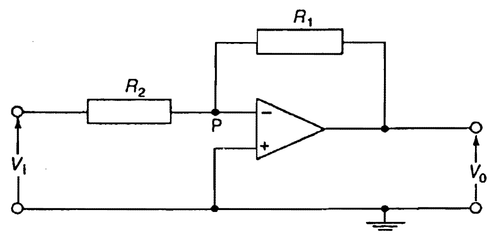


Fig. 18

Fig. 18 shows a circuit which incorporates an operational amplifier. Explain why the point P may be regarded as being at earth potential.

Show that the ratio of the output voltage V_0 to the input voltage V_1 is given by

$$\frac{V_0}{V_1} = -\frac{R_1}{R_2}$$

Explain the significance of the negative sign in this expression.

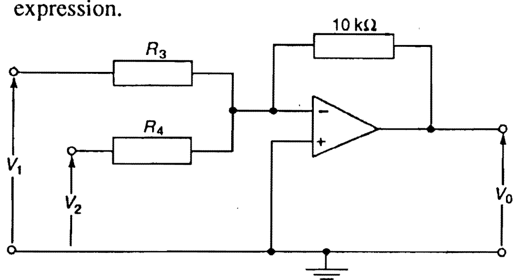


Fig. 19

Fig. 19 shows a modified circuit where V_1 and V_2 are two independent input voltages. What values for R_3 and R_4 would give an output voltage:

$$V_0 = -(4\ V_1 + 0.5\ V_2)\ ?$$

Suggest an application for this type of circuit. N86/III/13

20 *(d)* In the operational amplifier circuit of Fig. 20, a sinusoidal e.m.f. of 2.0 V (r.m.s.) and frequency 50 Hz is applied to the non-inverting input. The inverting input is at earth potential.

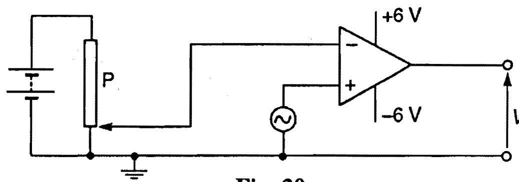


Fig. 20

Draw sketch graphs on the same axes to show the variation with time of

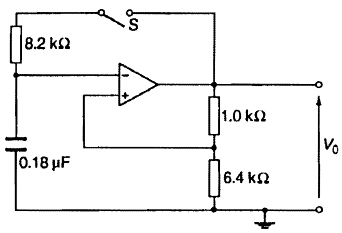
(i) the potential at the non-inverting input, [21

(ii) the output potential V_0. [2]

The potential at the inverting input may be made positive with respect to earth by adjustment of the potentiometer P. Draw a sketch graph to show, in detail, how V_0 varies with time *t* when the inverting input is held at +2.0 V. [7] J88/III/13(part)

21 *(c)* In the circuit of Fig. 21, the switch S is open, the inverting input is at 0 V and the output voltage is $+V_0$.

Fig. 21



Show that the non-inverting input is at potential $+0.86\ V_0$. [3]

(d) The switch S in Fig. 21 is now closed.

(i) Explain why the potential of the inverting input becomes progressively more positive. [2]

(ii) Calculate the time taken for the potential of the inverting input to reach the same potential as the non-inverting input. [2]

(iii) Describe and explain the subsequent variations in V_0. [6] N89/III/11 (part)

22 *(d)* The change in potential difference as found in *(c)* is to be amplified by means of a differential amplifier incorporating an operational amplifier so that the output may be read on a 0 – 1 V voltmeter. The voltmeter can then be calibrated to read temperature change directly. The circuit is shown in Fig. 22.

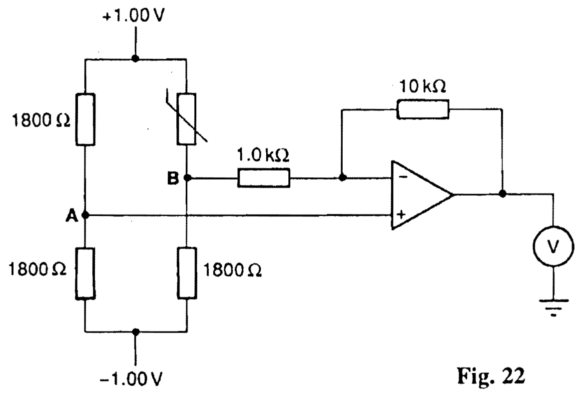


Fig. 22

(i) What will be the reading on the voltmeter before the gas expands? Explain your answer. (Resistance of thermistor = 1800 Ω.)

(ii) What is the potential difference between points **A** and **B** after the gas has expanded? (Resistance of thermistor = 1910 Ω.)

(iii) What will be the reading on the voltmeter after the expansion? [5] N95/III/5 (part)

23 *(a)* A student decided to build a device to monitor at a distance whether a door is open or closed. He fitted a switch in the door frame so that, when the door is closed, the switch is closed. This switch (S) was included in the circuit shown in Fig. 23.

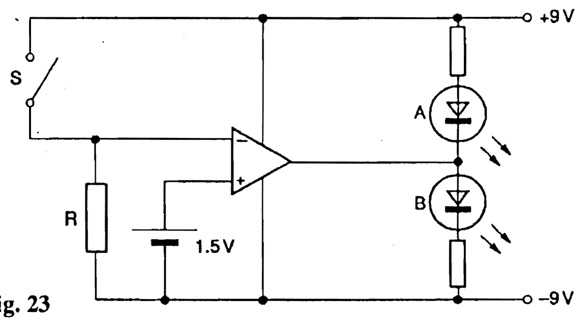


Fig. 23

(i) What is the function of the resistor R?

(ii) Deduce the state of the light-emitting diodes A and B when S is closed.

(iii) What change, if any, occurs in the states of A and B when S is opened? [7] J96/III/9 (part)

24 Fig. 24 shows an operational amplifier (op-amp) in a circuit. The op-amp in this question may be considered to be ideal.

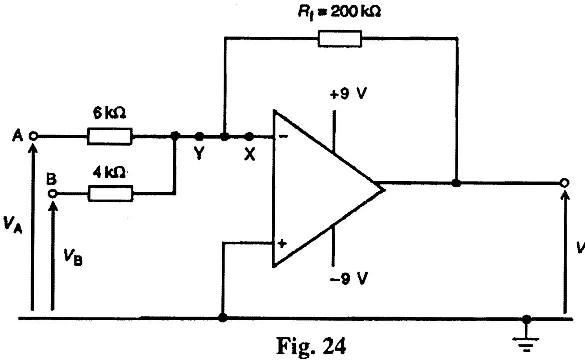


Fig. 24

(a) For the ideal op-amp, what can be stated about

(i) the potential at X,

(ii) the current in the wire at X,

(iii) the maximum and the minimum output potentials? [3]

(b) The potential at A is fixed at +1.8V and the potential at B is initially −0.4V. Calculate

(i) the input current at A,

(ii) the current at Y,

(iii) the current in the feedback resistor of value $R_f = 200\ k\Omega$,

(iv) the output potential. [7]

(c) The potential at B is now varied in the way shown in Fig. 25: the potential at A remains fixed at +1.8 V. Sketch the shape of the output potential. [5]

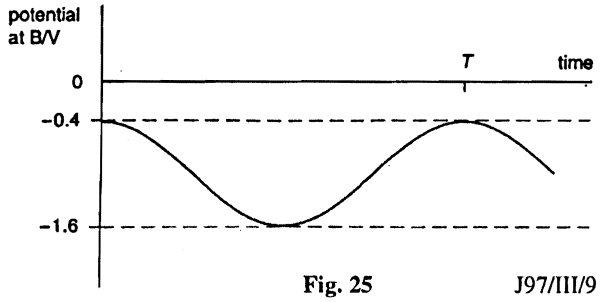


Fig. 25 J97/III/9

25 *(a)* A student set up the circuit of Fig. 26.

The LED's L_1 and L_2 emit light when the output from the appropriate operational amplifier is positive and high. When the thermistor T, which has a negative temperature coefficient, is at 70 °C, the potential difference across the resistor R is 3.5 V.

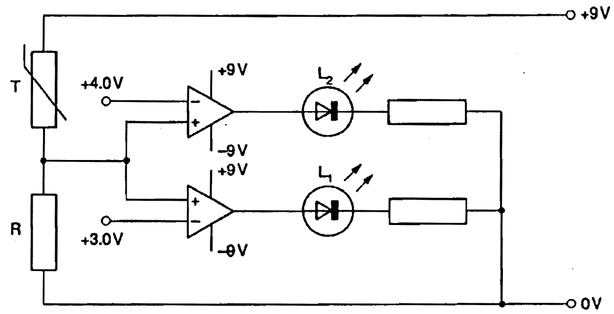


Fig. 26

(i) Explain why, when the thermistor is at 70 °C, L_1 emits light and L_2 does not.

(ii) The temperature of the thermistor is raised and there is a change of state of one or more of the LED's. State and explain what change is observed.

(iii) Suggest one use for the circuit of Fig. 26. [7] N97/III/9 (part)

26 *(a)* Fig. 27 shows the variation with frequency f of the voltage gain G, without feedback, of an ideal operational amplifier (op-amp).

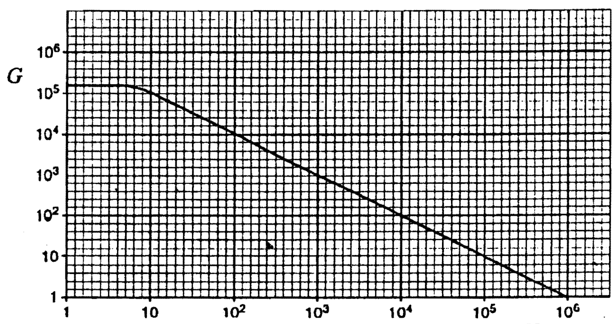


Fig. 27

The op-amp is used in the amplifier circuit of Fig. 28.

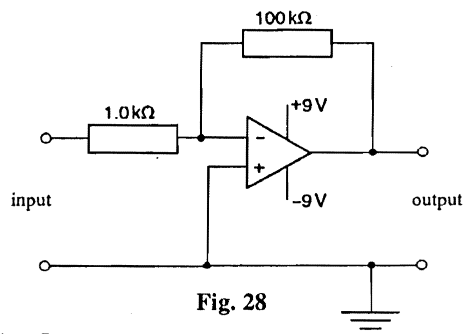


Fig. 28

(i) State

1. the type of amplifier shown in Fig. 28,
2. what is meant by *negative feedback*.

(ii) Calculate

1. the bandwidth of the amplifier,
2. the peak output voltage for an input signal of peak value 0.2 V and frequency 1.0×10^5 Hz.

[7] J98/III/9 (part)

27 *(d)* An operational amplifier, which can be considered to be acting ideally, is used in its inverting mode in the mixer circuit shown in Fig. 29.

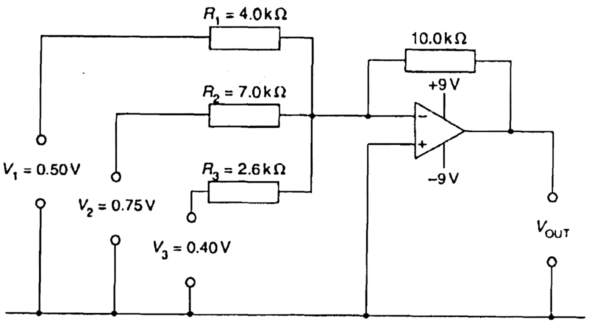


Fig. 29

(i) Calculate the value of the output when the resistors and the inputs have the values given on Fig. 29.

(ii) The constant inputs are replaced by microphones and the input resistors replaced by variable resistors. Explain how this circuit may behave as a mixer, that is, one which produces an output which combines various fractions of the inputs. [6]

(e) Draw a circuit diagram of an operational amplifier as a voltage follower. [2] N98/III/9 (part)

28 *(a)* Fig. 30 shows the variation with input voltage V_{IN} of the output voltage V_{OUT} for an amplifier.

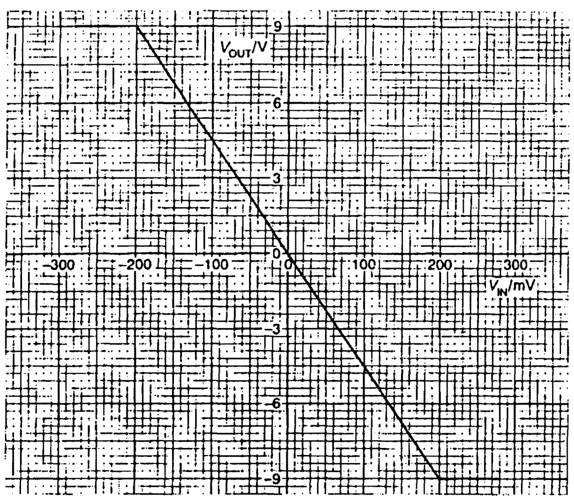


Fig. 30

(i) State whether the amplifier is an inverting or a non-inverting amplifier.

(ii) Use Fig. 30 to calculate the magnitude of the voltage gain of the amplifier.

(iii) Draw a circuit diagram for this amplifier, based on an ideal operational amplifier. On your diagram, indicate the input and output connections and also suitable values of any components used. [8] J99/III/9 (part)

29 *(a)* State the properties of an ideal operational amplifier (op-amp). [3]

(b) (i) Explain the meaning of the term *feedback* when applied to an op-amp circuit.

(ii) State the effect of negative feedback on

1. the gain,
2. the bandwidth of an op-amp circuit. [4]

(c) Describe the use of an op-amp EITHER as a summing amplifier OR as a comparator. [3]
N99/III/9 (part)

30 *(a)* Fig. 31 shows an inverting amplifier circuit incorporating an ideal operational amplifier (op-amp).

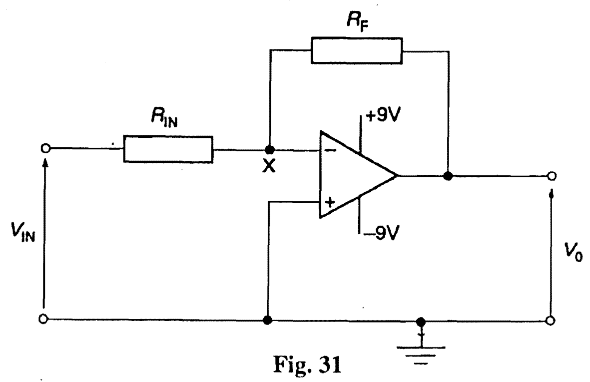


Fig. 31

(i) 1. Explain why the potential at point X is approximately 0 V unless the op-amp is saturated.

2. Derive an expression for the gain of the amplifier circuit in terms of the input resistance R_{IN} and the feedback resistance R_F.

(ii) In one particular application of the circuit, the gain of the amplifier is −10. State the value of the output voltage V_0 when the input voltage V_{IN} is

1. +0.1 V,
2. −1.0 V. [8]

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31 *(a)* A strain gauge is fixed very securely to a beam which is to be loaded. The strain gauge is connected into a circuit with a second strain gauge, two resistors, a meter and a power supply, as shown in Fig. 32.

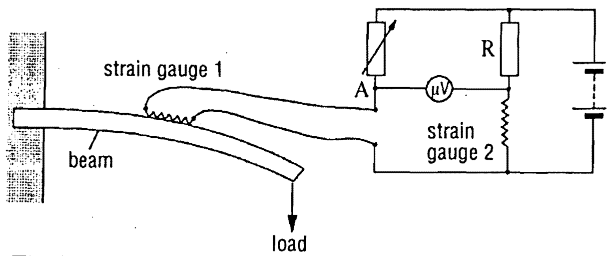

Fig. 32

(i) Explain how the potential at A changes as the load is applied.

(ii) What is the advantage of using two strain gauges in this arrangement? [5]

(b) An operational amplifier (op-amp) circuit could well be used instead of the meter in the circuit shown in Fig. 32. Fig. 33 shows such a circuit.

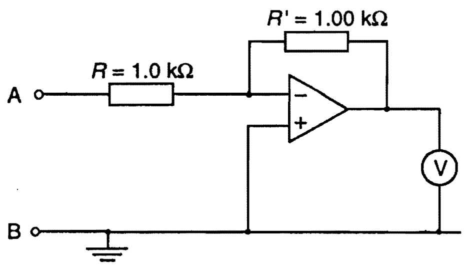

Fig. 33

(i) Describe the function of the circuit and explain its advantage over a simple meter.

(ii) Deduce the gain of the op-amp circuit. [5]

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