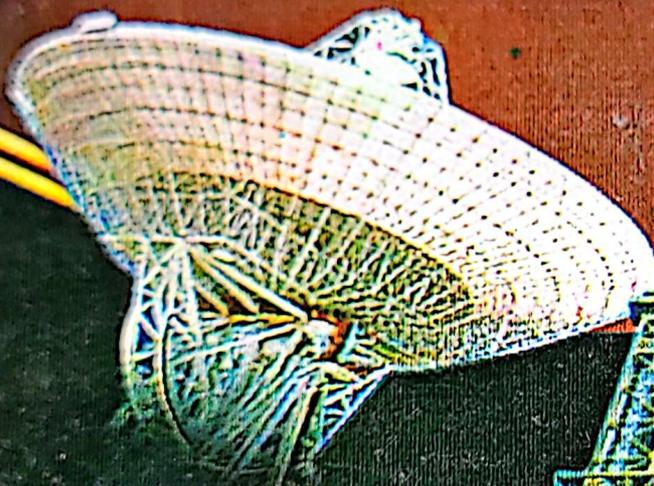


ELECTRONIC AND TELECOMMUNICATION LABOURATORY PRACTICE

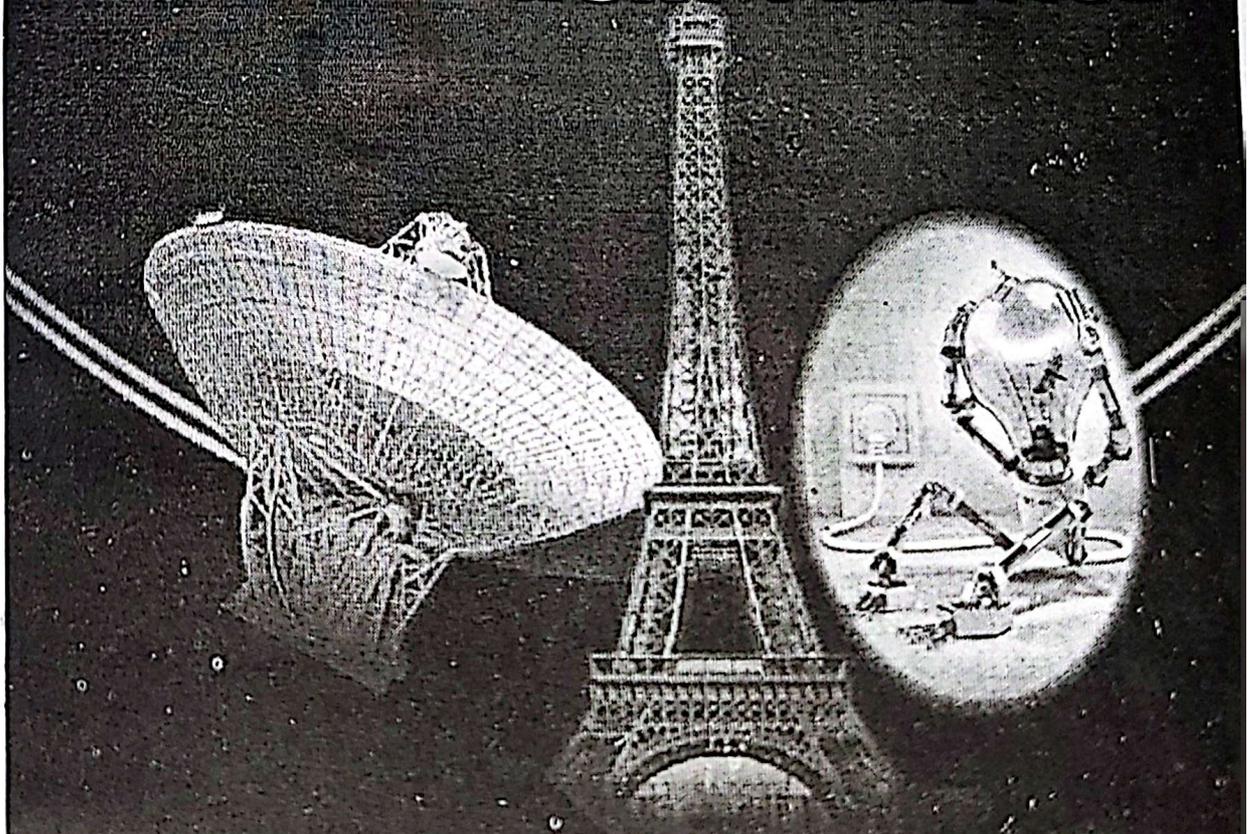


VOL.2

S. I. OKOLIGWE

LEBARI CHIBUEZE GRACIOUS

ELECTRONIC AND TELECOMMUNICATION LABOURATORY PRACTICE



VOL.2

S. I. OKOLIGWE

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DEDICATION

This book is dedicated to the Lord Jesus Christ, who gave me the grace, inspiration and energy to write this book. May His name alone be glorified forever and ever.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to my lovely wife, Evelyn Uchechukwu, whose encouragement and support have enabled me to write this book. I want to use this opportunity to thank the former Rector of Federal Polytechnic, Oko, Prof. Uba Nwuba for providing an enabling environment for this book to become a success. My gratitude also goes to Engr. Nwosu F.C., Engr. Onwubalili C.N., and Engr. Ugbo P.E., who are the Heads of Department of Electrical/Electronics Engineering, Federal Polytechnic, Oko, for their encouragement which have made this work to be successfully completed.

PREFACE

There has been a tremendous advancement in the field of electronics and the development of electronic equipment particularly, after the replacement of electronic tubes and valves by transistors and other solid-state devices like integrated circuit (IC) with thousands of components mounted on small chips. The advent of microprocessors of different configuration has not only added to the complexities of the design of modern electronic equipment, but it has also raised the problem of maintenance and repair of these electronic equipment for trouble free working. The maintenance and repair of these sophisticated electronic equipment do not only require specialized test and measurement devices, but also modern specialized skills, training and techniques on the part of those engaged in the maintenance and repair of these electronic equipment.

To understand the basic design, construction, test and measurement, this book will be very useful. This book is prepared to help students to understand some practical experiment on how to design, construct and test an electronic circuit. The knowledge of the experiments in this book will enable students and apprentices to repair an electronic equipment, also it is produced based on the scheme of work for the Electrical/Electronic Engineering. It contains the experimental section and the application section.

EXPERIMENT 1

TOPIC: Half-wave Rectifier

AIMS:

- To observe the input and output waveform of a half-wave rectifier.
- To measure the input and output voltages of a half-wave rectifier.

GENERAL THEORY

A half-wave rectifier is a circuit with a diode which allows an alternative current (ac) to flow through it only in forward direction. During the reversed direction, the current is blocked. The circuit in fig 1.1 shows a typical half-wave rectifier circuit.

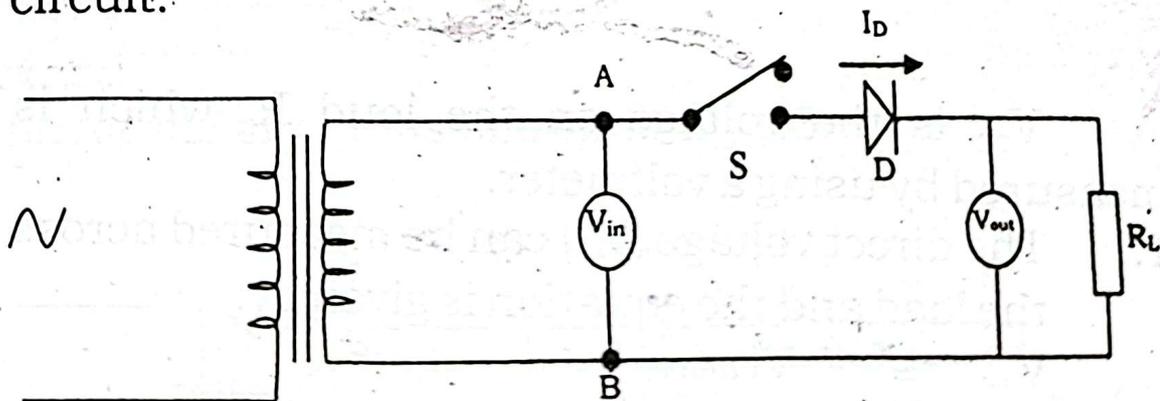


Fig 1.1

During the first half cycle, point A is positive and the diode D conducts and the voltmeter (V_o) indicate a voltage drop across R_L . In the second half cycle, the voltage is reversed and the diode D could not conduct. The voltmeter indicates no voltage

This process continues repeatedly. The waveform is shown in fig 1.2.

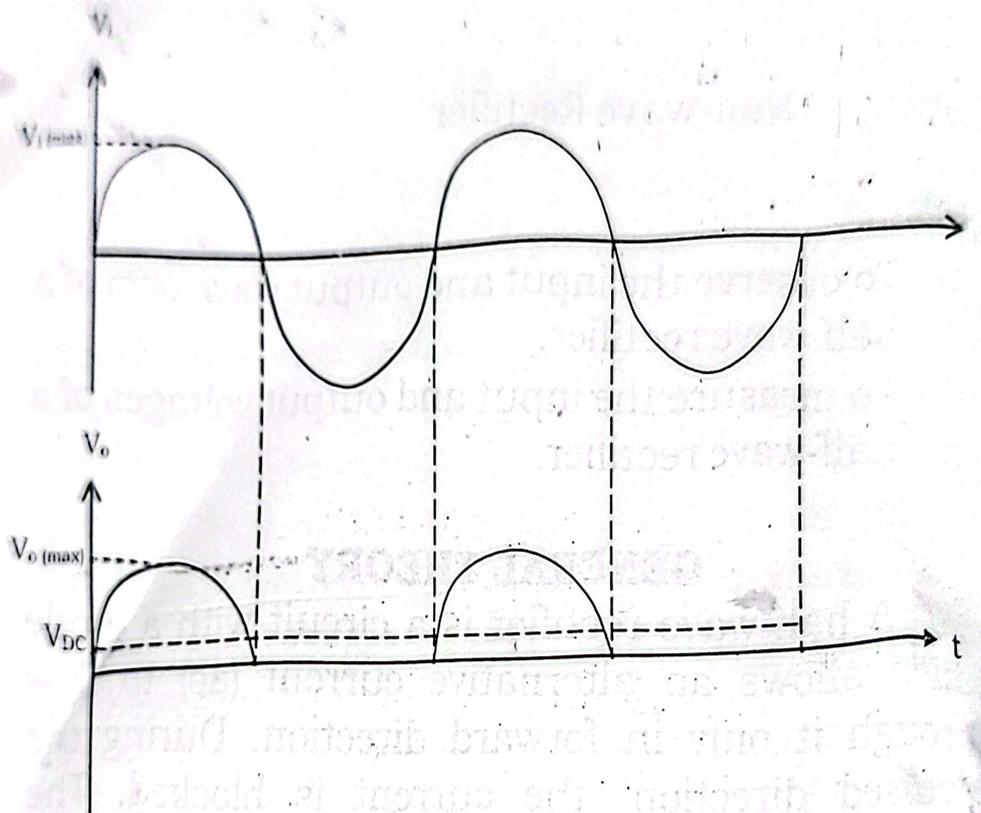


Fig 1.2

V_{DC} is the voltage on the load R_L which is measured by using a voltmeter.

1. The direct voltage (V_{dc}) can be measured across the load and the equation is given by:

$$V_{dc} = \frac{V_{i(max)}}{\pi}$$

2. The direct current (I_{dc}) flowing through the load is given by:

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{I_{i(max)}}{\pi}$$

3. The ripple factor (r) is the ratio of the root mean square (rms) value of the alternating component of the waveform on the load to the mean value of the waveform on the load.

$$r = \sqrt{\frac{(I_{rms})^2}{I_{dc}} - 1}$$

4. Regulation factor (S%) is the ratio of the output voltage (V_o) of no-load across the output of the rectifier circuit to the voltage V_L measured with the load resistance R_L .

$$S\% = \frac{V_o - V_L}{V_o} \times 100\%$$

Component and Equipment

1. Transformer 6-0-6V
2. Diodes IN 1001
3. Resistor 1K Ω
4. Voltmeter
5. Ammeter

Method

Connect the circuit as shown in fig 1.3

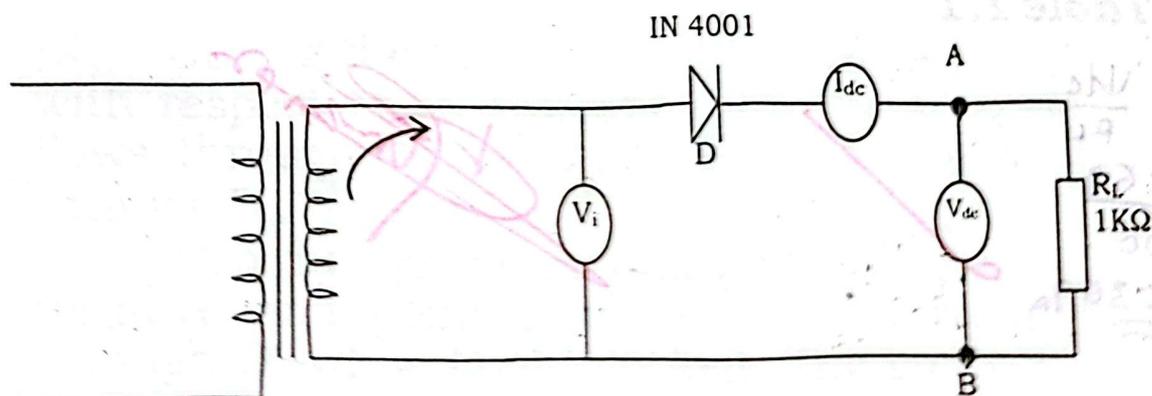


Fig 1.3

1. Measure the ac voltage (V_i) and dc voltage without the load resistor R_L .
Connect R_L and repeat step 1 and record your result.
3. Replace an oscilloscope with the voltmeter at point AB. Measure; (i) the voltage (ii) frequency and (iii) draw the waveform.
4. With the value of R_L , calculate the dc current I_{dc} .
5. Calculate the power output (P_o).
6. Tabulate your result as shown in table 1.1

V_i without RL	9v
V_{dc} without RL	
V_i with RL	6v
V_{dc} with RL	3.69v
I_{dc} measured	
I_{dc} calculated	0.0369A
P_o	0.1362w
$V_{o(max)}$ with Scope f	

Table 1.1

$$\begin{aligned}
 I_{dc} &= \frac{V_{dc}}{R_L} \\
 &= \frac{3.69}{100} \\
 &= 0.0369A
 \end{aligned}$$

$$\begin{aligned}
 P_o &= V_{dc} I_{dc} \\
 &= 3.69 \times 0.0369 \\
 &= 0.136161w \\
 &= 0.1362w
 \end{aligned}$$

EXPERIMENT 2

TOPIC: Bridge Rectifier

AIM:

- To observe the input and the output waveform of a bridge rectifier.
- To measure the input and the output voltages of a bridge rectifier.

GENERAL THEORY

A bridge rectifier circuit allows an output voltage to be obtained from the positive and negative cycle of the alternating voltage source. Fig 2.1 shows a circuit diagram of typical bridge rectifier circuit with four diodes.

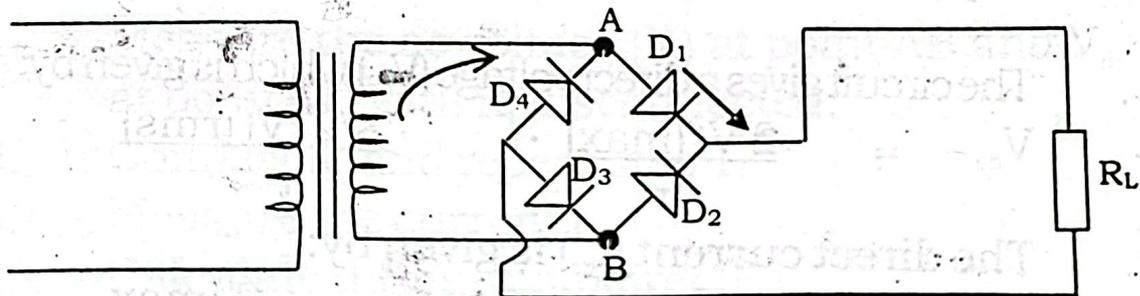


Fig 2.1

During the first half cycle, point A is positive with respect to B. Current from the transformer flows through diode (D_1) to R_L and returns back through D_3 .

Also during the second half cycle, point A is negative and point B is positive. Current flows through D_2 while D_3 is blocked. The current flows through R_L and back through D_4 . This process continues repeatedly as point A continues to change from negative to positive.

The waveform is shown in fig 2.2

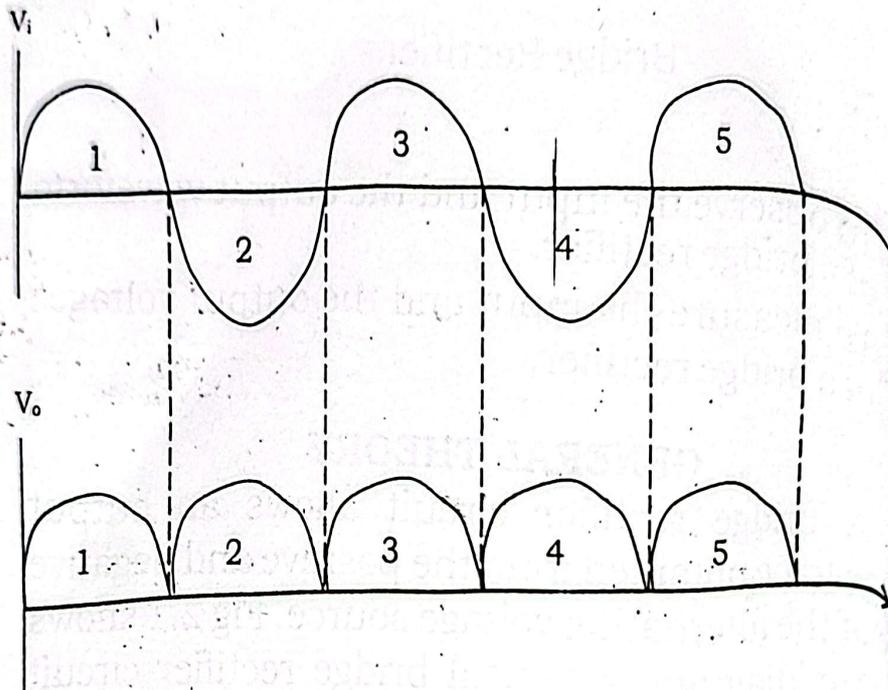


Fig 2.2

1. The circuit gives a direct voltage (V_{dc}) which is given by

$$V_{dc} = \frac{2 V_i (\max)}{\pi} = \frac{2\sqrt{2} \cdot V_i (\text{rms})}{\pi}$$

2. The direct current (I_{dc}) is given by:

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{2\sqrt{2} \cdot V_i (\text{rms})}{\pi \cdot R_L} = \frac{2 I_{\max}}{\pi}$$

$$\text{Where } I_{\max} = \frac{\sqrt{2} \cdot V_i (\text{rms})}{\pi}$$

3. Regulation factor (S%) is given by:

$$S = \frac{V_o - V_L}{V_o} \times 100\%$$

4. Ripple factor (r) is given by:

$$R = \sqrt{\left(\frac{I_{\text{rms}}}{I_{dc}}\right)^2 - 1}$$

Component and Equipment

1. Transformer 6-0-6V
2. Diodes IN 1001
3. Resistor 10KΩ
4. Voltmeter
5. Ammeter

Method:

Connect the circuit as shown in fig 2.3

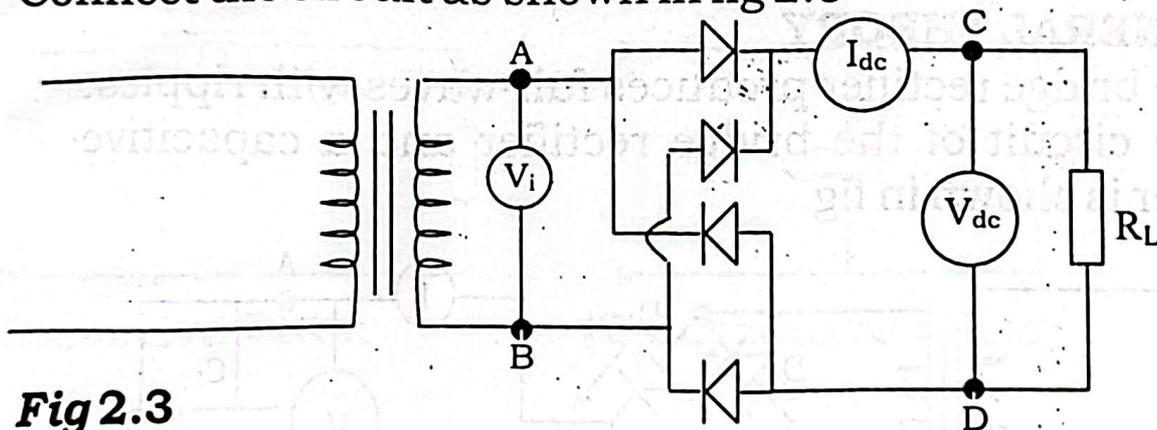


Fig 2.3

1. Measure the ac voltage (V_i) at point AB and V_{dc} at point CD with R_L disconnected.
2. Connect R_L and repeat step 1.
3. Measure the current I_{dc} .
4. Calculate the output power (P_o).
5. Tabulate your result as shown in table 2.1

V_i no load	
V_{dc} no load	
V_i	
V_{dc}	
I_{dc}	
P_o	

Table 2.1

EXPERIMENT 3

TOPIC: Bridge Rectifier With Filter

AIM:

- To analyse the effect of filters in a bridge rectifier circuit.

GENERAL THEORY

The bridge rectifier produces full-waves with ripples. The circuit of the bridge rectifier and a capacitive filter is shown in fig

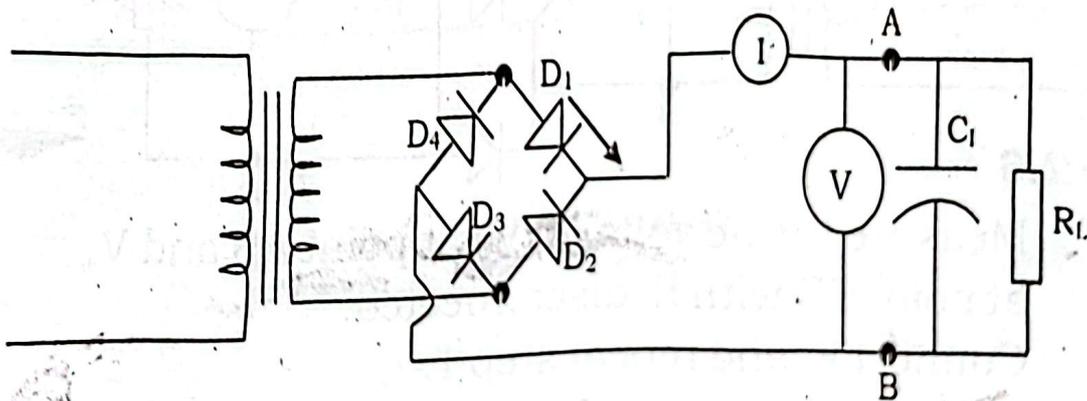


Fig 3.1

The voltage from the bridge rectifier is produced in a ripple form. During the first cycle, as the ripple voltage begins to rise, C₁ starts to charge. When the ripple voltage reaches the peak, the capacitor C₁ is charged to the maximum. As the ripple voltage begins to fall toward zero voltage, C₁ starts discharging, thereby preventing the ripple voltage from falling to zero voltage. Therefore, the ripple voltage is being smoothen to a minimum value by the

Use of a capacitor C_1 , as shown in fig 3.2, with the coupling of more capacitors in parallel with R_L further reduces the ripple voltage to a pure dc voltage.

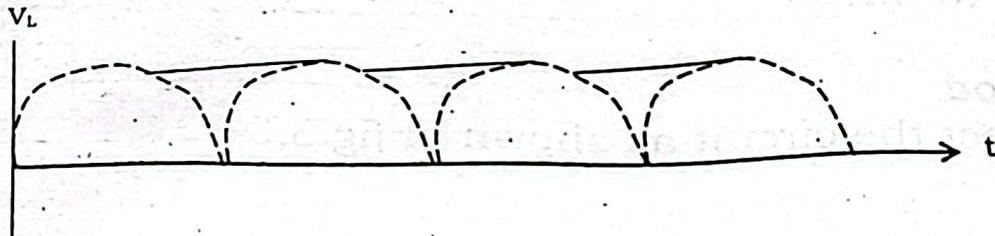


Fig 3.2 (a)

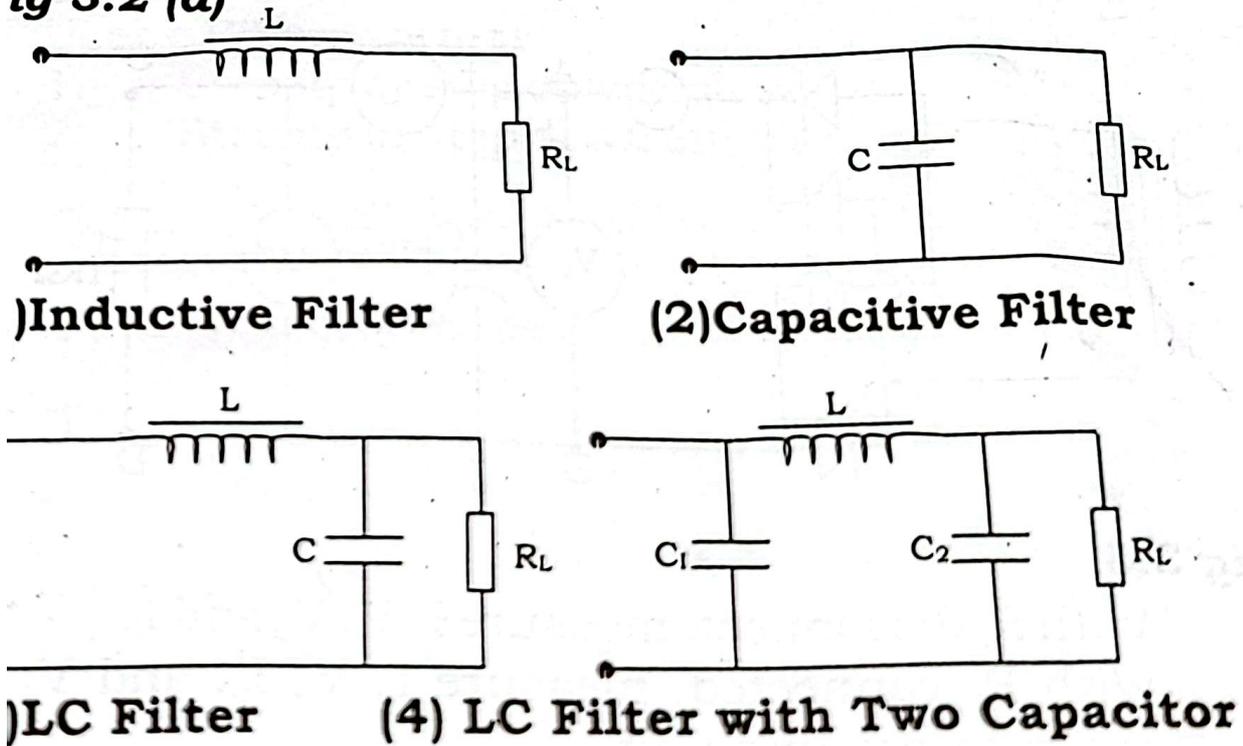


Fig 3.2 (b)

Component and Equipment

Transformer 6-0-6V, 600mH

Diodes IN 1001

Resistor 1K Ω

- 4. Capacitor 470 μ f
- 5. Ammeter
- 6. voltmeter

Method

Connect the circuit as shown in fig 3.3

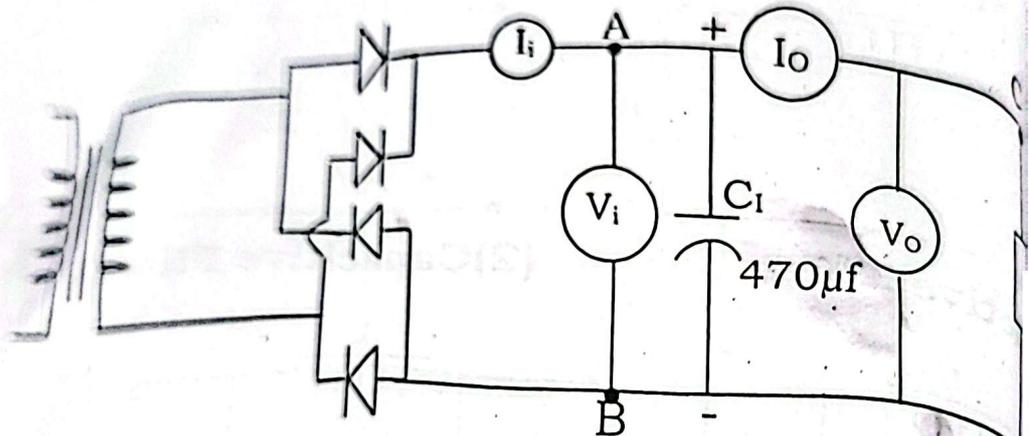


Fig 3.3

1. With R_L disconnect, measure I_i , V_i , V_o and I_o
2. With R_L connected, measure I_i , V_i , I_o , and V_o and record your result.
3. Calculate the power ($P_i = I_i V_i$ and $P_o = I_o V_o$)
4. Connect an oscilloscope to point AB and draw the waveform.
5. Remove the capacitive filter and connect other filters at point AB and repeat step 1 to 4.
6. Tabulate your result as shown in table 3.1

	Without filter	C filter 1	C filter 2	C filter 3	C filter 4
I_i	0.06v	470 μ F			
V_i	6v	470 μ F			
I_o	0.1133A	470 μ F			
V_o	11.33v	470 μ F			
P_i	0.36w	470 μ F			
P_o	1.284w	470 μ F			

Table 3.1

Uses of Transformer

1. Step up or step down voltage
2. Step up or step down current.

$$I_o = \frac{V_o}{R_L} = \frac{11.33}{100} = 0.1133A$$

$$P_i = I_i \times V_i = 0.06 \times 6v = 0.36w$$

$$I_i = \frac{V_i}{R_L} = \frac{6}{100} = 0.06A$$

$$P_o = I_o \times V_o = 0.1133 \times 11.33$$

$$= 1.283689$$

$$\approx 1.284$$

$$V_i = 6v$$

$$V_o = 11.33v$$

EXPERIMENT 4

TOPIC: Investigation of the Operation of Astable Multivibrator

AIM:

- To investigate the operation of astable multivibrator.
- To investigate the basic factors which influence the operation of a transistorized astable multivibrator.

GENERAL THEORY

Multivibrators are circuits which are capable of producing rectangular output wave shapes. These are electronic switches which may rely on charging and discharging of RC time constant circuits to produce the desired output wave shapes.

Astable multivibrator is a type of circuit which consists of two cross-coupled inverter circuit as shown in fig 4.1. The output of inverter is the input of the other circuit. The main feature of this circuit is that both of the inverters can not operate in the saturated condition simultaneously. Therefore, when one inverter circuit is conducting, the other inverter circuit is cut-off. Since Q_1 and Q_2 are constantly charging between off and on, this type of multivibrator does not have a stable state or condition, but has a two unstable state:

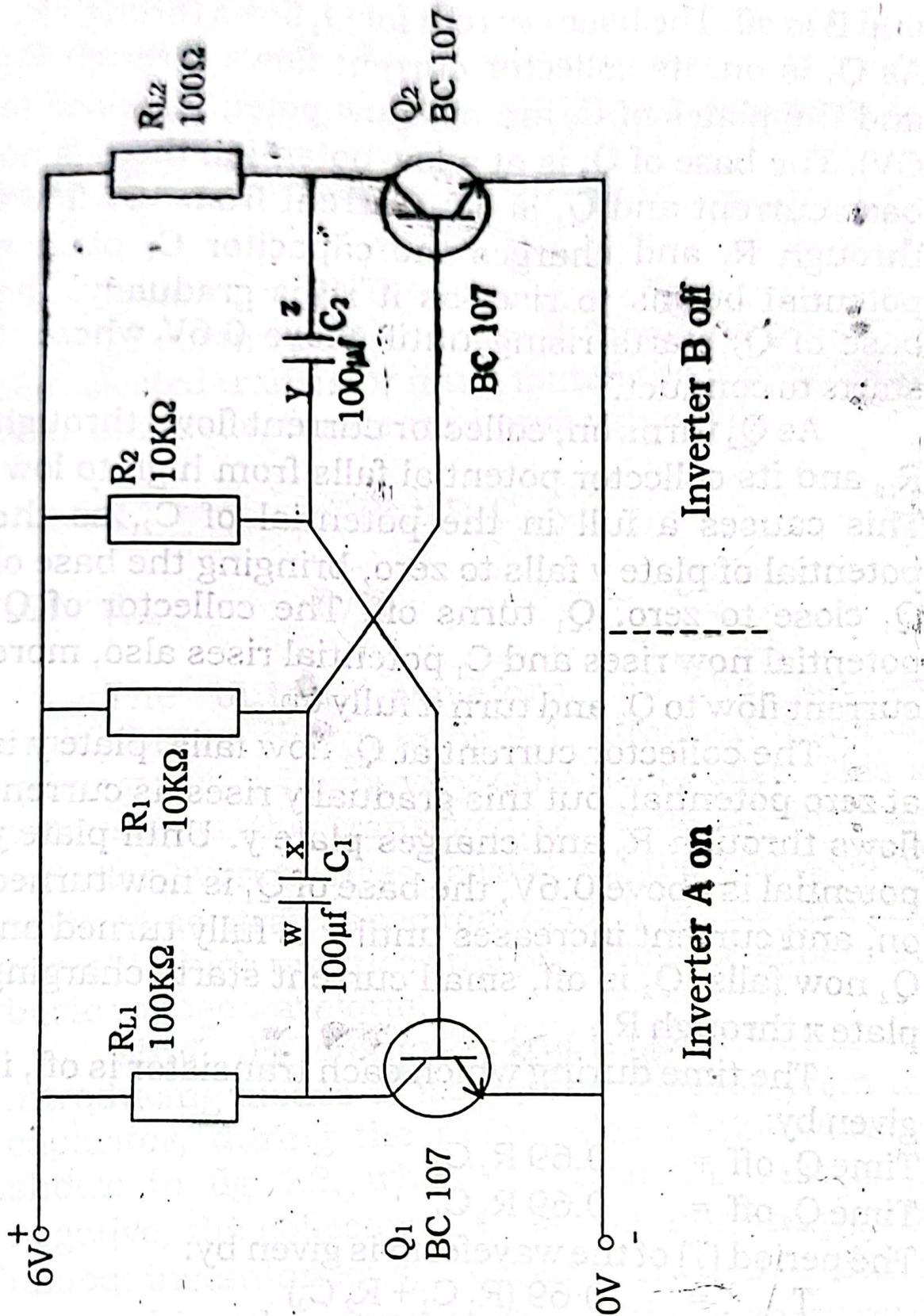


Fig 4.1 Astable Multivibrator

At the time of operation of the circuit, inverter A is on and B is off. The base current for Q_1 flows through R_1 . As Q_1 is on, its collector current flows through R_2 and the plates of C_1 are at a low potential (close to 0V). The base of Q_2 is at a low potential, there is no base current and Q_2 is off. Current from +6V flows through R_1 and charges the capacitor C_1 plate potential begins to rise, as it rises gradually, the base of Q_2 starts rising until above 0.6V where it starts to conduct.

As Q_2 turns on, collector current flows through R_2 and its collector potential falls from high to low. This causes a fall in the potential of C_2 , so the potential of plate y falls to zero, bringing the base of Q_1 close to zero, Q_1 turns off. The collector of Q_2 potential now rises and C_1 potential rises also, more current flows to Q_2 and turn it fully on.

The collector current at Q_2 now falls, plate y is at zero potential, but this gradually rises as current flows through R_2 and charges plate y. Until plate potential is above 0.6V, the base of Q_1 is now turned on, and current increases until it is fully turned on. Q_2 now falls, Q_2 is off, small current starts charging plate x through R_2 .

The time during which each transistor is off, given by:

$$\text{Time } Q_1 \text{ off} = 0.69 R_2 C_2$$

$$\text{Time } Q_2 \text{ off} = 0.69 R_1 C_1$$

The period (T) of the waveform is given by:

$$T = 0.69 (R_1 C_1 + R_2 C_2)$$

$$\text{When } R_1 C_1 = R_2 C_2 \\ T = 1.38 RC$$

The frequency (f) of the output waveform is given by:

$$F = 1/T = 1/1.38RC = 0.7/RC$$

$$\text{Duty Cycle} = T_1/T_1 + T_2$$

To ensure that the circuit functions properly, the selected transistor must match the proper value of hf_E or must saturate minimum value of β .

$$R_1 = hf_E(\text{sat}) R_2 C_2$$

$$\text{Or } \beta_{\min} = R/R_L$$

The output waveform of the astable multivibrator shown in fig 4.1, although definitely rectangular, it has a very slow rising edge. This is because, as the transistor Q_1 turns off and the collector current rises toward R_4 , the capacitor C_2 behaves as stray capacitors lead. It is this charging current which produces the positive over-shot in the basic voltage waveform.

This deficiency can be corrected by introducing diodes to isolate the collector from the capacitor, during the rising edge of the wave as shown in fig 4.2, when C_2 turns the base of Q_1 negative, the collector of Q_1 is able to rise up to V_{CC} almost instantaneously, because diode D_1 becomes reverse biased. R_3 is now responsible for charging

When \odot , turns on, D, conducts and the sequence of operations continues repeatedly. Fig. 4.2 shows the waveform without diode (a) shows waveform with diode.

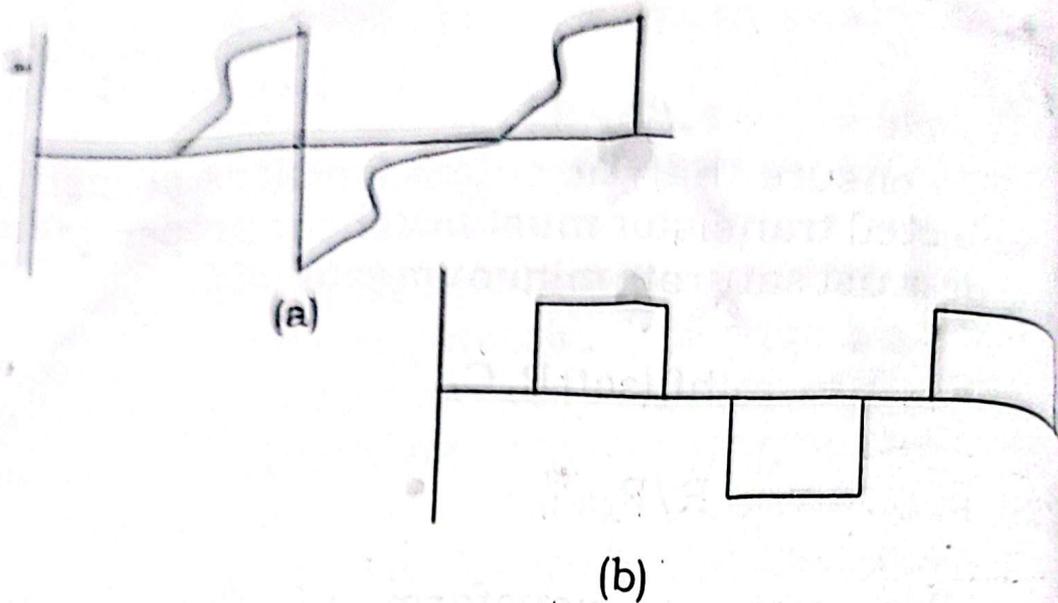


Fig 4.2

Some Calculated Examples

1. Determine the period, frequency of oscillation and the minimum value of transistor β for an astable multivibrator in fig 4.1 with the following component values:

$$R_1 = R_2 = 10K\Omega \text{ and } C_1 = C_2 = 100\mu\text{f}$$

Solution:

$$(i) \quad T = 0.69 (R_1 C_1 + R_2 C_2)$$

$$\text{But } T_1 = T_2 = 0.69 \times 10 \times 10^3 \times 100 \times 10^{-6} = 0.62\text{S}$$

$$T = T_1 + T_2 = 2 \times 0.69 = 1.38\text{S}$$

$$(ii) \quad f = 1/T = 1/1.38 = 0.725\text{Hz}$$

- (iii) Since $R_1 = R_2 = R$ and $R_{L1} = R_{L2} = R_L$, then $\beta_{min} = R/R_L$
 $\therefore \beta_{min} = R/R_L = 10 \times 10^3 / 100 = 100$
- (iv) Duty cycle = $(T_1 / (T_1 + T_2)) \times 100 = (0.62 / (0.62 + 0.62)) \times 100 = 50\%$
2. Determine the value of capacitor to be used in an astable multivibrator to provide a train of pulse 1s wide at a repetition rate of 10Hz. Given $R_1 = R_2 = 10K\Omega$

Solution

Pulse width time interval $T_1 = 1s$ and period $T_2 = 1/10 = 0.1s$

$$T_1 = 0.69 R_1 C_1 \quad \therefore C_1 = T_1 / 0.69 R_1$$

$$C_1 = 1 / (0.69 \times 10 \times 10^3) = 0.000145 = 145 \mu f$$

$$T_2 = 0.69 R_2 C_2$$

$$C_2 = 0.1 / (0.69 \times 10 \times 10^3) = 0.000014 = 14 \mu f$$

Component and Equipment

1. Transistors BC 107
2. Resistors $1K\Omega$, $10K\Omega$
3. Capacitors $100\mu f$
4. Diodes IN 1001
5. Light Emitting diodes
6. Power supply 9V.

Method

Connect the circuit as shown in fig 4.4

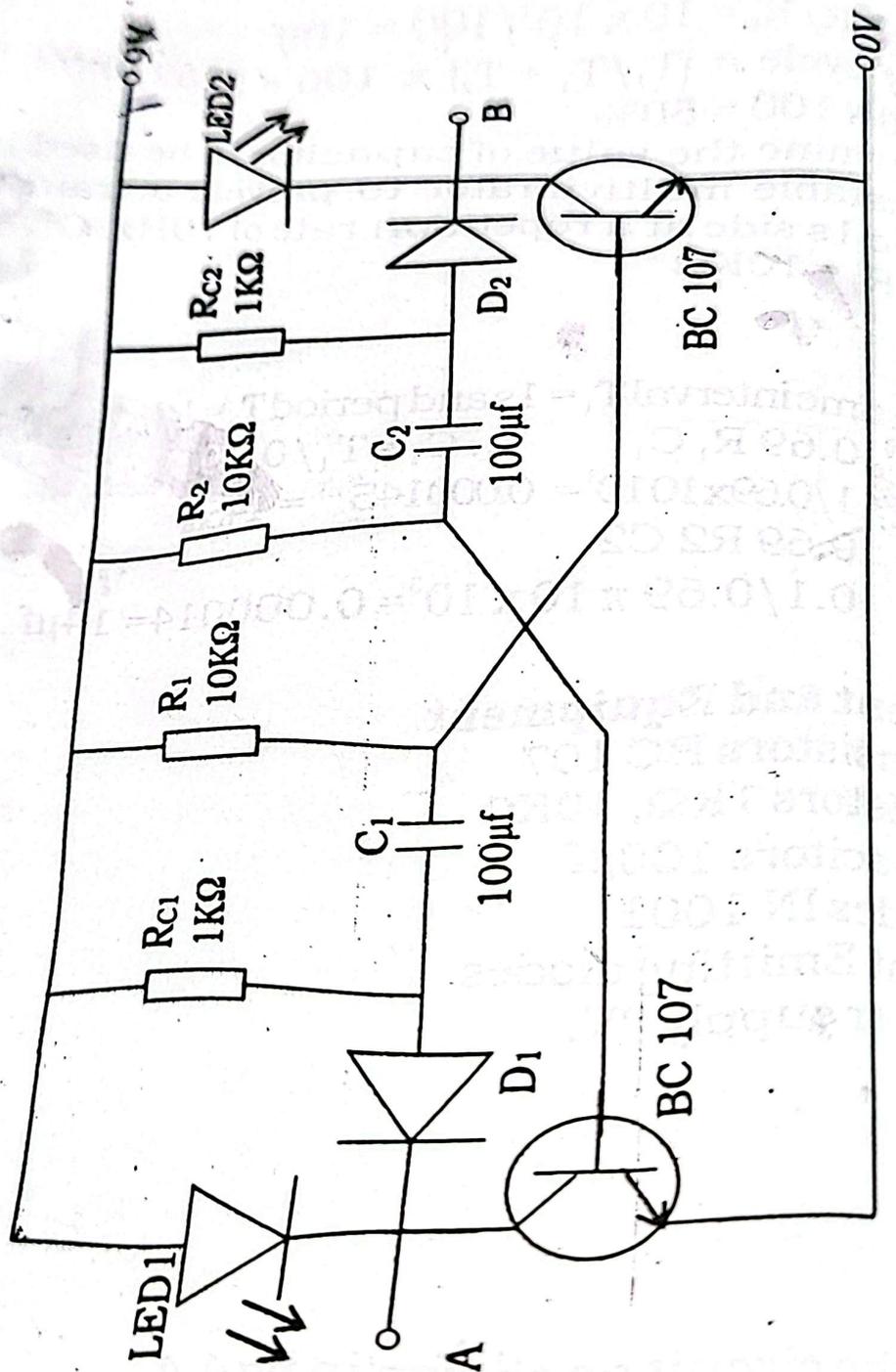


Fig 4.4 Astable Multivibrator

1. Use a stop watch to measure the period (T) at LED1 and LED2.
2. Calculate the frequency (f).
3. Replace C1 with 1000 μ f and measure the period (T) at LED1 and LED2.
4. Calculate their frequency (f).
5. Replace C₁ and C₂ with 0.01 μ f and measure the output period (T) at A and B with an oscilloscope and record your value.
6. Sketch the waveform.
7. Calculate the frequency.
8. Short circuit D₁ and D₂ and repeat step 5. Sketch the waveform, and compare with that of no. 6.
9. Is there any difference? If Yes, explain.
10. Using the value of R_{C1}, calculate the minimum transistor saturation value (β). Tabulate your result as shown in table 4.1.
11. Calculate step 1 to 5 for T and f, then compare your result with measured value.
12. Calculate the duty cycle for no. 3 and 5 and 11.

Result Analysts

Measured Value

Timing Component Value	Period (T)	Frequency (f)
R ₁ = R ₂ = 10K Ω C ₁ = 1000 μ f C ₂ = 1000 μ f		
C ₁ = 1000 μ f C ₂ = 1000 μ f		
C ₁ = 0.01 μ f C ₂ = 0.01 μ f		

Calculated Value

Timing Component Value	Period (T)	Frequency
$R_1 = R_2 = 10K\Omega$ $C_1 = 100\mu f$ $C_2 = 100\mu f$		
$C_1 = 100\mu f$ $C_2 = 100\mu f$		
$C_1 = 100\mu f$ $C_2 = 100\mu f$		

Timing Component Value	Period (T)	Frequency

EXPERIMENT 5

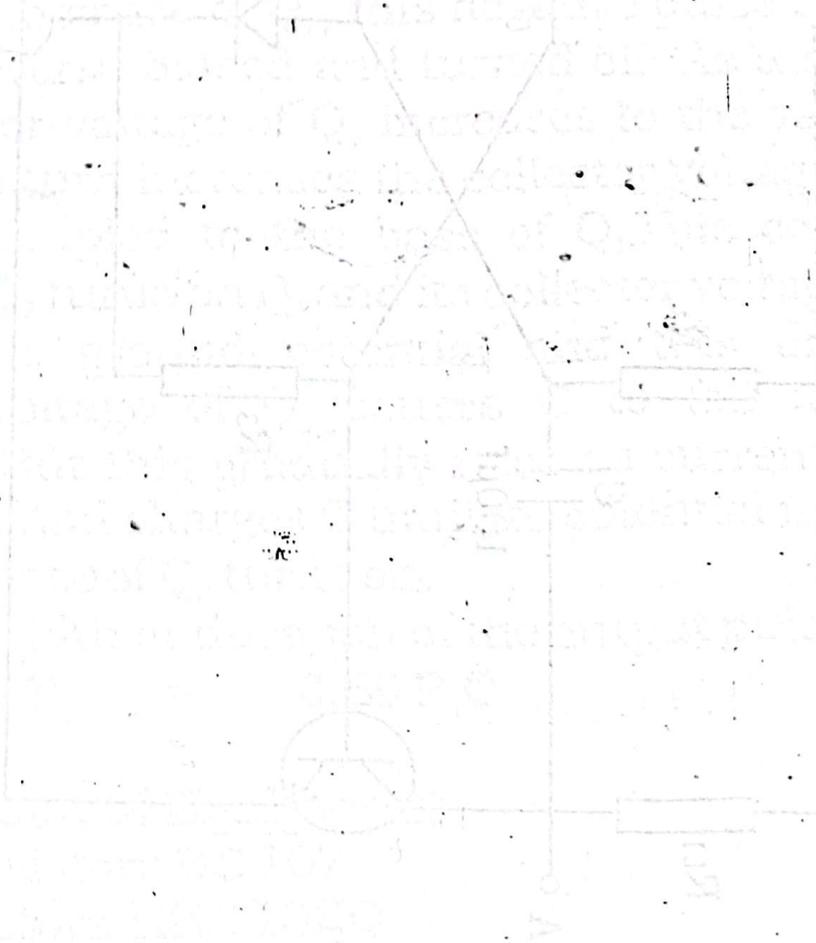
TOPIC: Operation of Monostable Multivibrator

AIM:

- To investigate the operation of monostable multivibrator.

GENERAL THEORY

The monostable multivibrator has one stable state. Fig 5.1 shows the circuit diagram of a monostable multivibrator.



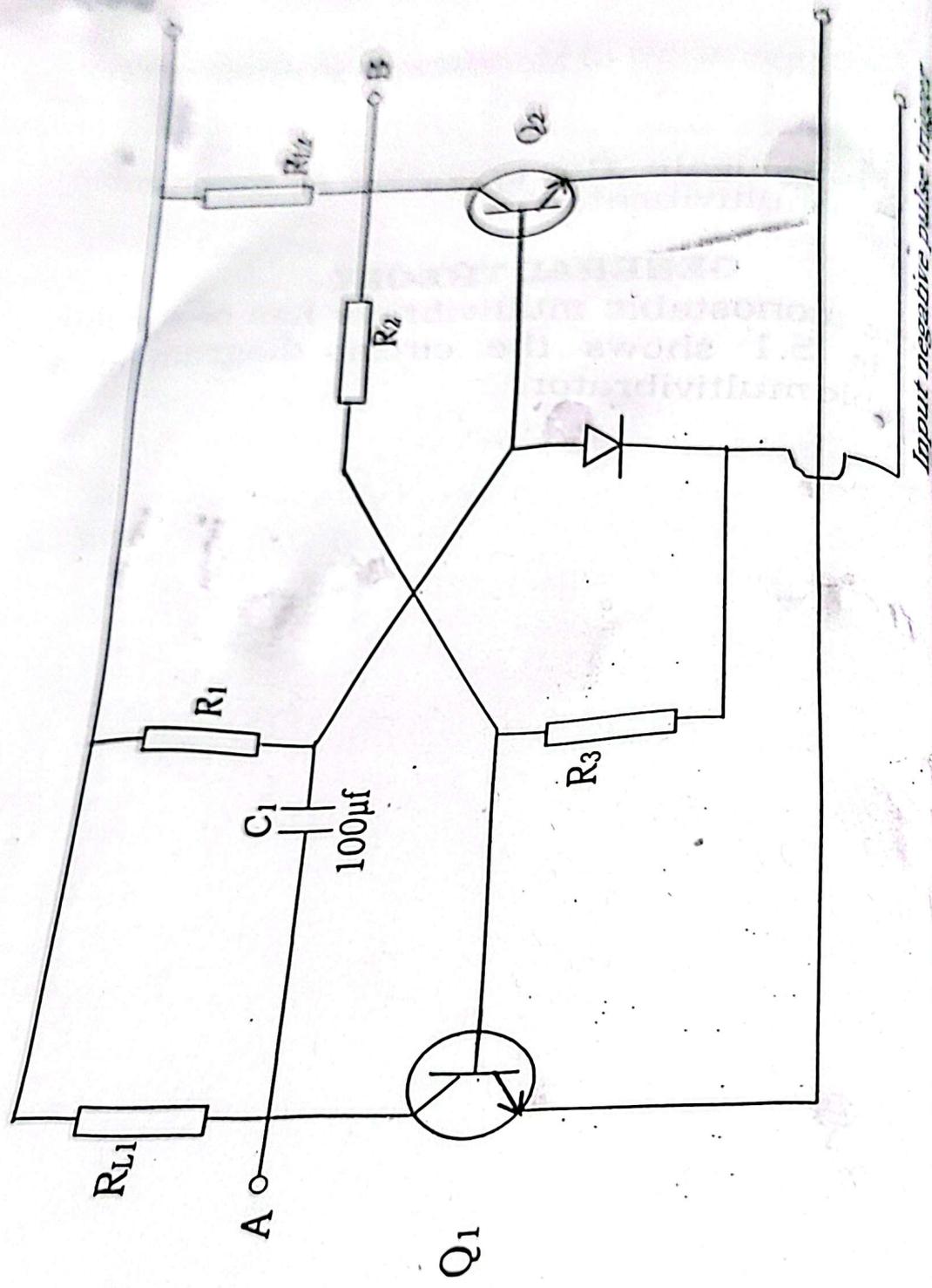


Fig 5.1 Monostable Multivibrator

One output A of the monostable multivibrator circuit is RC coupled to the opposite input of Q_2 , while the other output B is resistively coupled to the opposite input (base of Q_1). The monostable multivibrator will remain in its stable state until external trigger pulse is applied which will cause it to change from its stable to semistable state. The monostable multivibrator remains in this state for a time which is determined by the time constant RC.

Principle of Operation

Initially, monostable circuit is on its stable state, Q_1 is off and Q_2 is on. If a negative pulse is applied to the base of Q_2 , this negative pulse causes Q_2 to be reverse biased and turned off. As a result, the collector voltage of Q_2 increases to the value of V_{cc} . This in turn increases the collector voltage of Q_2 , which is coupled to the base of Q_1 . This collector voltage of Q_2 turns on Q_1 and its collector voltage now falls to the ground potential and this drop in collector voltage of Q_2 causes C to fall to zero potential. But this gradually rises as current flows through R_1 and charges C until its potential is above 0.6V. The base of Q_2 turns on.

The width or duration of the output pulse at Q_2 is given by: $T = 0.69 R_1 C$

Component and Equipment

1. Transistors BC 107
2. Resistors $1K\Omega$, $10K\Omega$
3. Capacitors $100\mu f$
4. Diodes IN 1001

- 5. Light Emitting diodes
- 6. Power supply 9V.

Method

Connect the circuit as shown in fig 5.2

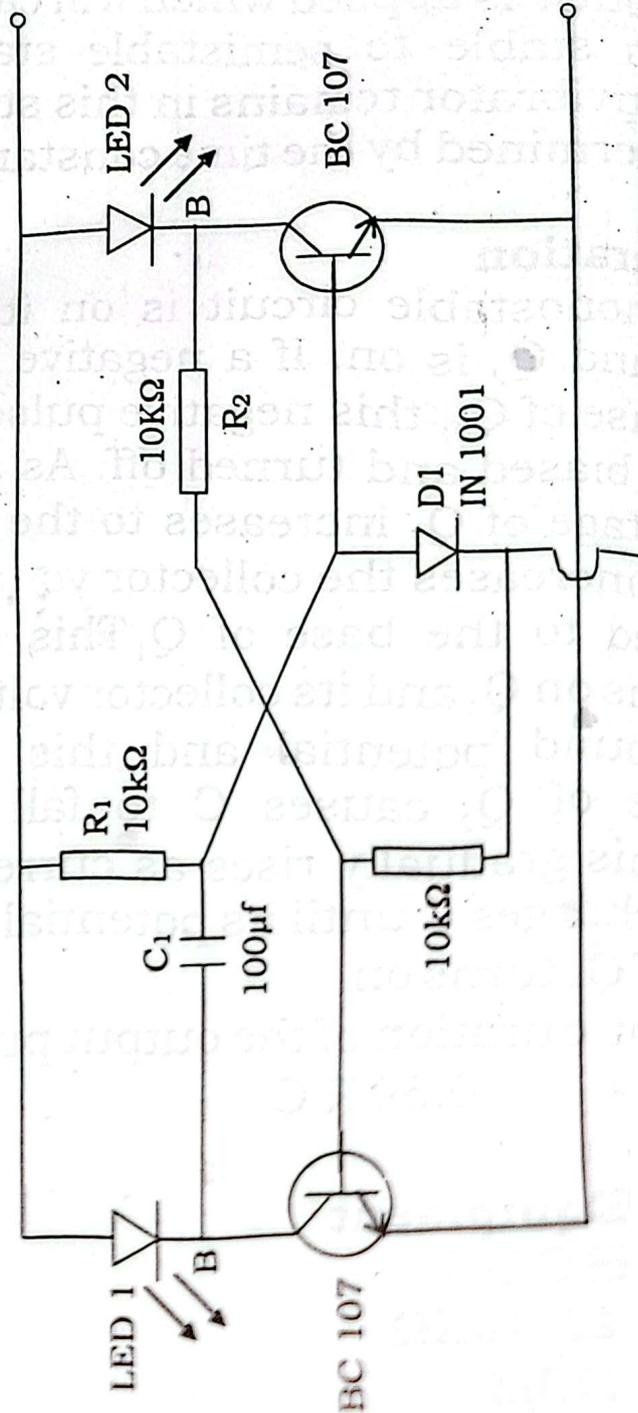


Fig 5.2 Monostable Multivibrator

Feed in a pulse into the input of the trigger signal. Use a stop watch to measure the period (T) of the pulse time at A.

Calculate the frequency (f).

Replace C_1 with $100\mu\text{f}$ and measure pulse time (T) at A.

Calculate the frequency.

Replace C_1 with $0.01\mu\text{f}$ and measure the period (T) using an oscilloscope.

Calculate the frequency.

With $R_1 = 10\text{K}\Omega$ and (i) $C_1 = 1000\mu\text{f}$, calculate the period (T) and frequency (f).

Tabulate your result as shown in table 5.1

Result Analysis

Measured Value

Timing Component Value	Period (T)	Frequency (f)
$R_1 = 10\text{K}\Omega$		
$C_1 = 100\mu\text{f}$ f		
$C_1 = 100\mu\text{f}$ f		
$C_2 = 0.0\mu\text{f}$ f		
Calculated Value		
$C_1 = 100\mu\text{f}$ f		
$C_1 = 100\mu\text{f}$ f		
$C_1 = 0.01\mu\text{f}$ f		

Table 5.1

EXPERIMENT 6

TOPIC: Operation of Bistable Multivibrator

AIM:

- To investigate the operation of bistable multivibrator.

GENERAL THEORY

The bistable multivibrator is also called flip-flop. The circuit has two stable state as shown in fig 6.1.

One of the transistors is saturated, and other is cut off. For instance; if the right transistor is saturated, its collector voltage will be approximately zero. This means that there is no base current in left transistor. As a result, the left transistor voltage is turned off, producing a high collector voltage. This high collector voltage produces a large base current that keeps the right transistor in saturation.

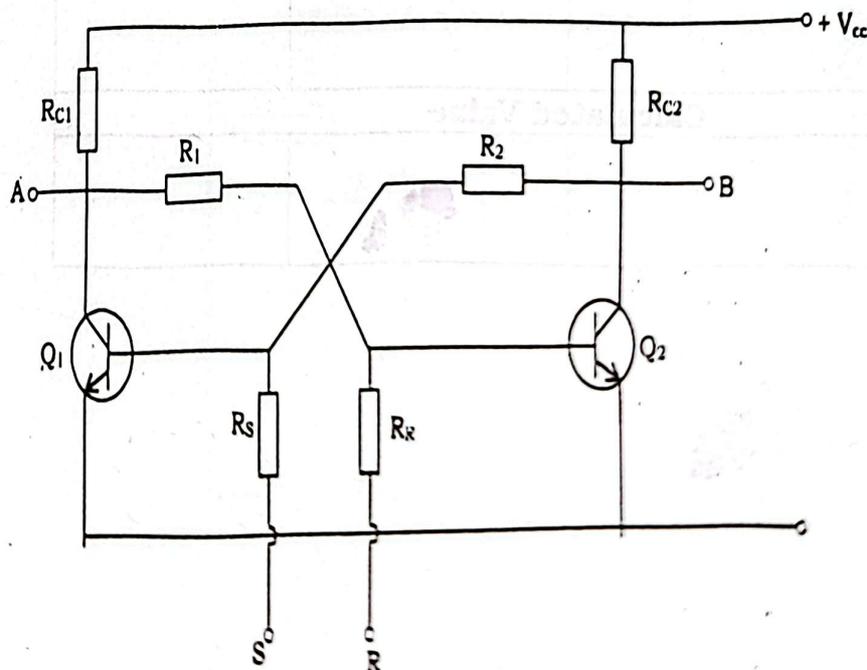


Fig 6.1 RS Flip-Flop Circuit

The RS flip-flop has two outputs, A and B. These are two-state outputs, either low or high voltages. Furthermore, the two outputs are always in opposite states. When B is low, A is high. When B is high, A is low. For this reason, A is called the complement of B. Often \bar{Q} is used in place of A and Q in place of B. The overbar on Q is used to indicate that it is the complement. We can control the output states with the S and R inputs, if we apply a large positive voltage to the S input, we can drive the left transistor into saturation. This will cut off the right transistor. In this case, B will be high and A will be low. The high S input can then be removed, because the saturated left transistor Q_2 is in cutoff.

Similarly, we can apply a large positive voltage to the R input. This will saturate Q_2 and cutoff Q_1 . For this condition, B is low and A is high. After this transition has occurred, the high R input can be removed because it is no longer needed.

Since the circuit is stable in either of two states, it is sometime called a bistable multivibrator. A bistable multivibrator latches in either of two states. A high S input forces B into the high state, and a high R input forces B to return to the low state. The output B remains in a given state until it is triggered into the opposite state.

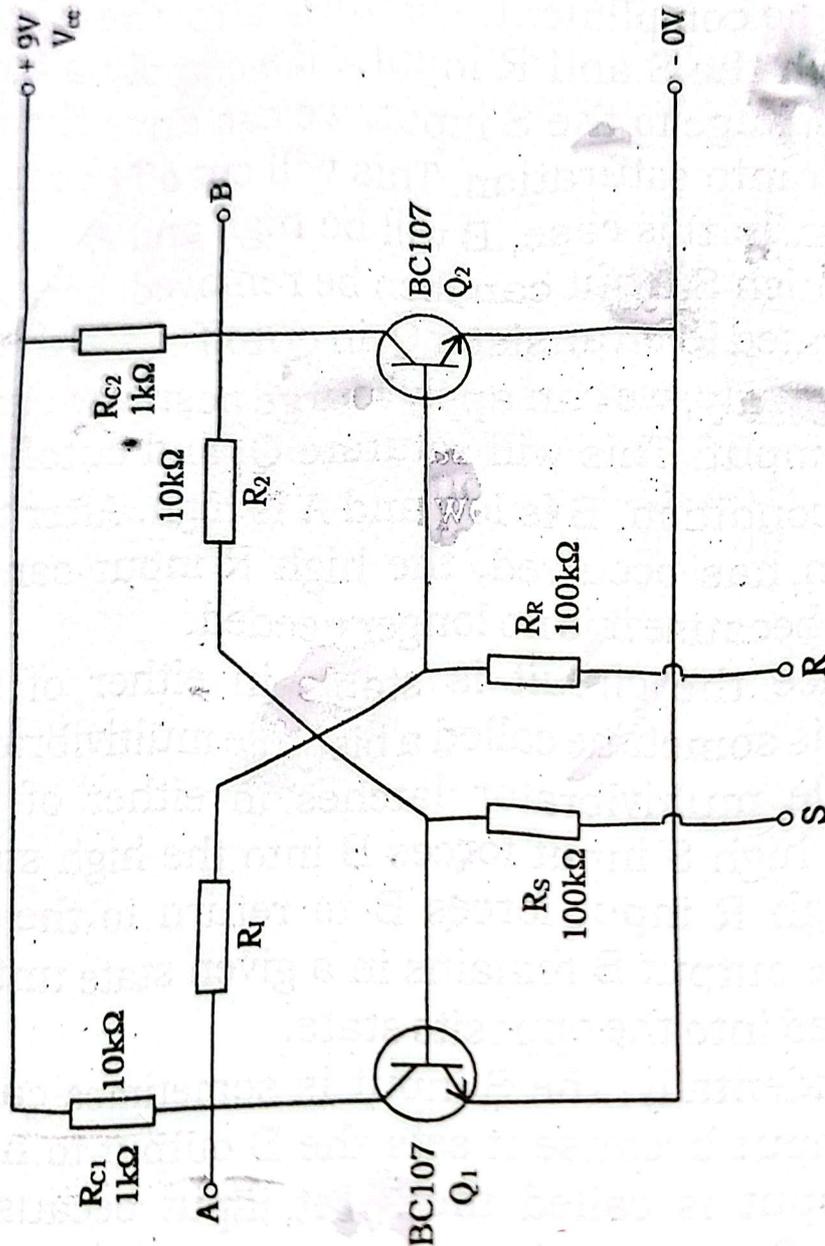
Incidentally, the S input is sometimes called the set input because it sets the B output to high. The R input is called the reset input because it resets the B output to low.

Component and Equipment

1. Resistors: $1\text{k}\Omega \times 2$, $10\text{k}\Omega \times 2$, $100\text{k}\Omega \times 2$
2. Transistors: BC107 $\times 2$
3. Power supply unit 9V

Method

Connect the circuit as shown in fig.6.2



6.2 Bistable Multivibrator

Connect S and R to the ground and measure the base voltage of Q_1 and Q_2 with respect to the ground. Also measure the output A and B with respect to V_{cc} and record your result.

Connect R to V_{cc} , while S is at the ground voltage. Measure the output voltages of A and B with a voltmeter and record your result.

Interchange R and S connection. (i.e. R to ground and S to V_{cc}) measure and record your result.

Connect both R and S to V_{cc} , measure and record your result.

Tabulate your result as shown in table 6.1

Input Voltage	Output voltage	
	A	B
$S = 0V$		
$S = V_{cc}$		
$R = 0V$		
$R = V_{cc}$		

EXPERIMENT 7

TOPIC:

Feedback Amplifier

AIMS:

- To investigate input and output impedance of negative feedback amplifier.
- To determine the frequency response of amplifier.

GENERAL THEORY

Feedback amplifier is the transferring of a fraction of amplifier output into the input circuit. This fraction of the output which is fed back to the input circuit helps to control the output. A feedback amplifier consists of an amplifier and a feedback circuit.

I. Positive Feedback:

Positive feedback occurs when the output voltage (or current) is applied to increase the input voltage (i.e. to be in phase with the input). Other names are: regenerative or direct feedback.

Since positive feedback produces excessive distortion, it is seldom used in amplifiers. However, it is used in oscillator circuits because it increases the power of the original signal.

Negative Feedback:

Negative feedback occurs when the output voltage (or current) is applied so as to reduce the amplifier input (i.e. output is 180° out of phase with input). Other names for it are: degenerative or inverse feedback.

For an amplifier without a feedback, the voltage gain (A_v) is given by the ratio of the output voltage (V_o) and input voltage (V_i).

$$A_v = V_o/V_i$$

This gain (A_v) is often called open-loop gain.

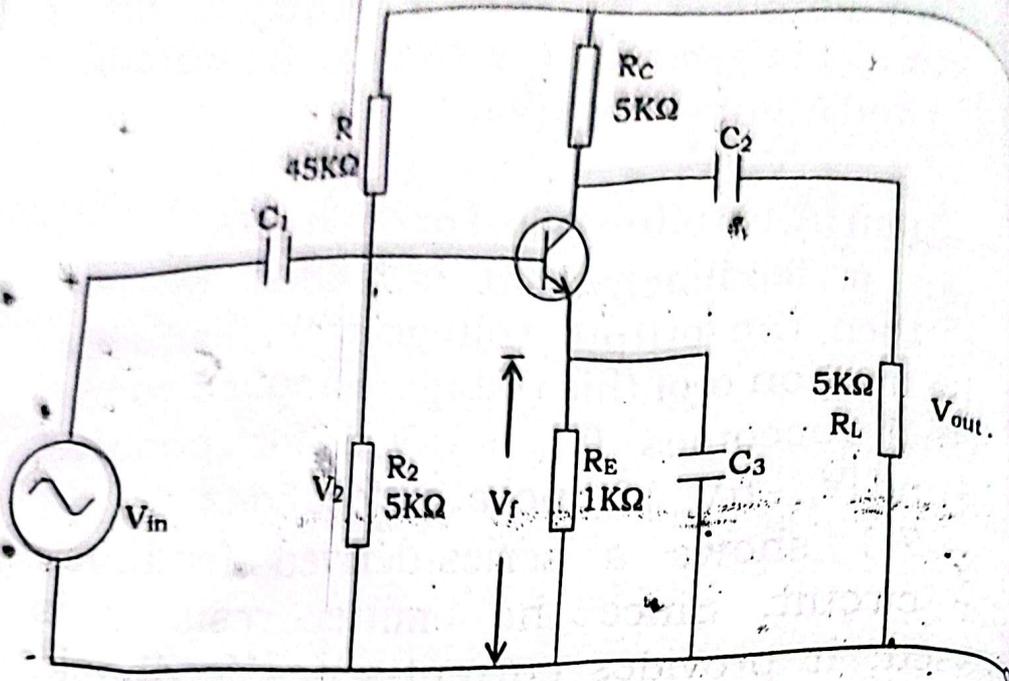
When a feedback loop is added to the amplifier, then the output voltage with feedback (V_{out}) and a fraction α of this voltage is applied to the input which becomes ($V_{in} + \alpha V_{out}$) for positive feedback and ($V_{in} - \alpha V_{out}$) for negative feedback.

Fig 7.1 shows a series-derived feedback amplifier circuit. Since the emitter resistor is unbypassed, it provides current-series feedback, when the emitter current (I_E) passes through the emitter resistor (R_E), the feedback voltage drop $V_f = I_E R_E$ is developed. This feedback voltage (V_f) is 180° out of phase with the input voltage (V_{in}) and it is being fed into the input. This negative feedback reduces the output voltage V_{out} .

This feedback can be eliminated by:

- i. Removing or short circuiting the emitter resistor (R_E)
- ii. Bypassing the emitter resistor R_E with a capacitor.

Note: α is used for feedback to differentiate with β which is the current gain of a transistor.



Feedback equation is given by:

1. Feedback (α) = R_E/R_C .
 2. Voltage gain without feedback (A_v) = $r_L/r_c = V_{out}/V_{in}$
 3. Voltage gain with feedback (A) = $r_L/r_c + R_E = V_{out}/V_{in}$
- Where $r_c = 25mV/I_E$
4. Feedback voltage drop (V_f) = $I_E R_E$
 5. Input impedance (Z_{in}) = V_{in}/i_b
 6. Output impedance (Z_{out}) = V_{out}/i_c
 7. Emitter current (I_E) = V_2/R_E
- Where β = the gain of the transistor
8. Feedback factor = αA_v
 9. Current gain (A_i) = $I_{out}/I_{in} = \beta$
 10. Output resistance (r_L) = $1/R_C + 1/R_L$
 11. Input resistance (r_{in}) = $1/R_1 + 1/R_2 + 1/\beta R_E$
 12. Base voltage (V_2) = $(R_2/R_2 + R_1) V_{cc}$
 13. Power gain (A_p) = $A_v \cdot A_i$

When the emitter bypass capacitor C_3 is removed to allow negative feedback, the formula become:

1. Input resistance (r_{in}) = $1/R_1 + 1/R_2 + 1/\beta(r_c + R_E)$
2. Voltage gain (A_v) = $r_1/(r_c + R_E)$

Frequency Response of an Amplifier: The frequency response of an amplifier is the graph of its gain versus the frequency.

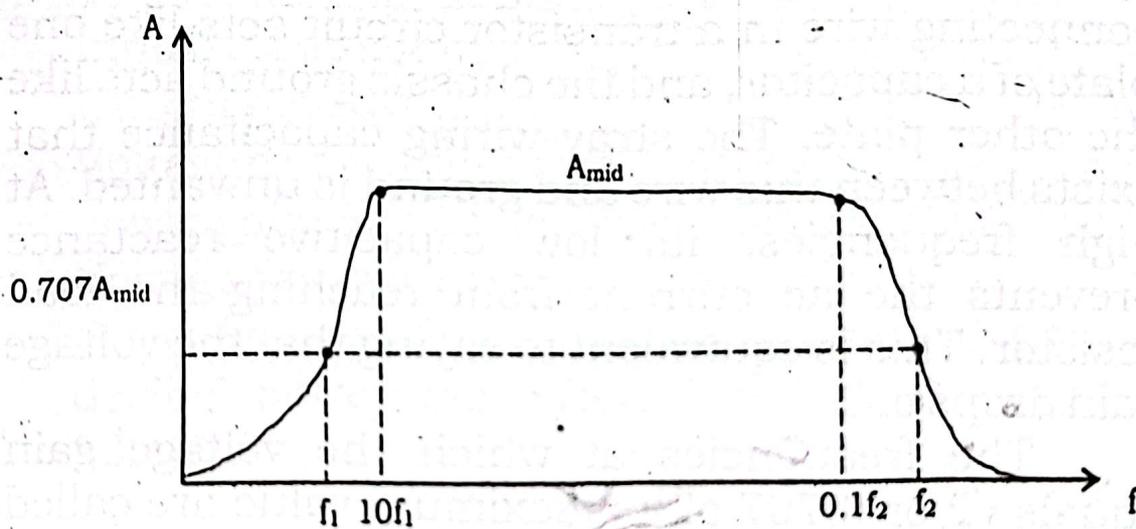


Fig 7.2: Frequency Response of an Amplifier

Fig 7.2 shows the frequency response of an ac amplifier. In the middle range of the frequencies, the voltage gain is at maximum. This middle range of frequencies is where the amplifier is normally operated. At low frequencies, the voltage gain decreases because the coupling and bypass capacitors no longer act like short circuits. Instead, their capacitive reactances are large enough to drop some of the ac signal voltage. The result is a loss of

voltage gain as we approach zero hertz (Hz).

At high frequencies, the voltage gain decreases for other reasons. A transistor has internal capacitances across its junctions, these capacitances provide bypass paths for the ac signal. As the frequency increases, the capacitive reactances become low enough to prevent normal transistor action. This results to a loss of voltage gain.

Stray-wiring capacitance is another reason for a loss of voltage gain at high frequencies. Any connecting wire in a transistor circuit acts like one plate of a capacitor, and the chassis ground acts like the other plate. The stray-wiring capacitance that exists between this wire and ground is unwanted. At high frequencies, its low capacitive reactance prevents the ac current from reaching the load resistor. This is equivalent to saying that the voltage gain drops off.

The frequencies at which the voltage gain equals $\sqrt{2}$ or 0.707 of its maximum value are called the cutoff frequencies.

Midband of an amplifier is the band of frequencies between $10f_1$ and $0.1f_2$.

Advantages of Negative Feedback

Although a negative feedback has disadvantage of reduced gain, there are numerous advantages which are:

1. Higher fidelity i.e. more linear operation.
2. Highly stabilized gain.
3. Increased bandwidth i.e. improved frequency response.

4. Less amplitude distortion.
5. Less harmonic distortion.
6. Less frequencies distortion.
7. Less phase distortion.
8. Reduced noise.
9. Input and output impedances can be modified as desired.

Few Calculated Examples

For the single-stage common emitter amplifier of fig 7.1, find the approximate value of:

1. Input resistance (r_{in}).
2. Output resistance (r_L).
3. Voltage gain without feedback (A_V)
4. Power gain (A_p) and decibel power gain (G_p)
5. Voltage gain with negative feedback (A)
5. Power gain with negative feedback (A_p) and decibel power gain. Take $\beta = 100$ and $r_e = 50\text{mV}/I_E$

Solution:

$$\begin{aligned} \text{Voltage drop across the base } (V_2) &= (R_2/R_2 + R_1) V_{cc} \\ &= (5\text{K}/5\text{K} + 45\text{K}) \times 20\text{V} = 2\text{V} \\ &= V_2/R_E = 2\text{V}/1\text{K}\Omega = 2\text{mA} \\ &= 50\text{mV}/I_E = 50\text{mV}/2\text{mA} = 25\Omega \end{aligned}$$

$$\begin{aligned} \text{Signal input resistance } (r_{in(\text{base})}) &= \beta r_e \\ &= 100 \times 25\Omega = 2.5\text{K}\Omega \end{aligned}$$

$$\begin{aligned} \text{Stage input resistance } (r_{in}) &= 1/R_1 + 1/R_2 + 1/r_{in(\text{base})} \\ &= 1/45\text{K} + 1/5\text{K} + 1/2.5\text{K} = 1.6\text{K}\Omega \end{aligned}$$

$$\begin{aligned} \text{Output resistance } (r_L) &= 1/R_c + 1/R_L = 1/5\text{K} + 1/5\text{K} \\ &= 2.5\text{K}\Omega \end{aligned}$$

$$3. A_v = r_i / r_e = 2.5K / 25\Omega = 100$$

$$4. A_p = A_v \cdot A_i = 100 \times 100 = 10,000$$

$$5. G_p = 10 \log_{10}^{10,000} = 4 \times 10 \times 1 = 40 \text{dB}$$

Note: R_E is not applicable in the calculation above because it was ac grounded by the bypass capacitor C_3 .

Now, when C_3 is removed from R_E , this allows negative feedback which reduces the gain of the amplifier.

Solution:

$$6. \text{ Stage input resistance } (r_{in}) = 1/R_1 + 1/R_2 + 1/\beta(r_e + R_E) \\ = 1/45K + 1/5K + 1/100(25 + 1K)$$

Since r_e and R_E are two small as compared we may decide to ignore them. Therefore

$$r_{in} \approx 1/45K + 1/5K + 1/100 = 5K\Omega$$

$$7. \text{ Output resistance } (r_L) = 1/R_C + 1/R_L = 1/5K + 1/2.5K \\ = 2.5K\Omega \quad \text{----- as before}$$

$$8. A_v = r_L / r_e + R_E \sim r_L / R_E = 2.5K / 1K = 2.5$$

$$9. A_p = A_v \cdot A_i = 2.5 \times 100 = 250$$

$$10. G_p = 10 \log_{10}^{250} = 24 \text{dB}$$

Component and Equipment

1. Resistors: $1K\Omega \times 2$, $5.6K\Omega$, $10K\Omega$, $56K\Omega$
2. Capacitors: $22\mu f \times 2$, $100\mu f$
3. Audio signal generator
4. Dual traced oscilloscope
5. Transistor BC 107
6. Power supply 10V

Method:

Connect the circuit as shown in fig 7.3 and disconnect C_3 from the circuit.

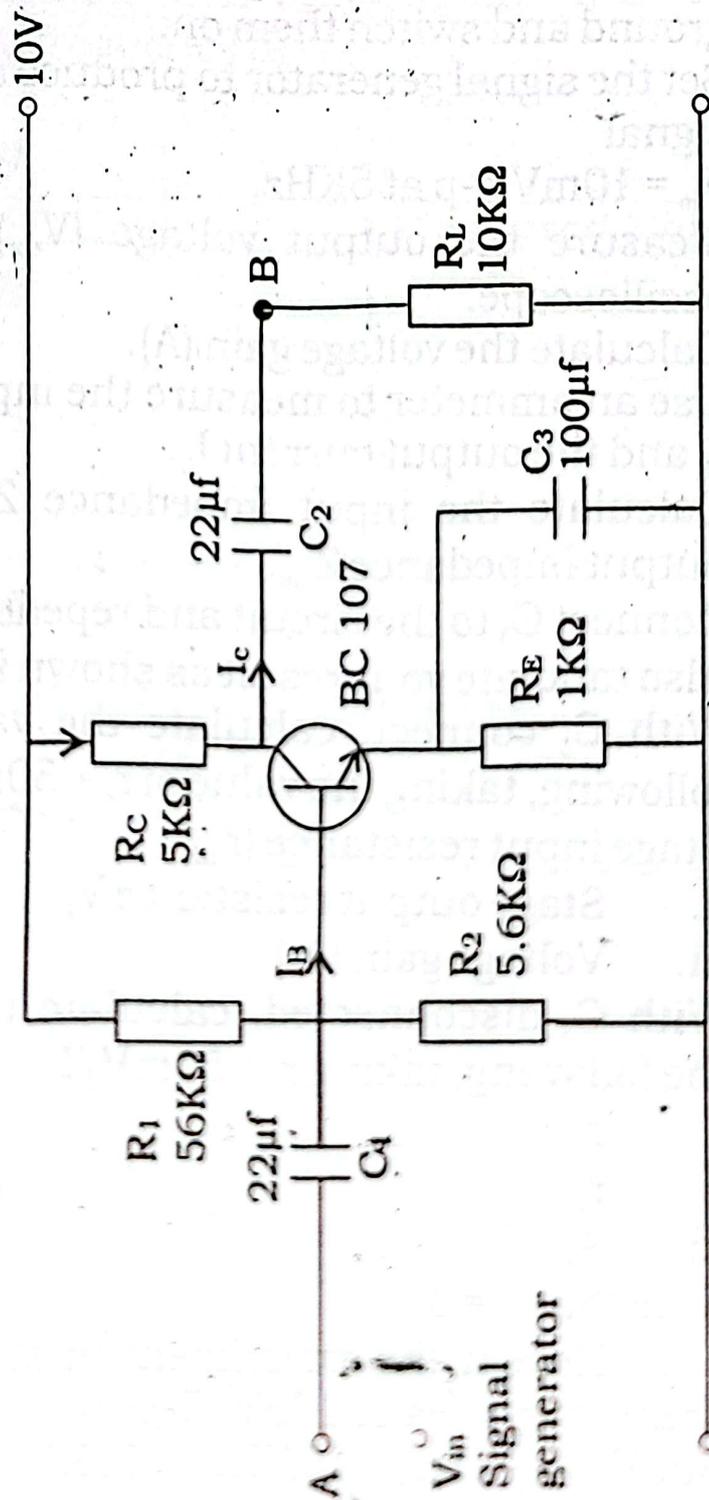


Fig 7.3

1. Power on the circuit.
 2. Connect the signal generator to point A respect to ground and also connect traced oscilloscope to point B with respect to ground and switch them on.
 3. Set the signal generator to produce a sine wave signal
 $V_{in} = 10\text{mV p-p}$ at 5KHz.
 4. Measure the output voltage (V_{out}) from oscilloscope.
 5. Calculate the voltage gain (A).
 6. Use an ammeter to measure the input current I_B and the output current I_C .
 7. Calculate the input impedance Z_{in} and output impedance Z_{out} .
 8. Connect C_3 to the circuit and repeat step 3 to 7. Also tabulate your result as shown in table 7.
 9. With C_3 connect, calculate the value of the following, taking the value of $r_c = 50\text{mV}/I_E$
 - i. Stage input resistance (r_{in})
 - ii. Stage output resistance V_L
 - iii. Voltage gain (A_v)
 10. With C_3 disconnected, calculate the value of the following, taking $r_c = 50\text{mV}/I_E$
 - i. r_{in}
 - ii. r_L
 - iii. A_v
- Note that $I_C = \beta I_B$
11. Repeat the experiment in step 3 to 4 at the frequencies of 10Hz, 50Hz, 100Hz, 300Hz, 500Hz, 1KHz, 10KHz, 50KHz, 100KHz, 500KHz and 1MHz.

Result Analysis

- Use the data in table 7.2 to plot the frequency response curve of voltage gain (A) in decibel against frequency (f).

Table 7.1 (a)

Parameter	Measured Value
V _{in}	
V _{out}	
A	
I _{in}	
I _{out}	
Z _{in}	
Z _{out}	

Table 7.1 (b)

Parameter with C ₃ Connected	Measured Value
r _{in}	
r _L	
A _v	
C ₃ Opened	
r _{in}	
r _L	
A _v	

Table 7.2

Frequency (f)	10 Hz	50 Hz	100 Hz	300 Hz	500 Hz	1K Hz	10K Hz	100K Hz	500K Hz	1M Hz
V _{in} (mV)										
V _{out} (mV)										
Gain(A _v) $= \frac{V_{out}}{V_{in}}$										
A = $20 \log_{10} A_v$										

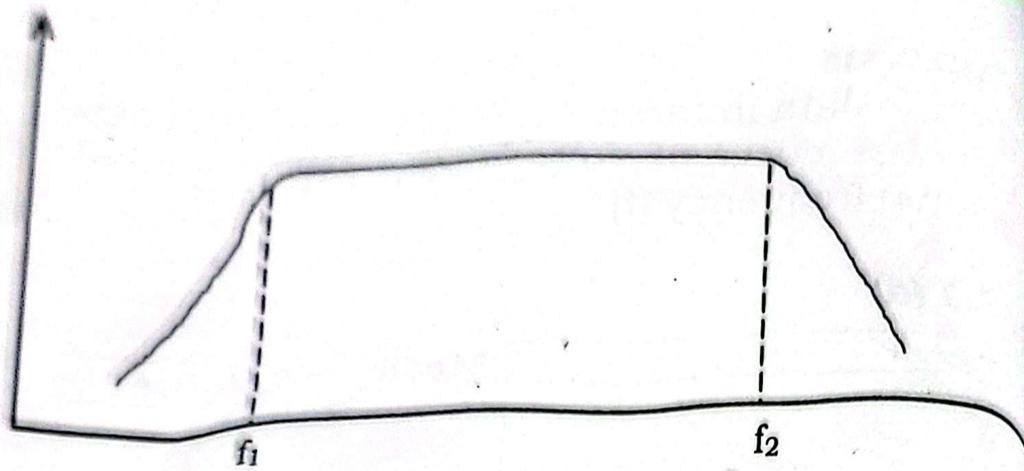


Fig 7.4

EXPERIMENT 8

TOPIC: Class A Transistor Power Amplifier

AIMS:

- To verify the efficiency of class A transistor power amplifier.
- To determine the voltage and the power gain of class A transistor amplifier.

GENERAL THEORY

The circuit in fig 8.1 shows a single-stage common emitter amplifier using an NPN transistor. The driving element is the base. The input signal is injected into the base-emitter circuit whereas the output signal is taken out from the collector-emitter circuit. The Q-point or working condition is determined by V_{cc} together with R_B and R_C .

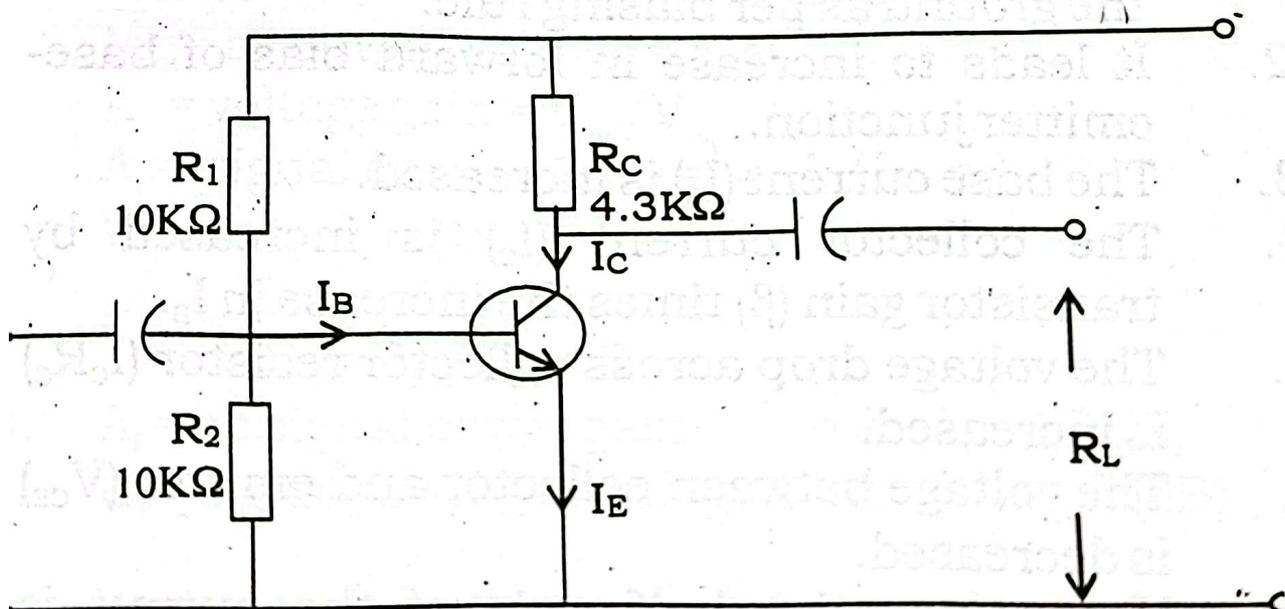


Fig 8.1

The dc equation is:

$$I_B = \frac{V_{BB}}{R_B} \quad \text{neglecting } V_{BE}$$

where $R_B = R_1/R_1 + R_2$

$$I_C = \beta I_B$$
$$V_{CE} = V_{CC} - I_C \cdot R_C$$

Where β = transistor gain
 V_{BB} = Base voltage
 V_{CE} = Voltage between collector and emitter
 V_{BE} = Voltage between base and emitter resistor of the transistor

The ac Input Signal

When an ac signal is applied at the input terminal circuit during positive half-cycle, the following conditions are obtained:

1. The base-emitter voltage (V_{BE}) is increased because it is already positive with respect to the ground as per biasing rule.
2. It leads to increase in forward bias of base-emitter junction.
3. The base current (I_B) is increased.
4. The collector current (I_C) is increased transistor gain (β) times the increase in I_B .
5. The voltage drop across collector resistor ($I_C R_C$) is increased.
The voltage between collector and emitter (V_{CE}) is decreased.

Hence, negative half-cycle of the output is obtained. It means that a positive-going input signal gives a negative-going output signal. So

Useful formulae are:

$$1. \quad r_e = \text{ac emitter diode resistance} = 25\text{mV}/I_E$$

$$I_E = V_{BE}/R_E$$

$$V_{BE} = V_{BB} - 0.7\text{V}$$

$$V_{BB} = V_{CC}/2$$

Where V_{BE} = Base-Emitter Voltage

V_{BB} = Base Supply Voltage

V_{CC} = Collector Supply Voltage

0.7V = Knee voltage for silicon transistor.

r_L = External ac emitter (output signal) resistance or output impedance (Z_o) = $1/R_E + 1/R_L$

A = Voltage gain = $r_L / (r_L + r_e)$

$Z_{in}(\text{base})$ = base input impedance = $\beta(r_L + r_e)$

Where β = transistor gain

$Z_i(\text{stage})$ = stage input impedance or input signal resistance = $1/R_{B1} + 1/R_{B2} + \beta(r_L + r_e)$

V_{in} = ac input voltage = $Z_{in} \cdot V_{ac}$

Where V_{ac} = input signal voltage

V_{out} = ac output voltage = $A \cdot V_{in}$

A_v = voltage gain = V_{out}/V_{in}

A_i = signal current gain = $I_C/I_B = \beta$

Where $I_C = \beta \cdot I_B$,

$I_B = V_{BE}/R_B$ and

$R_B = R_{B1}/R_{B1} + R_{B2}$

2. A_p = ac signal power gain = $A_v \cdot A_i = \beta \cdot Z_o/Z_i$

1. G_p = signal power gain in logarithm = $10 \log_{10}^{AP}(\text{dB})$

Characteristics of a Common-emitter (CE) Amplifier

A common-emitter (CE) transistor amplifier

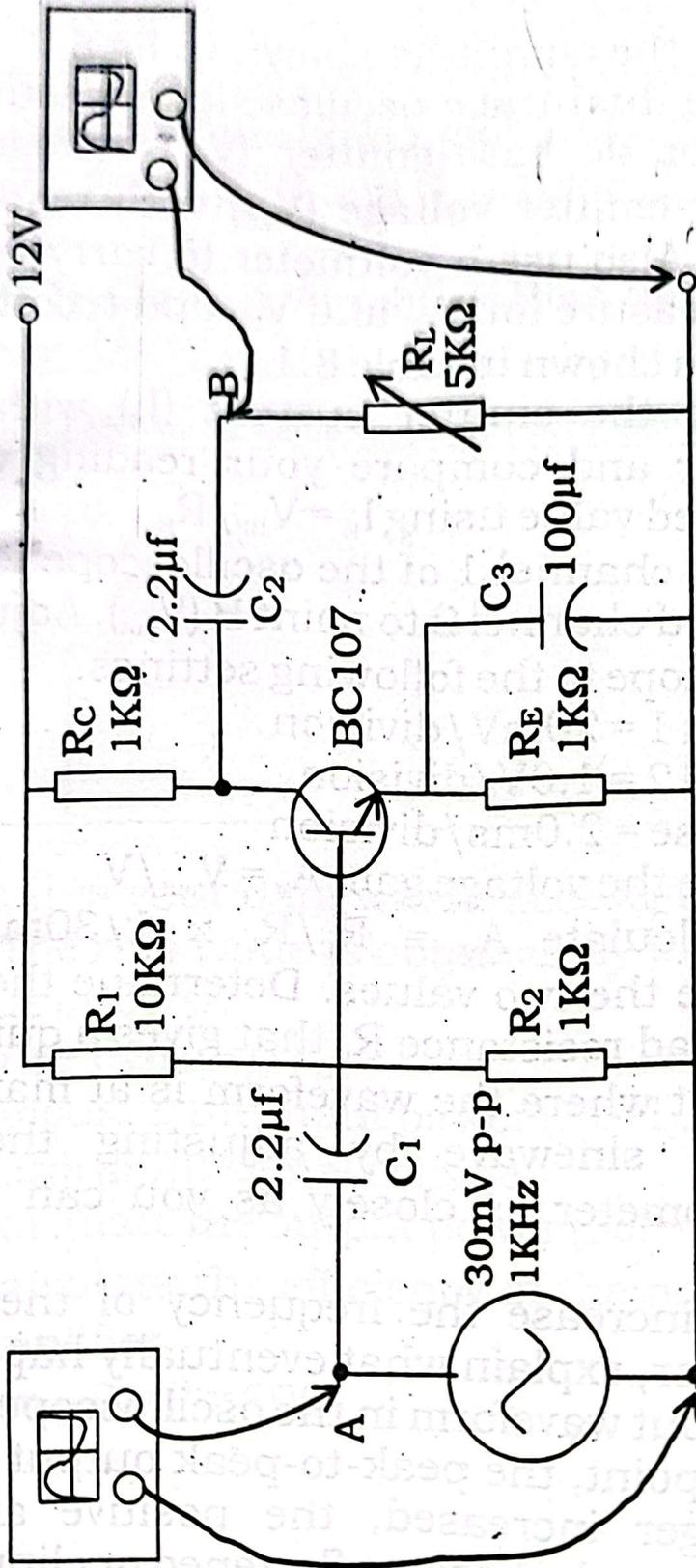
has the following characteristics:

1. It has moderately low input resistance (Z_i)
2. Its output resistance is moderately large (Z_o)
3. Its current gain (β) is high.
4. It has very high voltage gain (A_v)
5. It produces very high power gain (A_p)
6. It produces phase reversal of input signal i.e. input output signals are 180° out of phase with each other.

Component and Equipment

1. Resistors: $1K\Omega$ x 3, $10K\Omega$, $5K\Omega$
2. Capacitors: $2.2\mu f$ x 2, $100\mu f$
3. Audio signal generator
4. Dual traced oscilloscope
5. Transistor BC 107
6. Power supply 12V

ethod



8.2

- 1.
2. Connect the circuit as shown in fig 8.2. With the dual-trace oscilloscope measure transistor dc base-emitter (V_{BE}) voltage collector-emitter voltage (V_{CE}) with respect to ground. Also use a voltmeter to carry out the same measure for V_{BE} and V_{CE} and record your values as shown in table 8.1
3. Measure the emitter current (I_E) with an ammeter and compare your reading with the calculated value using $I_E = V_{BE}/R_E$
4. Connect channel 1 of the oscilloscope to point A (V_{in}) and channel 2 to point B (V_{out}). Adjust the oscilloscope to the following settings.
 Channel 1 = 20mV/division
 Channel 2 = 1.0V/division
 Time base = 2.0ms/division
5. Measure the voltage gain $A_v = V_{out}/V_{in}$. Also calculate $A_v = R_C/R_L \times 1/30mV$ and compare the two values. Determine the value of the load resistance R_L that gives a quiescent (Q) point where the waveform is at maximum uniform sinewave by adjusting the potentiometer as closely as you can to the value.
6. Slowly increase the frequency of the signal generator, explain what eventually happens to the output waveform in the oscilloscope? After a point, the peak-to-peak output voltage no longer increased, the positive and negative peaks become flattened or clipped. Measure the base current (I_B). also calculate the base current (I_B) using $I_B = V_{BE}/R_B$.

8. Measure the collector current I_C and by calculation, find $I_C = \beta \cdot I_B$ where $\beta = 50$.
9. Determine the current gain (A_i) and $A_i = I_C/I_B$.
10. Determine the power gain (A_p) and calculate $A_p = A_v \cdot A_i$ or $\beta \cdot Z_o/Z_i$ and $G_p = 10 \log_{10} A_p$ (dB).

Table 8.1: Class A Amplifier Bias Parameters and Efficiency

Parameter	Measured Value	Calculated Value	Error
V_{BE}			
V_{CE}			
I_E			
I_B			
I_C			
A_v			
A_i			
A_p			
G_p			

Full in your data where necessary in the table above. The rms value is obtained by multiplying the p-p value by 0.707

$$\% \eta = P_o (\text{rms}) / P_{DC} \times 100$$

11. Calculate the input power (P_i) = $I_C \cdot V_{BE}$ where V_{BE} is the input signal voltage

12. Calculate the output power (P_o) = $I_C \cdot V_{CE}$.

13. Calculate the efficiency of the power (η) of the amplifier

$$\% \eta = P_o / P_i \times 100$$

EXPERIMENT 9

TOPIC:

Push Pull Power Amplifier

OBJECTIVE:

To determine of the efficiency of the class B Push Pull Power Amplifier

GENERAL THEORY

Class B operation means that, the collector current flows for only 180° of the ac cycle. For each half cycle, the Q point is located at cutoff on both the load line and the ac load lines. The advantages of class B amplifier are the lower current drain and the higher stage efficiency.

Fig 9.1 shows one way to connect a class B push pull emitter follower. Here, we have an NPN emitter follower and a PNP emitter follower connected in a push-pull arrangement.

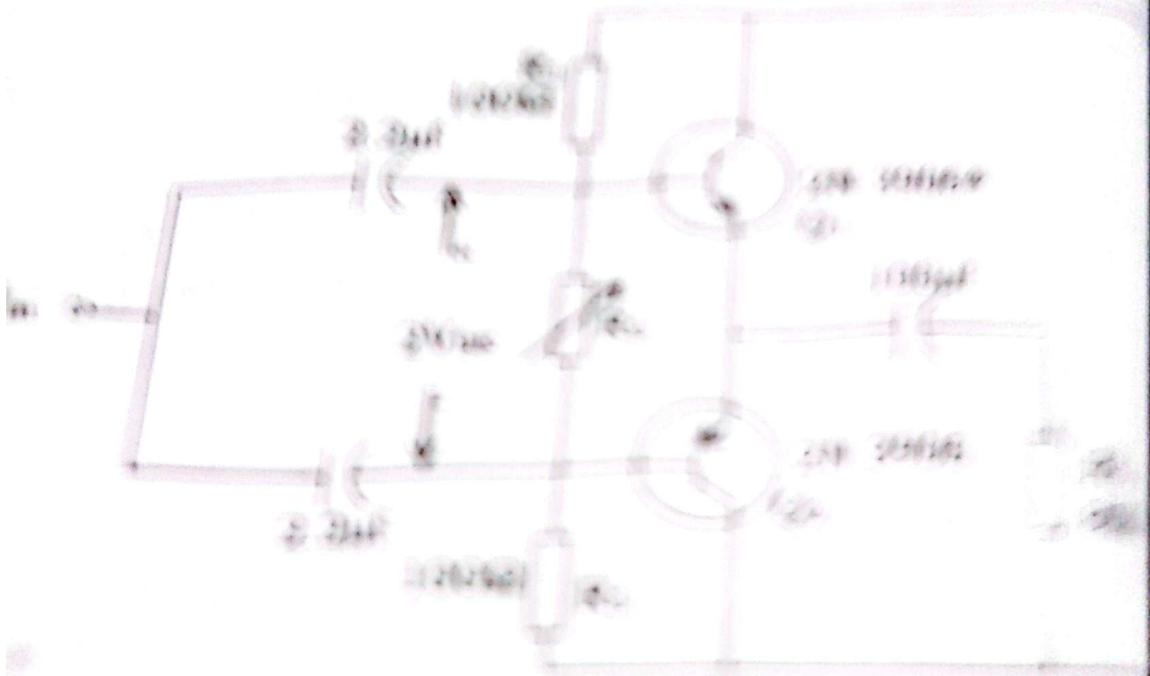


Fig 9.1 Class B Push-Pull Emitter Follower

The designer selects biasing resistors to set the Q point at cutoff. This biases the emitter diode of each transistor between 0.6 and 0.7V, so that it is on the verge of conduction.

$$I_{CQ} = 0$$

Because the biasing resistors are equal, each emitter diode is biased with the same value of voltage. As a result, half the supply voltage is dropped across each transistor's collector-emitter terminals. That is:

$$V_{CEQ} = V_{CC}/2$$

DC Load Line

Since there is no dc resistance in the collector or emitter circuit, the dc saturation current is infinite. This means that the dc load line is vertical, as shown in fig 9.2.

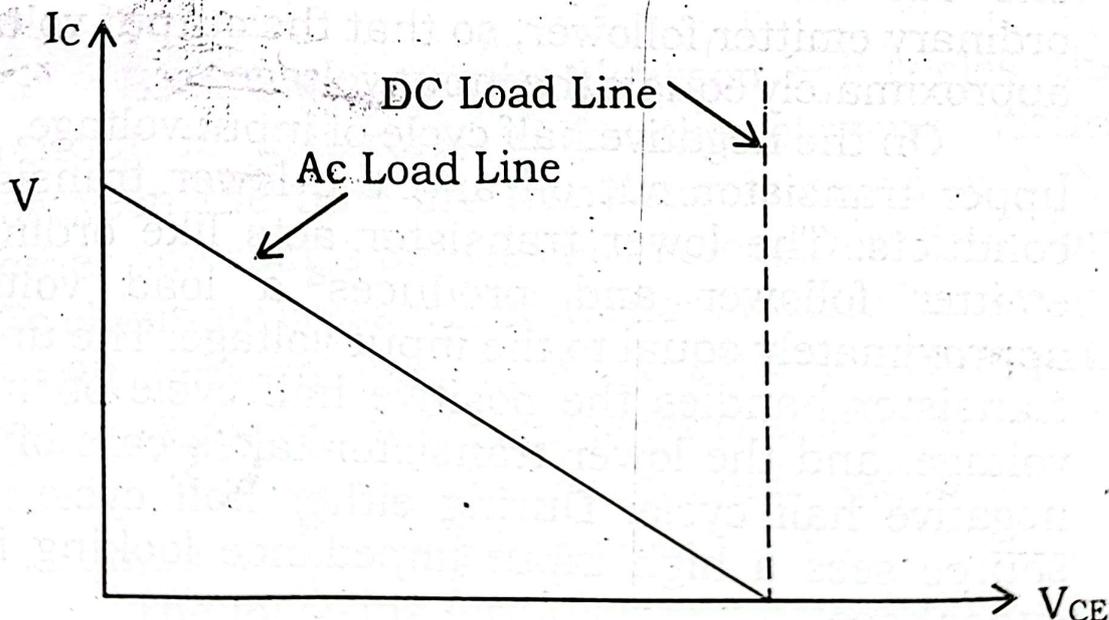


Fig 9.2: DC and ac Load Line

If you think that this is a dangerous
you are right. The most difficult thing
designing a class B amplifier is setting up a
point at cutoff. Any significant decrease in
temperature can move the Q point up the dc load
to dangerously high currents.

AC Load Line

Fig 9.2 shows the ac load line. When the
transistor is conducting, its operating point
moves up along the ac line. The voltage swing of the
conducting transistor can go all the way from cutoff
to saturation. On the alternate half cycle, the
transistor does the same thing. This means the
maximum peak-to-peak output is:

$$MPP = V_{CC}$$

Overall Action

On the positive half cycle of input voltage,
the upper transistor of fig 9.1 conducts and the
lower one cuts off. The upper transistor acts like an
ordinary emitter follower, so that the output voltage is
approximately equal to the input voltage.

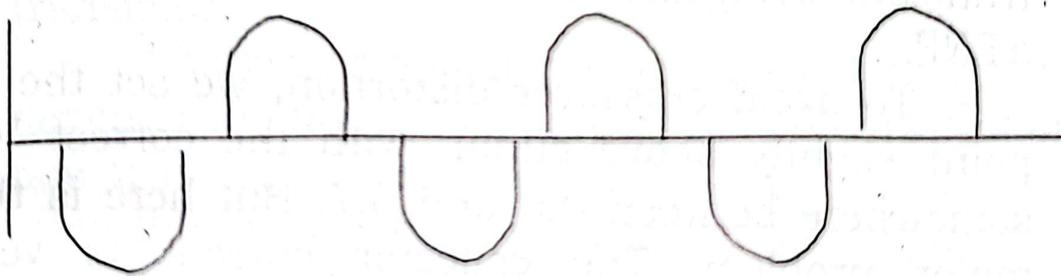
On the negative half cycle of input voltage,
the upper transistor cuts off and the lower transistor
conducts. The lower transistor acts like an ordinary
emitter follower and produces a load voltage
approximately equal to the input voltage. The
upper transistor handles the positive half cycle of
input voltage, and the lower transistor takes care of
the negative half cycle. During either half cycle,
the source sees a high input impedance looking
into either base.

Crossover Distortion

Suppose that no bias is applied to the emitter diode, then the incoming ac voltage has to rise to about 0.7V to crossover the barrier potential of the emitter diode. Because of this, no current flows through Q_1 when the signal is less than 0.7V.

The action is similar on the other half cycle. No current flows through Q_2 until the ac input voltage is more negative than -0.7V. For this reason, if no bias is applied to the emitter diodes, the output of a class B push-pull emitter follower looks like that of fig 9.3.

Fig 9.3: Crossover Distortion of Unbiasing Class B Push-Pull Amplifier



Because of clipping between half cycles, the output is distorted. Since the clipping occurs between the time are transistor is cutoff and the other one comes on, we call it crossover distortion. To eliminate crossover distortion, we need to apply a slight forward bias to each emitter diode. This means locating the Q point slightly above cutoff. As a guide, an I_{CQ} from 1 to 5 percent of I_c (sat) is enough to eliminate crossover distortion.

The following formulae apply to all classes of

operation of class B push pull amplifier.

1. Power gain (G) = P_{out} / P_{in}
2. Ac output power (P_{out}) = $V_{out}^2 / 8R_L$
3. Maximum ac output power (P_{MPP}) = $MPP^2 / 8R_L$
4. DC input power (P_{dc}) = $V_{CC} \cdot I_{dc}$
5. Efficiency (η) = $P_{out} / P_{dc} \times 100\%$

Voltage Divider Bias

Fig 9.1 shows voltage-divider bias for a push-pull circuit. The two transistors are complementary, that is, they must have similar characteristics, maximum ratings, and so forth. One transistor being an NPN transistor and the other a PNP.

To avoid crossover distortion, we set the Q-point slightly above cutoff, with the collector current somewhere between 0.6 and 0.7. But here is a major problem. The collector current is very sensitive to changes in V_{BE} .

Data sheets for 2N3904 and 2N3906 show that an increase of 60mV in V_{BE} produces as much collector current because of this sensitivity. An adjustable resistor is needed to set the Q-point.

But an adjustable resistor does not solve the temperature problem. Even though the Q-point is perfect at room temperature, it will change as the temperature changes. V_{BE} decreases approximately by 2mV per degree rise. As temperature increases, the fixed voltage

emitter diode forces the collector current to increase rapidly.

If the temperature increases by 30° , the collector current increases by a factor of 10 because the fixed bias is 60mV which is too high. Therefore, the Q point is very unstable with voltage-divider bias.

The ultimate danger is thermal runaway when the temperature increases, the collector current increases. As the collector current increases, the junction temperature increases even more, further reducing the correct value of V_{BE} . This escalating situation means that the collector current may "run away" by rising until excessive power destroys the transistor.

Whether or not thermal runaway takes place depends on the thermal properties of the transistor, how it is cooled, and type of heat sink used. More often than not, voltage-divider bias like fig 3.1 will produce thermal runaway which may destroy the transistors.

Diode Bias

One way to avoid thermal runaway is to connect resistor with diode bias as shown in fig 9.4. The idea is to use compensation diode to produce the bias voltage for the emitter diode. For this scheme to work, the diode curves must match the V_{BE} curves of the transistors. Then, any increase in temperature reduces the bias voltage developed by the compensating diodes by just the right amount.

For instance, assume that a bias voltage of

0.65V is used to set up 2mA of collector current. When the temperature rises up to 30°C, the voltage across each compensating diode drops 60mV. Since the required V_{BE} also decreases by 60mV, collector current remains fixed at 2mA.

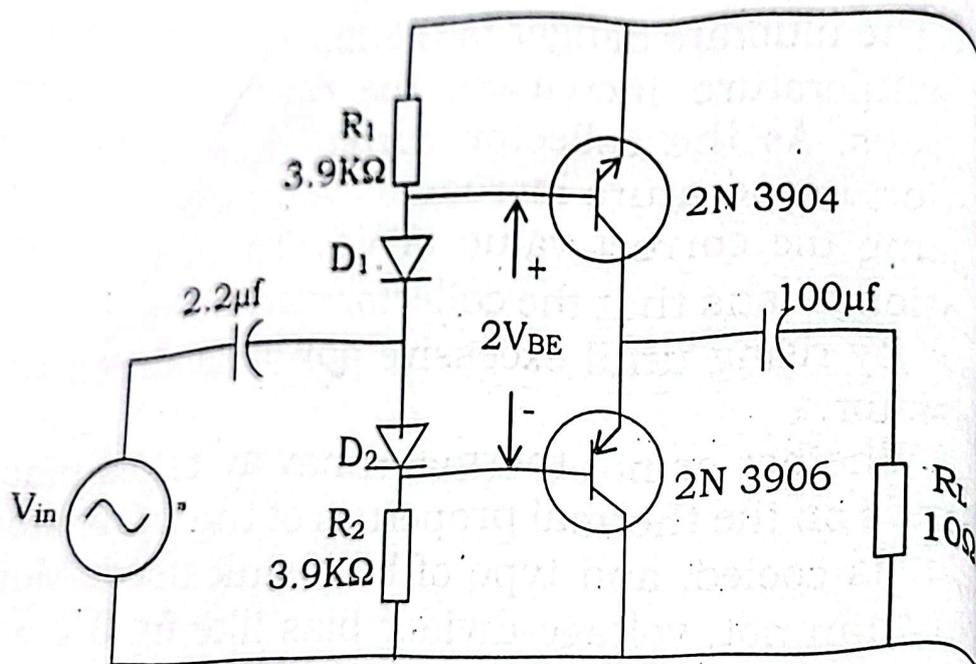


Fig 9.4 Diode Bias of Class B Push-Pull Amplifier

For diode bias to be immune to change in temperature, the diode curves must match the transistor curves over a wide temperature range. This is easily done with discrete circuit because of the close tolerance of components.

With diode bias, the bias current through each compensating diode is

$$I_{bias} = \frac{V_{CC} - 2V_{BE}}{2R}$$

When the compensation diodes match the

curves of the transistor, I_{CQ} has the same value as $I_{C(sat)}$. I_{CQ} should be between 1 and 5 percent of $I_{C(sat)}$ to avoid crossover distortion.

For the purpose of designing, let us make some calculations.

Examples of Calculation

1. The adjustable resistor of fig 9.1 sets both emitter diodes on the voltage of condition. What is the maximum transistor power dissipation and the maximum output power?

Solution

The maximum peak-to-peak output is:

$$MPP = V_{CC} = 20V$$

$$P_{D(max)} = MPP^2 / 40R_L$$

Where 40 is a constant for each transistor in all class B push-pull amplifier.

$$P_{D(max)} = 20V^2 / 40 \times 8\Omega = 1.25W$$

The maximum output power is:

$$P_{out(max)} = MPP^2 / 8R_L = (20V)^2 / 8 \times 8\Omega = 6.25W$$

2. If the adjustable resistor is adjusted to 15Ω, what is the efficiency in the preceding example?

Solution 2:

The dc current through the biasing resistors is:

$$I_{bias} = 20V / (100 + 15 + 100)\Omega$$

$$= 20V / 215\Omega = 0.093A$$

Saturation current $I_{CC(sat)}$ is the dc current through the upper transistor. The collector-emitter voltage (V_{CEQ}) of the upper

transistor = 10V

$$\therefore I_{C(sat)} = V_{CEQ} / K_L = 100V / 8\Omega = 1.25A$$

The collector current in the conducting transistor is a half-wave signal with a peak of

$I_{C(sat)}$. therefore, it has an average value of:

$$I_{av} = I_{C(sat)} / \pi = 1.25 / \pi = 0.398A$$

The total current drain is:

$$I_{dc} = 0.093A + 0.398A = 0.491A$$

The dc input power is:

$$P_{dc} = V_{CC} \cdot I_{dc} = 20V \times 0.491A = 9.82W$$

The efficiency of the stage is:

$$\eta = P_{out} / P_{dc} \times 100\% = 6.25W / 9.82W \times 100\% = 63.6\%$$

What is the quiescent collector current and the maximum efficiency of the amplifier in fig 9.4.

Solution

The bias current through the compensating diodes is:

$$I_{bias} = V_{CC} - 2V_{BE} / 2R = 20V - 1.4V / 2 \times 3.9K\Omega$$

$$\text{Where } 2V_{BE} = 2 \times 0.7V = 1.4V$$

$$\therefore I_{bias} = 2.38mA$$

If the compensating diodes match the emitter diodes, 2.38mA is the value of the quiescent collector current.

The collector saturation current is:

$$I_{C(sat)} = V_{CEQ} / R_L = 10V / 10\Omega = 1A$$

The average value of the half-wave collector current is:

$$I_{av} = I_{C(sat)}/\pi = 1A/\pi = 0.318A$$

The total current drain is:

$$I_{dc} = I_{bias} + I_{av}$$

$$= 2.38mA + 0.318A = 0.32A$$

The dc input power is:

$$P_{dc} = V_{cc} \cdot I_{dc} = 20 \times 0.32 = 6.4W$$

The maximum ac output power is:

$$P_{out(max)} = MPP^2 / 8R_L = (20V)^2 / 8 \times 10\Omega = 5W$$

The efficiency of the stage is:

$$\eta = P_{out} / P_{dc} \times 100\% = 5W / 6.4W \times 100\% = 78.1\%$$

Component and Equipment

Resistor $10K\Omega \times 2$, $3.9K\Omega \times 2$, $100\Omega \times 2$, 8Ω , 10Ω

$1K\Omega$

Potentiometer $5K\Omega$

Capacitor (25V) $2.2\mu f \times 2$ and $100\mu f$

Diodes IN 4001 $\times 2$

NPN silicon transistor 2N 3904

PNP silicon transistor 2N 3906

power supply 0-20V

meter, ammeter

signal generator

1 trace oscilloscope

breadboard and connecting wires.

Method

Construct the circuit as shown in fig 9.5(a) set the potentiometer to $2K\Omega$.

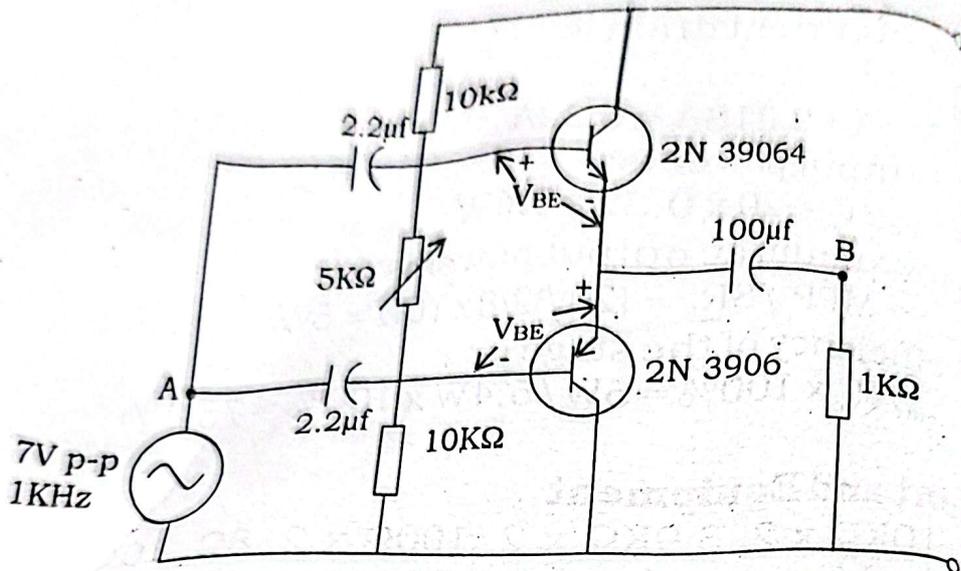
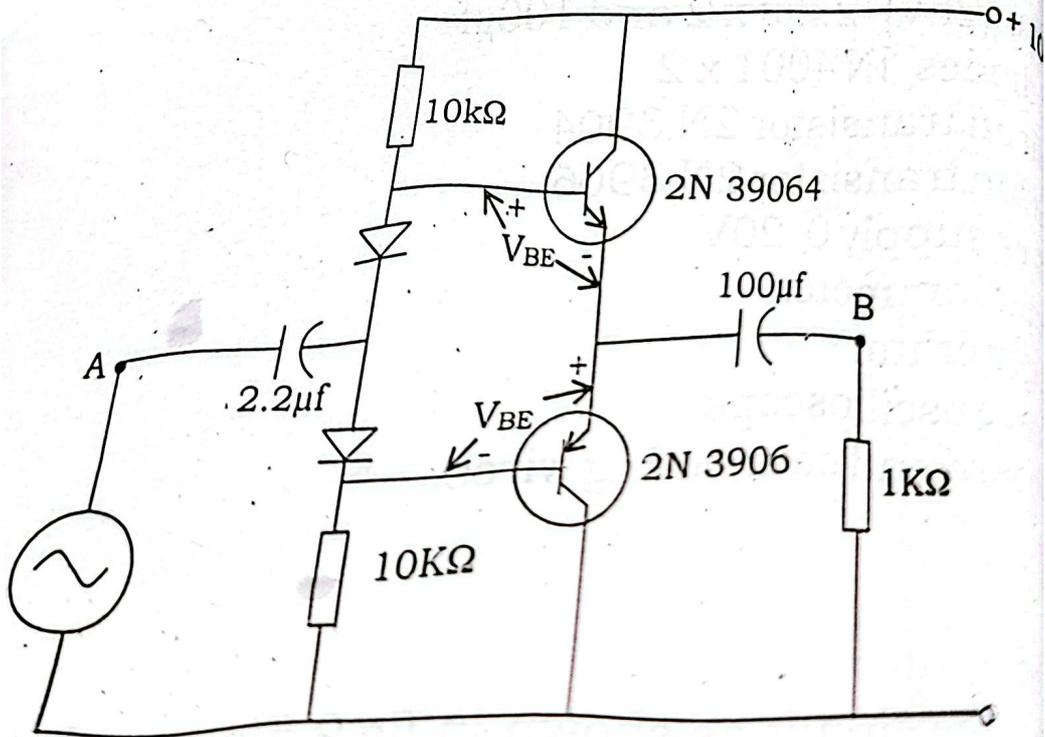


Fig 9.5(a) Class B Push-Pull Emitter Follower



v) Diode Bias of Class B Push-Pull Amplifier

Apply 10V to the circuit and use the Oscilloscope to measure the following

transistor voltages with respect to ground: (i) dc base 1 (V_{B1}), (ii) base 2 (V_{B2}) and (iii) emitter voltage (V_E). Record your results as shown in table 9.1. Also measure the base-emitter voltage (V_{BE}). Is the value different from 0.7V?

Connect channel 1 of the oscilloscope to point A (V_{in}) and channel 2 to point B (V_{out}). Adjust channel 1 and 2 of the scope to 1V/division and time base to 0.2ms/division.

Adjust the sine wave output from the signal generator to 7V peak-to-peak at a frequency of 1KHz. (i) Sketch the output waveform from the oscilloscope when the input signal voltage is zero. Note that the output waveform should be distorted within the vicinity of zero volts. This condition is referred to as crossover distortion, resulted from the base-emitter diode of both transistors being not forward bias until the input signal exceeds approximately 0.7V in both direction. (ii) Sketch the output signal voltage when the input signal is 7V peak-to-peak.

With the signal generator set to 7V peak-to-peak at 1KHz, carefully adjust the potentiometer so that the crossover distortion just appears. Notice that the output voltage vary nearly equals the input, so the voltage gain is essentially equal to one. As in number 1, using the oscilloscope, measure the transistor dc base 1, base 2 and emitter voltage with respect to ground, record your results as shown in table 9.2.

5. Replace the potentiometer with two silicon diodes as shown in fig 9.5(b). With the generator set to 7V peak-to-peak at 1kHz, sketch the output voltage and compare to the waveform of number 3.
You should find that there is virtually no crossover distortion. The voltage required for forward bias both transistors is now supplied by the voltage drops of the two silicon diodes which are also forward biased.
6. With the oscilloscope, measure the transient dc base 1, base 2 and emitter voltages with respect to ground and record your results as shown in table 9.3.
7. Carefully increase the peak-to-peak input signal so that the output peaks just clip. With the voltmeter measure the rms voltage across the $1k\Omega$ load capacitor (V_{CEQ}), and compute the rms output power of the amplifier ($P_{out(max)}$).
8. In order to measure the dc power supplied to the amplifier, use the ammeter to measure the dc collector current [$I_c(dc)$] of either transistor. Compute the dc power supplied and record your result.
Calculate the efficiency ($\eta\%$) of the amplifier and compare it with the theoretical maximum of 75.3% of the class B amplifier. Record your result as shown in table 9.4.

Result Analysis:

Parameter	Measured Value	Expected Value	% Error
1			
2			
E1			
E2			

Table 9.1 Voltage Divider Bias With Crossover Distortion

Parameter	Measured Value
V_{B1}	
V_{B2}	
V_E	

Table 9.2 Voltage Divider Bias With No Crossover Distortion

Parameter	Measured Value
V_{B1}	
V_{B2}	
V_E	

Table 9.3 Diode Bias With No Crossover Distortion

Parameter	Measured Value
V_{CEQ} (dc)	
$V_{out(max)}$ I_c	Calculated Value

Table 9.4 Class B Amplifier Efficiency

Questions:

1. What is crossover distortion? How can it be eliminated?
2. Draw the complete circuit diagram in fig 9.4.
3. From your diagram, determine by calculation:
 - (a) What is the quiescent collector current in the circuit drawn in fig 9.5(b)?
 - (b) Calculate the maximum efficiency of the amplifier?

1. Tabulate your result as shown in table 9.5

Parameter	Value
I_{bias}	
$I_{C(sat)}$	
I_{av}	
I_{dc}	
P_{dc}	
$P_{out(max)}$	
η	

Table 9.5

EXPERIMENT 10

TOPIC: The Study of Field Effect Transistor (FET)

OBJECTIVE:

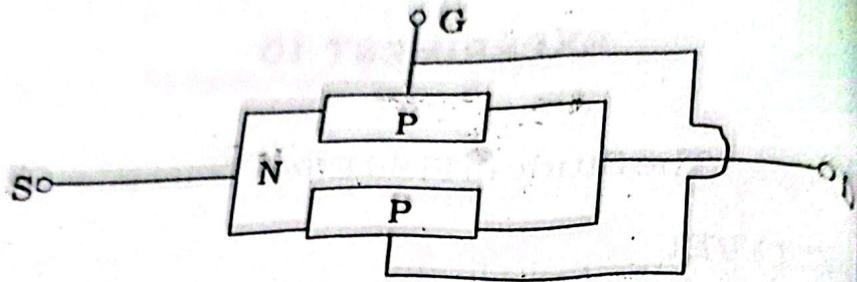
- To understand the operation of JFET.
- To investigate the static output (drain) characteristics of junction field effect transistor (JFET) in the common-source configuration.
- To investigate the transfer characteristics of JFET.
- To display output characteristics curves on the oscilloscope.

GENERAL THEORY

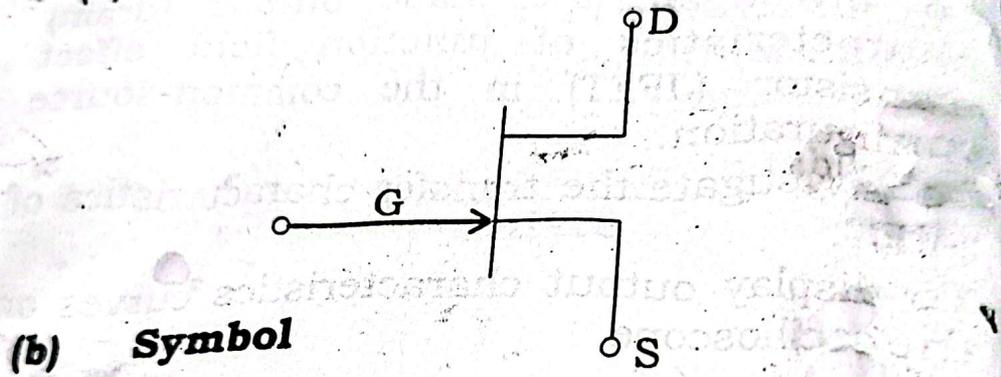
The field effect transistor (FET) is a three terminal device. The terminals are called Drain, Source and Gate, corresponding to the collector, Emitter and Base of a bipolar transistor respectively.

A JFET (Junction FET) is made up of an N or P silicon bar called channel (of N or P type, respectively) on which two materials are obtained which are electrically interconnected, but of different kind of material against the channel.

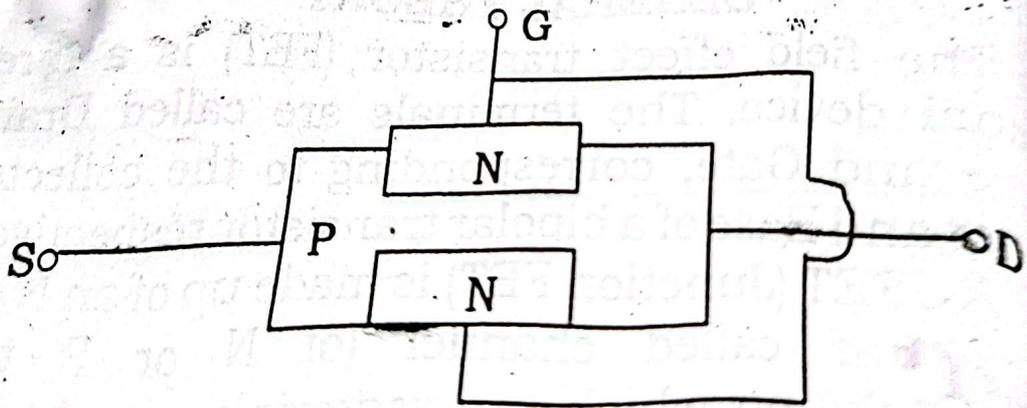
One material forms the Gate, while the other material forms the Drain and the Source respectively as shown in Fig 10.1



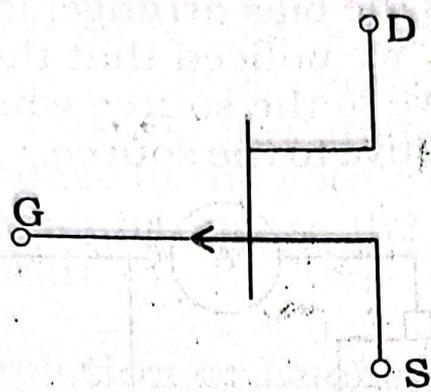
(a) **N Type Construction**



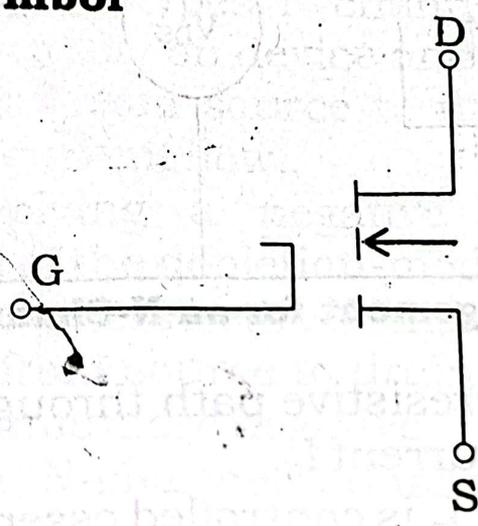
(b) **Symbol**



(c) **P-Type Construction**



(d) Symbol



(e) Enhancement-Mode N-Channel IGFET
Fig 10.1 N-Type and P-Type JFET

Unlike the bipolar transistor, the FET is, voltage controlled device. But when a reverse voltage is applied to the gate-source junction, the channel becomes tighter and therefore, the conduction through the source-drain channel is reduced. As the gate reverse voltage is increased more and more, the device will reach where the source-drain channel voltage V_{DS} is blocked. In this condition the channel is said to be cut-off.

Fig 10.2 shows the bias arrangement for an N-channel JFET. Here, we noticed that the gate is reverse-biased relative to the source while the drain is forward-biased relative to the source.

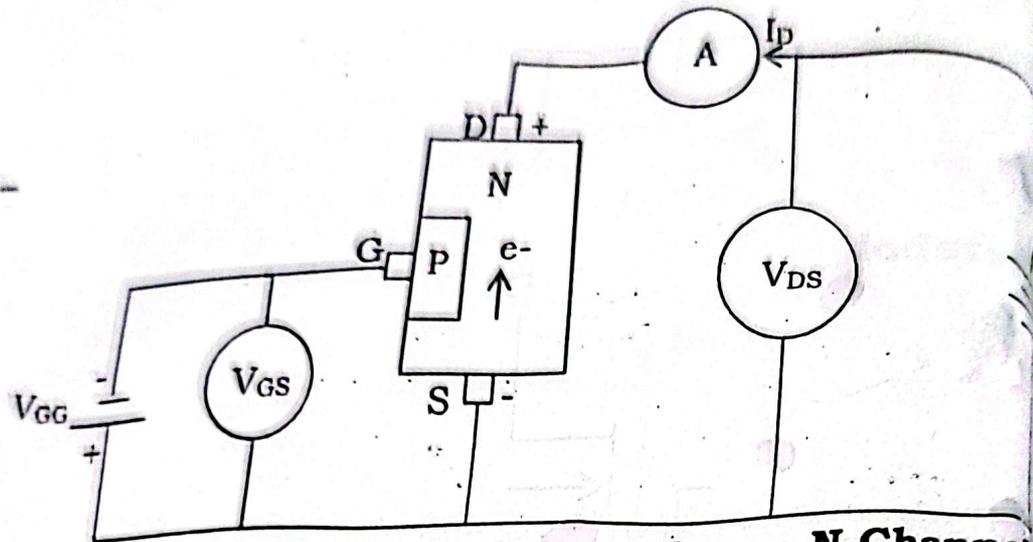


Fig 10.2 The Bias Arrangement for an N-Channel

The channel is a resistive path through which a voltage V_{DS} can drive a current I_D .

The drain current I_D is controlled essentially by varying a reverse-biased voltage V_{GS} . Inverting a negative value of V_{GS} has the effect of widening the depletion region in the channel.

Function of the Gate

Input signal is generally applied to the gate with amplified output from the gate and channel. Like two plates of capacitor. A charge of one plate on the gate induces an equal and opposite charge on the channel. As a result, the conductivity of the channel can be increased or decreased by the

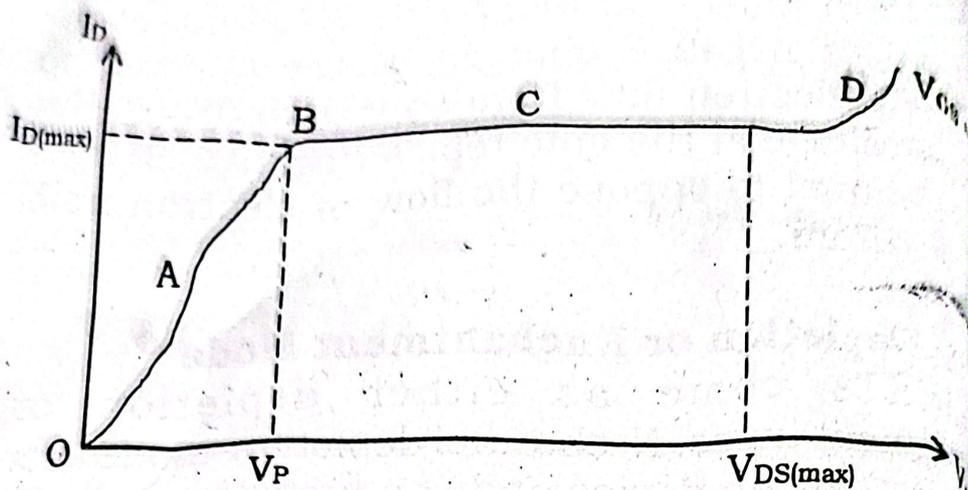
voltage. With an N-channel, positive voltage at the gate induces negative charges in the channel to allow more electron flow from source to drain. But negative voltage at the gate repels negative charges in the channel to oppose the flow of electron from source to drain.

Depletion or Enhancement Mode

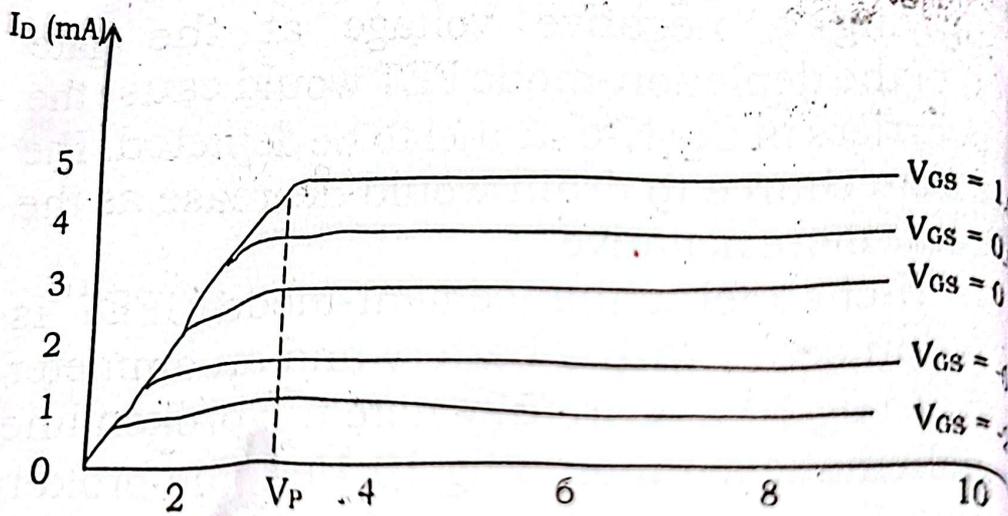
JFETs come as either depletion or enhancement types. N-channel depletion-mode acts like a normally on device and conducts through the channel from source to drain. The ammeter (A) shows a current flow.

Applying a negative voltage at the gate terminal of the depletion-mode FET would cause the current carriers in the N-channel to be depleted. The current from source to drain would decrease as the gate become more negative.

An N-channel enhancement-mode JFET is connected in series with a battery and an ammeter shown in fig 10.2. Carefully note the broken line in the schematic symbol in fig 10.1(e). The broken channel line suggests that, the N-channel is normally open for the enhancement-mode. With the gate connected as shown in fig 10.1, no current flows from source to drain. When a positive voltage is applied to the gate, current carriers are enhanced in the N-channel. More current carriers in the N-channel causes reduced resistance, which produces the current flow. An increase positive voltage at gate causes a proportional increase in current from source to drain of the N-channel enhancement-



(a) Output (drain) Characteristics of JFET When $V_{GS} = 0$



(b) Output (drain) Characteristics Curves of Channel JFET

10.3 Output Characteristics Curves of JFET

As shown in fig 10.3(a), the pinch-off voltage is the voltage value at which I_D no longer increases with increased V_{DS} , probably until $V_{DS(max)}$ is reached. Fig 10.3(b) shows the family of

characteristics for different values at a constant value of V_{GS} .

Each output (drain) characteristics can readily be subdivided into four regions, as indicated in fig 10.3a. These regions are:

The resistive region, where V_{DS} less than V_P (region A).

Onset of pinch-off, where V_{DS} is equal to V_P (region B).

Pinch-off region, where V_{DS} is greater than V_P (region C).

Breakdown region, (region D).

From the characteristic curves, it is possible to determine the following parameters of JFET:

Drain (output) resistance $R_D = \Delta V_{DS} / \Delta I_D$ (Ω) for a fixed $V_{GS} = \text{constant}$ (1)

Voltage gain, $\Delta V = \Delta V_{DS} / \Delta V_{GS}$ for a fixed $I_D = \text{constant}$ (2)

Mutual conductance, $g_m = \Delta I_D / \Delta V_{GS}$ for a fixed $V_{DS} = \text{constant}$.

Note that g_m can be determined directly from the transfer characteristic shown in fig 10.3.

The transfer characteristic is a plot of I_D versus V_{GS} for a constant value of V_{DS} .

Alternatively, we can select a value of V_{DS} (e.g. = +6V) on the drain characteristics in fig 10.3(b) then draw a line vertically upward to intercept drain characteristic curve.

Transconductance or mutual conductance is the slope of transfer characteristic.

$g_m = \text{change in } I_D / \text{change in } V_{GS}$ (S) for V_{DS} constant.

Its unit is Siemens (S) called the mathematical expression for g_m . The equation is $I_D = I_{DSS} (-V_{GS}/V_P)^2$, because of the square-law term in the equation, JFETs are referred to as square-law devices.

Component and Equipment

R_1 = Linear potentiometer $3K\Omega$

R_2 = Linear potentiometer $10K\Omega$

T_1 = N-channel JFET 2N 2319 or 2N 5484

D_1 = Diode IN 4001

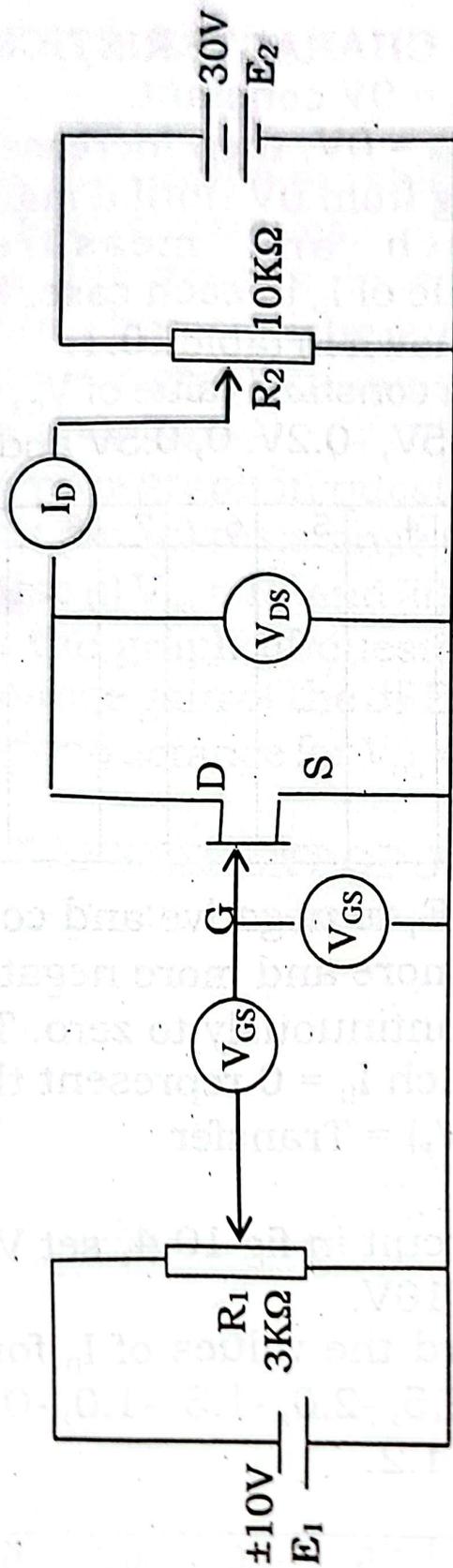
I_G and I_D = DC ammeter (0 10) mA and (0 20) mA

V_{GS} and V_{DS} = DC voltmeter (-10V 0 + 10V) and (0 10V)

e = Sinusoidal generator, 10V, 50 Hz
oscilloscope.

Procedure

Connect the circuit as shown in fig 10.4



1.4

DRAIN (OUTPUT) CHARACTERISTICS

Vary R_1 to give $V_{GS} = 0V$ constant.

Adjust R_2 to set $V_{DS} = 0V$, then increase step of $1V$, starting from $0V$ until a maximum of $10V$ is reached and measure corresponding value of I_D in each case. Record your readings as shown in table 10.1.

Repeat step (ii) for a constant value of $V_{GS} = 12V, -1V, -0.7V, -0.5V, -0.2V, 0, 0.5V$ and

		0	1	2	3	4	5	6	7	8	9
10V	I_D										
9V	I_D										
8V	I_D										
7V	I_D										
6V	I_D										
5V	I_D										
4V	I_D										
3V	I_D										
2V	I_D										
1V	I_D										
0V	I_D										

At $V_{DS} = 5V$, vary E_1 to negative and continue to make V_{GS} to be more and more negative until I_D would decrease continuously to zero. The value of V_{GS} for which $I_D = 0$ represent the pinch-off voltage (V_P) = Transfer characteristic

In the same circuit in fig 10.4, set V_{DS} at constant voltage of $10V$.

Measure and record the values of I_D for each $V_{GS} = 0V, -2.5, -2.0, -1.5, -1.0, -0.5$ and $0V$ in table 1.2.

5	-2.0	-1.5	-1.0	-0.5	0

le 10.2

tions

Using the results in table 10.1, plot the drain characteristic curves.

Using the results in table 10.2, plot the transfer characteristic curve.

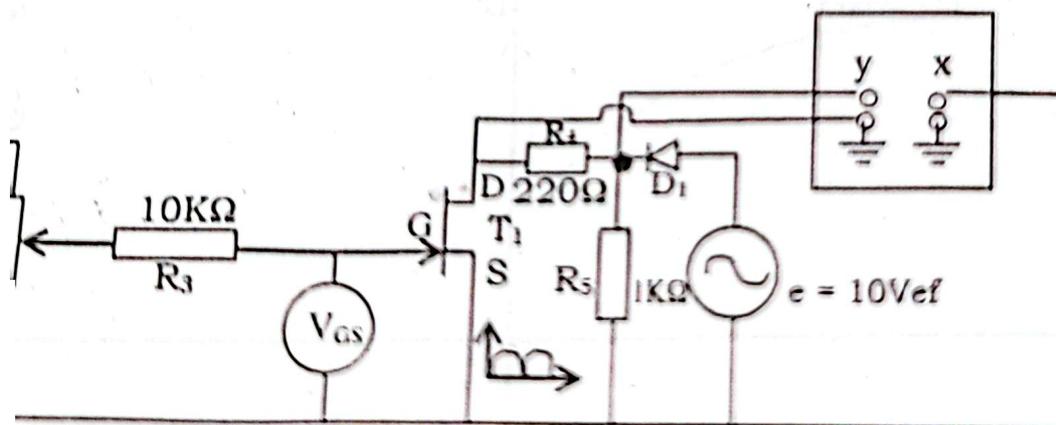
From your graph in question 2, estimate the value of V_p , I_{DSS} .

From your graph in question 1, determine the output (drain) resistance (R_D), when $V_{GS} = 0.5V$ and also (i) $V_{DS} = 1V$ and (ii) $V_{DS} = 8V$.

From the graph of question (1), determine (i) the voltage gain of the JFET for $I_D = 2mA$ (ii) the transconductance for $V_{DS} = 4V$.

EXPERIMENT OF JFET

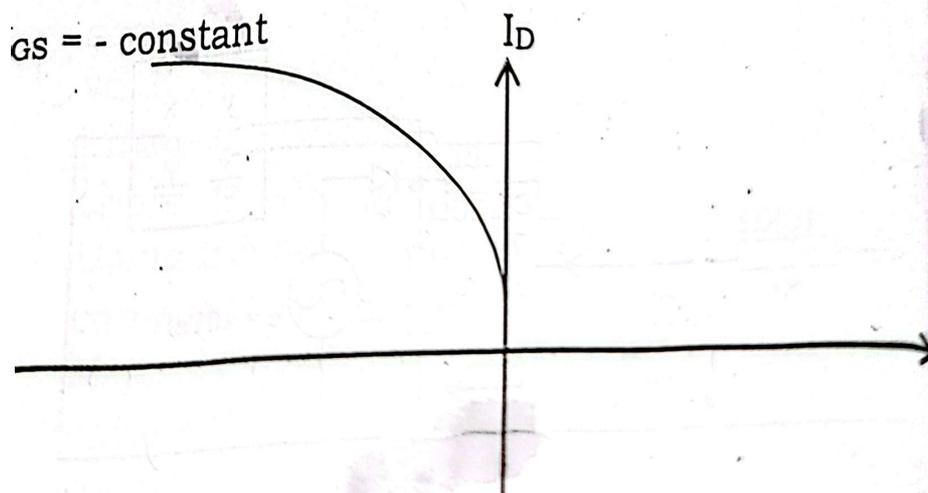
Use the circuit as shown in fig 10.5



The circuit allows to display one by one the output characteristics of the N-channel JFET on an oscilloscope.

The output circuit (Drain-Source) is supplied with a pulsating voltage due to the presence of a power supply unit e , the rectifier diode D_1 and a resistance R_5 . Across the R_5 , the pulsating voltage is available that makes the current I_D flow through the JFET.

The voltage V_{DS} is negative, the drain is connected to the ground of the oscilloscope. Therefore, on the x-axis of the oscilloscope the spot will move towards the left, on the other hand, the voltage across R_4 (proportional to I_D) is positive, therefore on the y-axis of the oscilloscope the spot will move upwards. In conclusion, therefore, the connection characteristic will be displayed in the second quadrant. See fig 10.6, instead of the first.



10.6 Output Characteristic of JFET Displayed on the Oscilloscope

Procedure

Set $e = 10V$, 50 or 60Hz and V_{GS} between 0V and -6V: the oscilloscope should display the output characteristic curve JFET associated to the selected V_{GS} . Given that the value of the voltage connected to the x and y axes, will display the characteristic in the second quarter instead of the first.

Measure the main points of the characteristic curve.

Set other values of V_{GS} (between 0 and -6V) to display other characteristics.

Make the suitable observation of the results obtained.

EXPERIMENT 11

TOPIC: LC Colpitts Oscillator

AIM:

- To investigate the condition for oscillation
- To measure the frequency and the amplitude of the signal of an LC Colpitts Oscillator

GENERAL THEORY

One way to produce high-frequency oscillations is with an LC oscillator, a circuit that can be used for frequencies between 1 and 500 MHz. The frequency range is beyond the f_{unity} of most op-amps, this is why a bipolar transistor or a FET is used for the amplifier. With an amplifier and feedback circuit, we can feedback a signal with the same amplitude and phase to sustain oscillations.

The analysis and design of high-frequency oscillators are difficult. This is because, at high frequencies, stray capacitances and inductances become very important in determining the oscillation frequency, feedback fraction, and other ac quantities. This is why it is possible to use computer to do the initial design as an approximation, before the construction and testing of the oscillator in order to observe its performance. Fig 11.1 shows the circuit of an LC Colpitts oscillator.

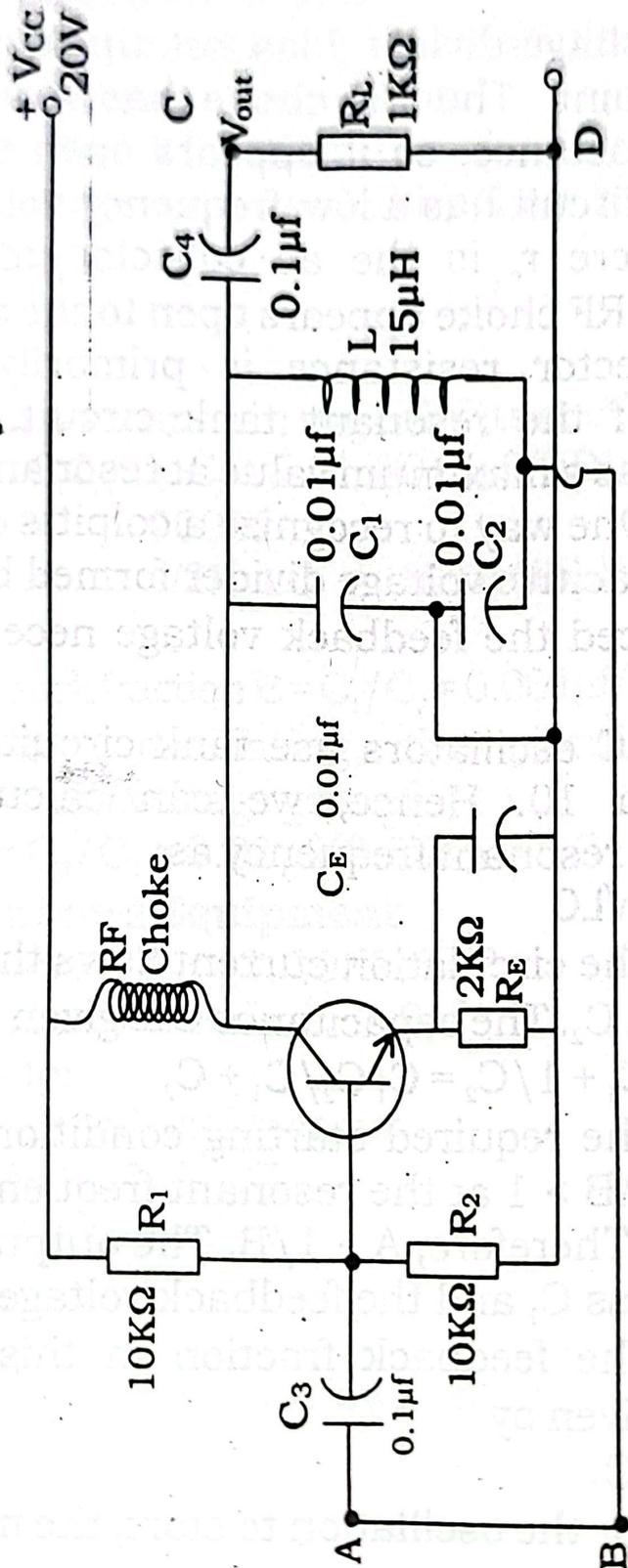


Fig 11.1

The voltage-divider bias set up a quiescent operating point. The RF choke has a very high inductive reactance, so it appears open to the signal. The circuit has a low-frequency voltage gain of r_c/r_e , where r_c is the ac collector resistance. Because the RF choke appears open to the ac signal, the ac collector resistance is primarily the resistance of the resonant tank circuit. This resistance has a maximum value at resonance.

1. One way to recognize a colpitts oscillator is by the capacitive voltage divider formed by C_1 and C_2 . It produced the feedback voltage necessary for oscillations.

Most LC oscillators use tank circuits with Q greater than 10. Hence, we can calculate approximate resonant frequency as:

$$f_r = 1/2\pi\sqrt{LC}$$

2. The circulation current flows through C_1 in series with C_2 . The capacitance C is given by

$$C = 1/C_1 + 1/C_2 = C_1 C_2 / C_1 + C_2$$

3. The required starting condition for an oscillator is $AB > 1$ at the resonant frequency of the tank circuit. Therefore, $A > 1/B$. The output voltage appears across C_1 and the feedback voltage appears across C_2 . The feedback fraction in this type of oscillator is given by

$$\beta = C_2/C_1$$

4. For the oscillation to start, the minimum voltage gain is:

$$A_{min} = C_1/C_2$$

Some Calculated Examples

1. Using the circuit in fig 11.1, calculate
 - i. The frequency of oscillation.
 - ii. The feedback fraction.
 - iii. The voltage gain needed by the circuit to start oscillating.

Solution

The capacitance in the colpitts oscillator is:

$$C = \frac{C_1 C_2}{C_1 + C_2} = \frac{(0.01\mu\text{f})(0.01\mu\text{f})}{0.01\mu\text{f} + 0.01\mu\text{f}}$$
$$= 909\text{Pf}$$

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(15\mu\text{H})(909\text{Pf})}} = 36\text{MHz}$$

- i. Feedback fraction $B = C_1/C_2 = 0.001\mu\text{f}/0.01\mu\text{f} = 0.1$
- ii. To start oscillating, the circuit needs a minimum voltage gain of
$$A_{\text{min}} = C_2/C_1 = 0.01\mu\text{f}/0.001\mu\text{f} = 10$$

Component and Equipment

Resistors: $1\text{K}\Omega \times 3$, $10\text{K}\Omega$, $5\text{K}\Omega$

Capacitors: $2.2\mu\text{f} \times 2$, $100\mu\text{f}$

Inductor

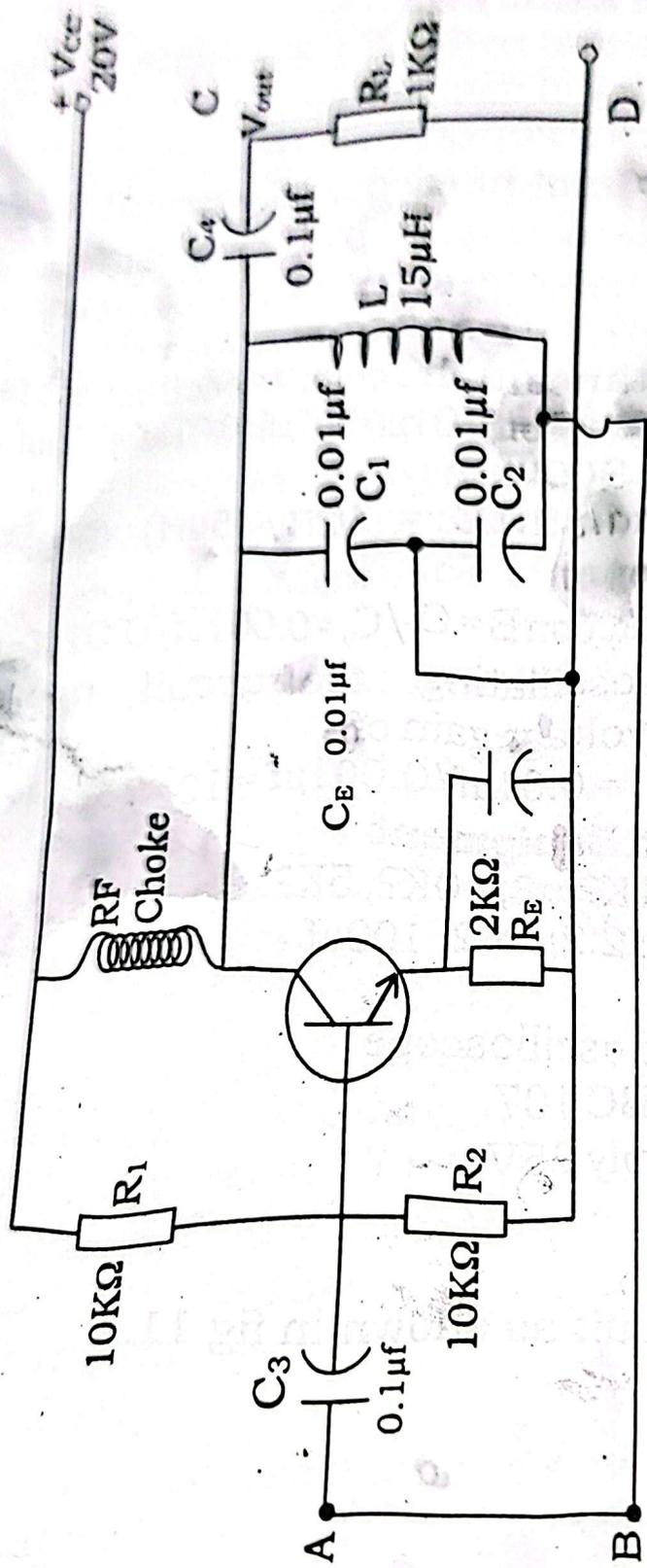
Dual traced oscilloscope

Transistor BC 107

Power supply 25V

Method:

Connect the circuit as shown in fig 11.2



1.2

Connect an oscilloscope with calibration up to 5MHz at point AB, measure the amplitude of the signal (A_i) and the frequency (f_i).

Connect an oscilloscope at point CD, measure the amplitude of the signal (A_i) and the frequency (f_o), then record your result.

Calculate for the value of the following; (i) f_o (ii) B (iii) A_{min} .

Tabulate your result as shown in table 11.1

Measured Value

A_i	
f_i	
A_o	
f_o	

Table 11.1 (a)

Calculated Value

f_o	
B	
A_{min}	

Table 11.1 (b)

Instructions: Answer T for True and F for False

A half wave rectifier makes use of two diodes in forward bias. _____

In a half wave rectifier, current is not blocked in a reverse direction. _____

3. The ripple factor of a rectifying voltage is same as the root mean square _____
4. A full wave rectifier can make use of two diodes _____
5. In a full wave rectifier, more than _____ capacitors can be used for _____
6. In a filter unit of a rectifier, an inductor can be used _____
7. Astable multivibrator is also called a flip-flop _____
8. The frequency of oscillation of a multivibrator can be increased by increasing the value of capacitor _____
9. What differentiates the monostable with bistable is the pulse trigger _____
10. A bistable multivibrator has no stable state on both sides _____
11. Diodes has no effect on a multivibrator _____
12. A negative feedback helps to increase the gain of an amplifier _____
13. An advantage of a negative feedback is that it increases the bandwidth _____
14. A negative feedback produces a reduction in distortion, _____
5. A positive feedback can also be called as regeneration _____
5. A positive feedback is used mostly in high fidelity signals. _____
- Positive feedback produces less harmonic distortion _____

. The output of a positive feedback amplifier is 180° out of phase with the input _____

. A positive feedback is best for oscillator circuits than an amplifier circuits _____

. An audio amplifier, responses better under a high frequency signal _____

. Q-point is also known as a working condition of amplifiers _____

. One of the characteristics of a common-emitter amplifier is that it has a low input resistance _____

. It produces a phase reversal of the input signal _____

. The Q-point of class B amplifiers is located at cut off on the load line _____

. The gate and the channel of a junction field effect transistor act like a two plates of a capacitor _____

. Pinch off voltage occurs in a field effect transistor when the voltage begins to conduct _____

. Pinch off voltage is also known as a break down voltage in FET _____

. The base of a tripolar transistor represent the gate of a FET _____

. A colpitt oscillator is not meant for a low frequency _____

. LC oscillators use tank circuits with Q greater less than 1 _____

SECTION B

TELECOMMUNICATION

EXPERIMENT 1

TOPIC: Low Frequency Generation

OBJECTIVE: To observe the waveform generated at a low frequency

GENERAL THEORY

In communication, audio frequencies fall within the low frequency range. Audio wave is made of sound which can be heard by human being. Sound from air current, animal, gun, thunder, and musical instrument have their range of frequency. Human voice has an audio frequency range of about 20 Hz.

When a sound enters into a microphone, the microphone converts it into electrical signal which is measurable by a measuring instrument. Microphone impedances fall within the values 30-50 Ω , 200 Ω , 1k Ω or 47k Ω . The suitability depends on the application. One of the determining factors is the microphone cable capacitance. Its reactance increases with cable length and increasing frequency. Therefore, long runs of cable impose a low value shunt across the output of the microphone which decreases further as the frequency rises. So to maintain the maximum high frequency response with long cables low impedance is necessary as it is commonly used in recording audio. High impedance while offering a high signal voltage results in noticeable loss of treble (high frequencies) even over a moderate cable length.

Frequency response of a good microphone is

the output of the microphone within $+1\text{dB}$ of the output at 1kHz . Although the audio frequency range extends from 20Hz to 20kHz , however a microphone which gives a flat response without $+1\text{dB}$ frequency between 80Hz to 8kHz is quite acceptable for a normal programme, but a better system is required for high fidelity work.

From design consideration, a microphone is considered to be a vibrating system consisting of electrical induction and capacitance corresponding to the mass and compliance of the vibrating system. Thus, the system has a natural resonant frequency at which the output of the microphone is suddenly boosted up thereby adversely affecting the frequency response of the microphone. The vibrating system is so designed that the natural resonant frequency is outside the normal operating range of the microphone.

The frequency response of some of the commonly used microphones is given below;

- Moving coil 40Hz to 10kHz
- Ribbon type 16Hz to 15kHz
- Crystal 50Hz to 10kHz
- Condenser 20Hz to 20kHz
- Carbon 100Hz to 7kHz .

When a microphone is connected to an amplifier, an audio current will drop a voltage across the speaker. The amplitude of the audio waveform could be measured with an oscilloscope. Also the voltage drop across the speaker could be measured with a voltmeter. Figure 1.1 shows the sound which is converted to audio current.

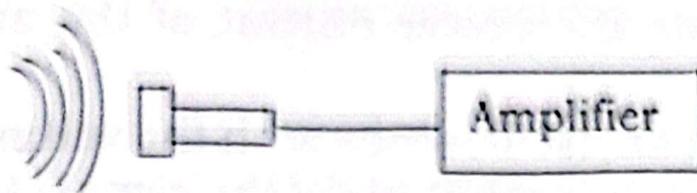
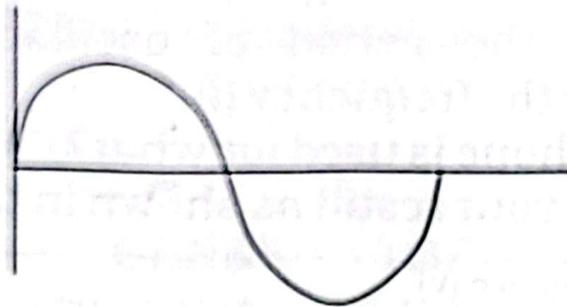


Figure 1.1 (a) Audio from mic



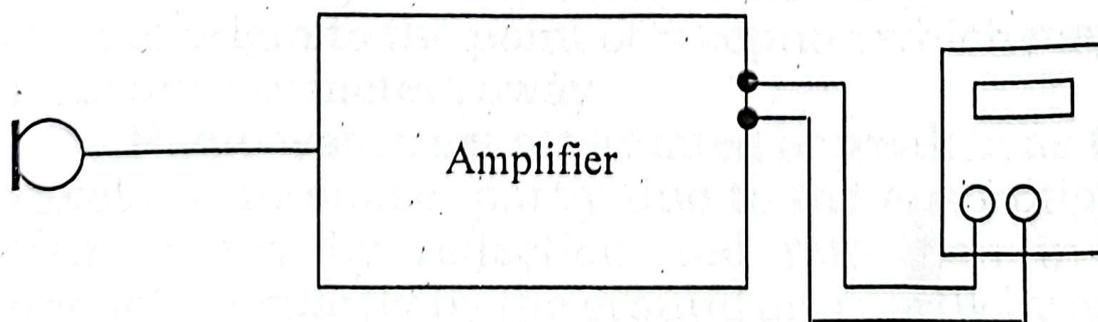
(b) Audio current

Equipment:

1. Power amplifier
2. Dual traced oscilloscope
3. Microphone
4. Loud speaker
5. Digital multimeter

Method:

Connect a microphone to an amplifier and a voltmeter to the output of the amplifier.



2. Measure the voltage drop across the speaker of the amplifier and record your value (V_1).
3. Measure the resistance of the speaker and record your value (R_1).

4. Calculate the power output of the audio V_1^2/R_1 .
5. Replace an oscilloscope with the voltmeter, measure the amplitude of the signal (A).
6. Determine the voltage V_2 .
7. Measure the period of oscillation (T), calculate the frequency (f).
8. A microphone is used for what?
9. Tabulate your result as shown in table 1.1

Amplifier output voltage (V) Voltage drop across speaker (V_1) Speakers resistance (R_1) Power output (P) Signal amplitude (A) Signal voltage (V_2) Period (T) Frequency (f)	
---	--

Table 1.1

EXPERIMENT 2

TOPIC: High frequency

OBJECTIVES: To understand the use of high frequency in radio transmission.

GENERAL THEORY

High frequencies can travel to a far distance. They have short wavelengths. They are used for a long distance communication. Radio communication is made possible by the use of high frequencies. These high frequencies use for radio communication are also called radio wave and they contain electromagnetic wave like light wave. This radio wave spreading out in space from its point of origin, travels at the speed of light (3×10^8 m/s in vacuum) and can induce weak currents of the same frequency in any metallic objects that fall in its way. When suitably modulated, this radio wave can be used to convey information or messages from its point of origin to the point of reception which may be thousands of meters away.

Radio waves get attenuated or weaken as they travel out in space, partly due to the absorption of their energy by reflection and refraction in the ionosphere, partly by the ground and partly by other object which these radio waves strike. The behavior of radio waves of different frequencies is different in so far as their reflection or absorption by other

subject is concerned. The propagation characteristics of radio waves of different frequencies mainly decide the use to which the waves can be put for communication purpose.

Equipment:

1. Radio frequency generator
2. Dual traced oscilloscope

Method:

1. Display a high frequency in the range electromagnetic wave on an oscilloscope by using a signal generator.
2. Determine the frequency (f) from the signal generator equipment.
3. Calculate the wavelength (λ) using the speed of light.
4. Calculate the period (T).
5. Measure the amplitude (A) of oscilloscope.
6. Determine its voltage (V).
7. Why is high frequency necessary in radio transmission?
8. Tabulate your results as shown in table 1.2
9. Draw the waveform with the dimension of amplitude measured.

Parameter	
F	
λ	
T	
A	
V	

Table 1.2

EXPERIMENT 3

TOPIC: Amplitude Modulation

OBJECTIVE: To Demonstrate an Amplitude Modulation

GENERAL THEORY

Amplitude modulated (AM) transmitters are mostly used for the broadcast of speech or music. The transmitters either operate on the broadcast band of 535 to 1605KHz or medium-wave and provide steady service over a limited range. When used for long distance communications such as overseas broadcasts, these transmitters operate on higher frequencies between 3 and 30MHz and are known as High frequency (Hf) transmitters or short-wave (SW) transmitters.

RADIO BROADCASTING OR TRANSMISSION

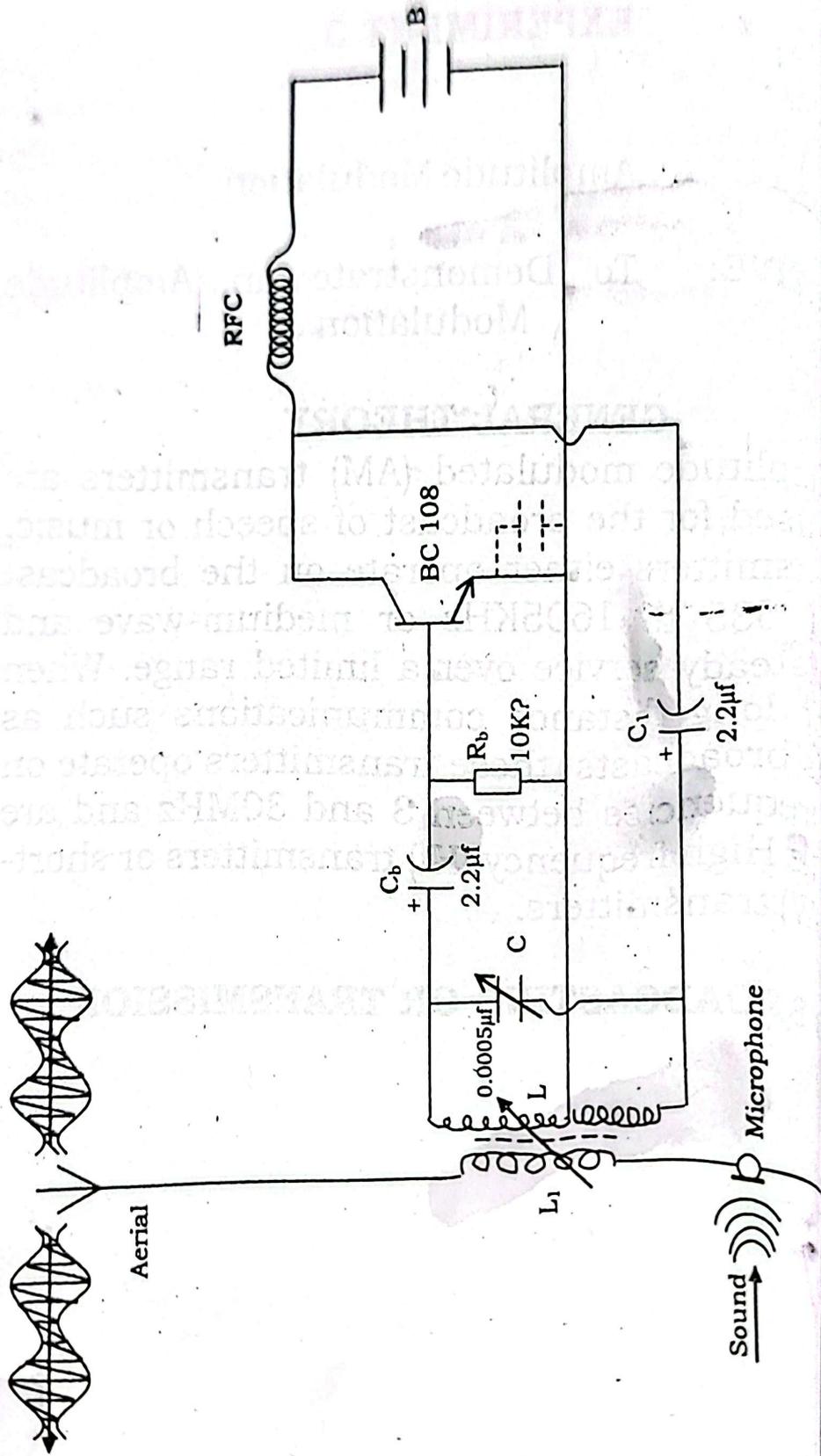


Fig3.1: Hartley Oscillator

The speech is converted into electric current with the help of a crystal microphone. The frequency variation of the current lies in the audio-range, hence it is known as audio frequency signal. The audio-frequency cannot be radiated out from the antenna directly, therefore, for this purpose, oscillation of very high frequency or radio-frequency is produced with the help of oscillator. The electromagnetic wave produced is a constant amplitude and extremely high frequency. It can neither be seen nor heard, but it travels through space with the velocity of light i.e. 3×10^8 (m/s) approximately.

The audio-frequency signal which is to be broadcasted is then superimposed on the R.F. wave, which is known as the carrier wave (because they carry the audio frequency signal through the space to a distant place. The process by which audio frequency (AF) signal is impressed on the carrier wave (RF) is known as modulation.

The carrier (RF) wave carries the audio-frequency (AF) signals, through space. At the receiving end, they strike the receiver aerial and enter the receiver which separates the R.F. and A.F. The R.F. which is very high frequency is bypassed by capacitor (and returns back) and the audio wave is passed through inductor of loud speaker and is converted into sound.

The process by which R.F. and A.F. is separated is known as detector or demodulation.

ESSENTIALS OF DETECTION DEMODULATION

The radio frequency modulated wave radiated out from the transmitter antenna traveling through space, they will strike the receiver aerials inducing a very weak radio frequency current and voltage into aerials. If the frequency current, passes through a headphones or loudspeaker, it will produce no effect on it because all the sound-producing devices are unable to respond to such a high frequency because of the inertia of vibrating disc, which will become ineffective. Therefore, sound cannot be produced to human ears because their frequencies are much beyond the audible frequencies. Hence, it is necessary to demodulate them.

A block diagram for an amplitude modulated transmitter is shown in fig (3.2), and wave output of each component is also shown.

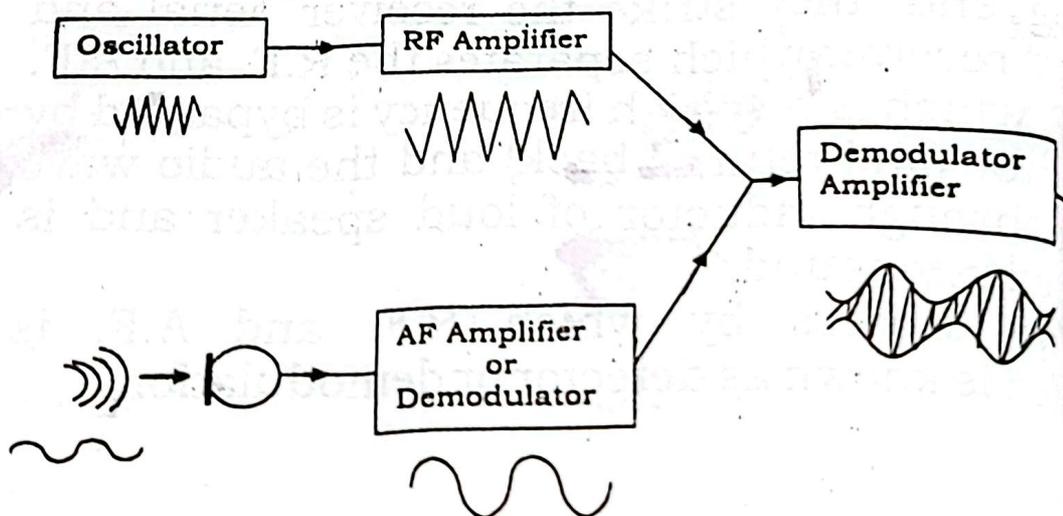


Fig (3.2)

The oscillation generates carrier wave of radio frequencies which are made stronger by the radio frequency amplifier. Sound waves strike the diaphragm of the microphone which converts them into a tiny varying current which varies according to the variation of the pressure in the sound wave. The audio output of the microphone is amplified with a suitable audio frequency (A.F.) amplifier. The audio frequency (A.F.) amplifier output is then used to modulate the radio frequency (R.F.) carrier wave obtained from the R.F. amplifier.

The modulated wave, if it is fed into the modulated amplifier which after amplifying, it will send the wave into its antenna which then radiates it out into the space.

DETECTION

To recover the audio frequency (A.F.) waveform from the modulated wave (i.e., the mixture of AF wave and RF carrier wave), rectifier with a separator is needed.

When the rectified modulated wave is passed through a headphone or a loudspeaker shunted with a suitable capacitor, the audio-frequency will pass through the headphone or speaker whereas, the radio frequency wave will be by-passed by the capacitor (because the high conductance of the magnetic coils of the headphone or loudspeaker will offer great impedance to the high frequency of the RF current and only by-pass low frequency. Since, a capacitor blocked low frequencies and by-passed only high frequencies, the two frequencies (AF and RF) will be separated.

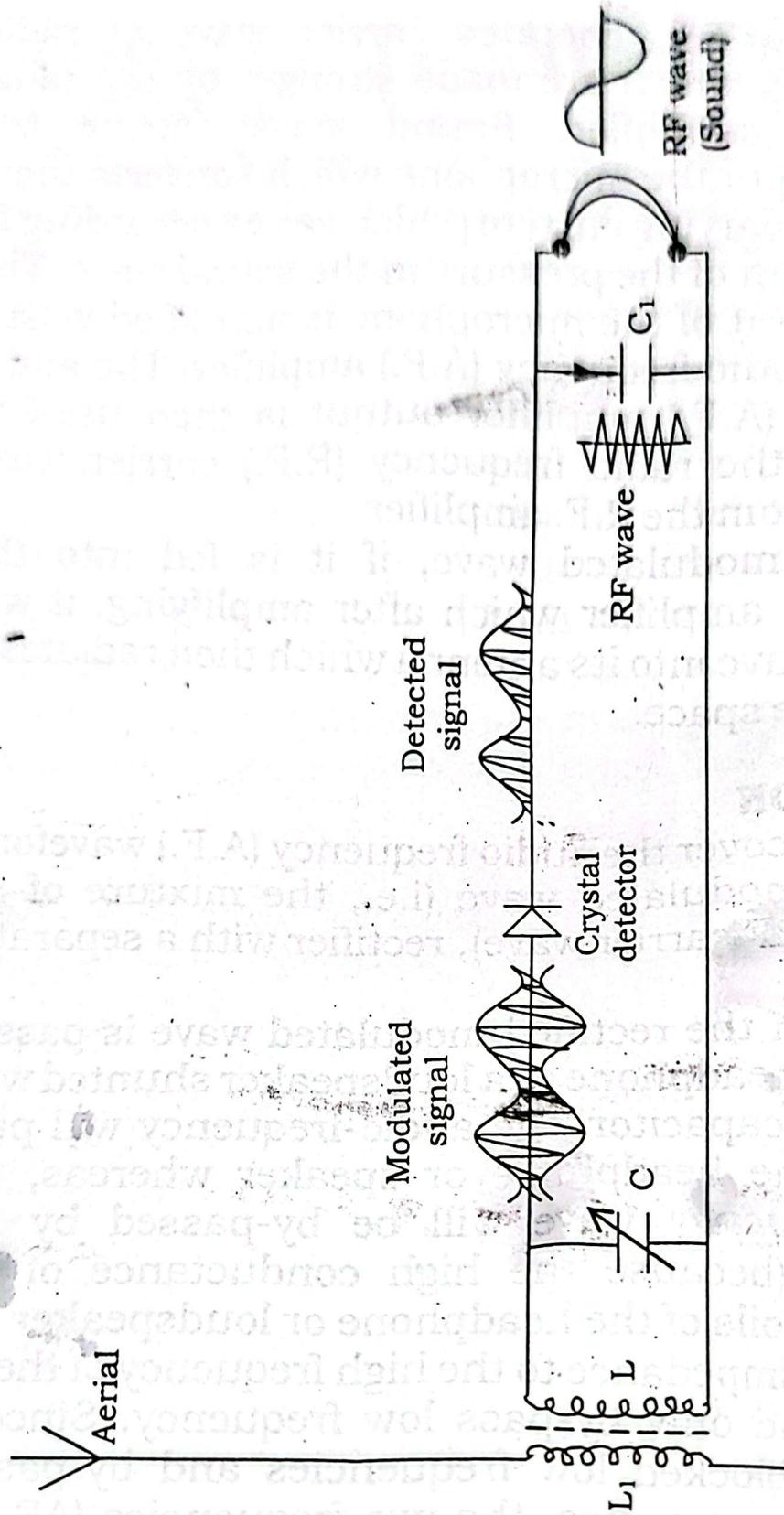


Fig (3.3)

Equipment:

1. Radio frequency generator
2. Power amplifier
3. Microphone
4. Loudspeaker
5. Dual traced oscilloscope
6. Digital multimeter

Method

1. Connect the audio signal from the amplifier to the oscilloscope and the amplitude displayed. Determine the voltage from your reading.
2. Connect the signal from the radio frequency generator to channel B of the oscilloscope and measure the amplitude. Determine the voltage from your reading.
3. Add the two signals together to obtain a modulated signal.
4. Measure the maximum and minimum amplitude modulated signal and record your value.
5. Draw the modulated signal with the accurate measurement on a graph sheet.
6. Divide the amplitude of the audio signal by the amplitude of the radio frequency signal. This is the modulation index (M_i).
i.e. $M_i = \frac{\text{audio signal amplitude}}{\text{radio frequency amplitude}}$
7. Determine the percentage modulation (M) i.e. $M = M_i \times 100\%$.
8. Tabulate your result as shown in table 1.3

Audio signal amplitude	
Radio frequency amplitude	
Maximum modulated amplitude	
Minimum modulated amplitude	
Modulation index	
Percentage modulation	

Table 1.3

SECTION C

APPLICATIONS AND PROJECTS

WATER-OPERATED SWITCHES

INTRODUCTION

You may have already noticed that, in Projects 9 and 10 with your fingers, the bulb operated. Your fingers, particularly if they are wet, act as a low resistance which triggers the circuit as surely as if the illumination increased on the photocell or the pressure increased on the resistor. The resistance between two fingers on one hand or between each hand, is very dependent on whether your hands are wet with water or perspiration. **Water is a very good electrical insulator**, but water in the body contains dissolved body salts, and makes perspiration a good electrical conductor. You can easily investigate the resistance of the body and the way it is affected by perspiration, by using the ohmmeter scale of a multimeter.

This project makes use of the fact that water, in general, is a good electrical conductor because it contains dissolved impurities. This is even true of rainwater, which contains dissolved carbon dioxide and sulphur dioxide from the atmosphere making the rain acidic and conductive.

THE CIRCUIT

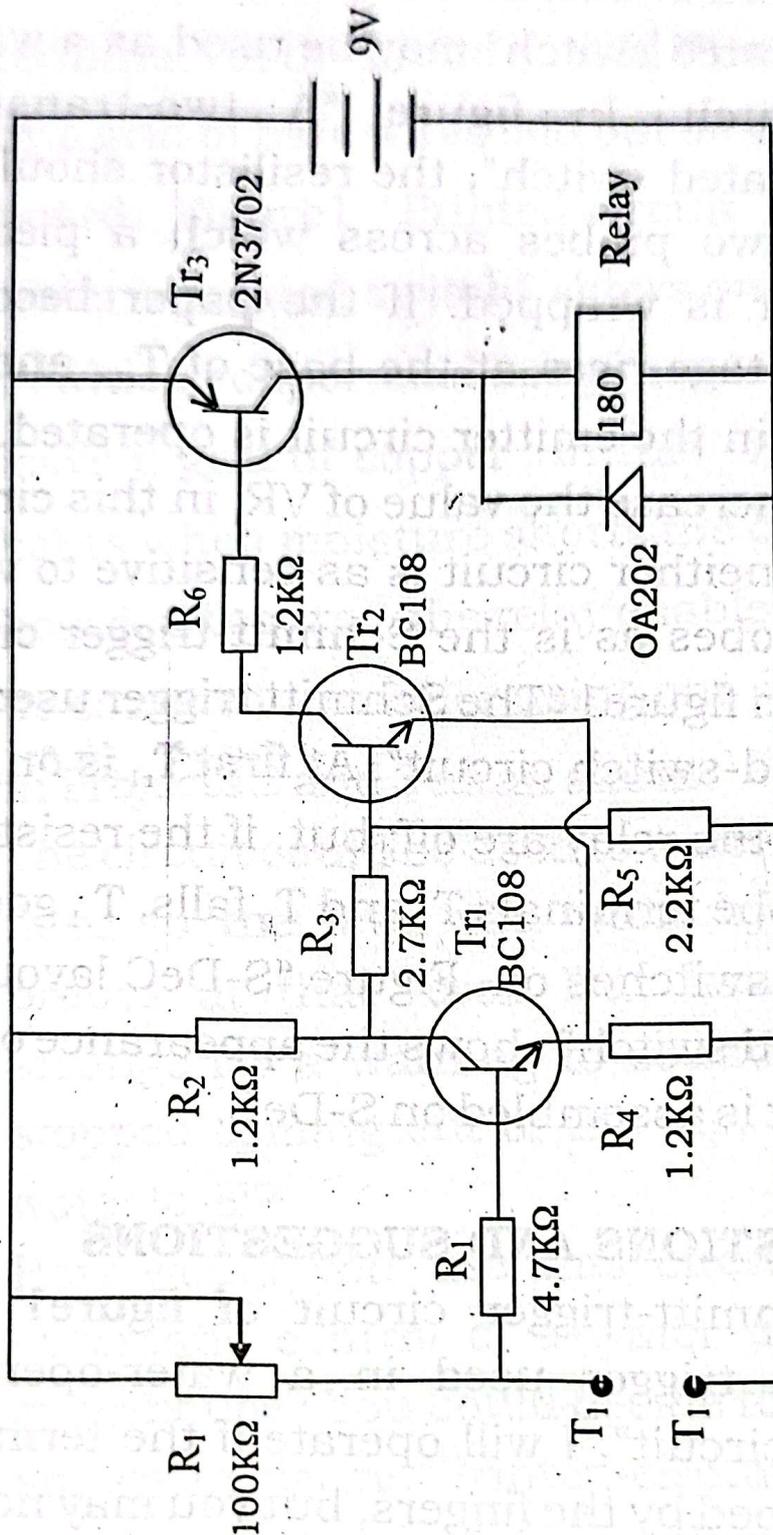


fig.1 Schmitt-trigger used in water operated switch

Either of the circuit of figures "One-transistor pressure-operated switch" and "A two-transistor pressure-operated switch" may be used as a water-operated switch. In figure "A two-transistor pressure-operated switch", the resistor should be replaced by two probes across which a piece of blotting paper is wrapped. If the paper becomes damp, the voltage rises at the base of T_{r1} , and the lamp or relay in the emitter circuit is operated. You may need to increase the value of VR_1 in this circuit but, even so, neither circuit is as sensitive to water across the probes as is the Schmitt-trigger circuit shown again in figure 1 "The Schmitt trigger used in water-operated-switch circuit". At first T_{r1} is on, and hence T_{r3} and the relay are off; but, if the resistance across the probe terminals T_1 and T_2 falls, T_{r1} goes off and the relay switches on. Figure "S-DeC layout of water-operated switch" shows the appearance of the circuit when it is assembled on S-DeC.

QUESTIONS AND SUGGESTIONS

The Schmitt-trigger circuit of figure 1 "The Schmitt trigger used in a water-operated switch circuit". It will operate if the terminals are gripped by the fingers, but you may need to change the value of VR_1 to $0.25M\Omega$ or higher.

2. The circuit could be used in a rain-warning device, or as a fog and mist detector. The terminals of the probe should then be replaced by a grid of bare wires laid out on an insulating board. Figure 1 "Printed-circuit layout for a water-operated switch" shows one possibility, in which copper-clad board has been etched to leave a grid of copper. In this circuit, a bulb lights when moisture shorts the copper on the board. Of course, the relay enables an alarm to be sounded. Consider using one of the circuits in Projects 2 and 3 as an alarm.
3. The circuit could be used to warn that a bath is filled to the level you want by placing the probes at that level. But how would you arrange for a warning to sound if the water stopped coming out of the tap, whatever the water level?
4. How would you use this circuit to provide automatic control of a water sprinkler in a greenhouse? You could decide to use a grid as shown in figure "Printed-circuit layout for a water-operated switch", so that the sprinkler

is turned on when the grid becomes dry (which would really be a control of humidity), you could decide to stick the probes in the soil so that the sprinkler operates when the soil dries out.

HEAT-OPERATED SWITCHES

INTRODUCTION

A thermistor is the transducer used for this project. You will remember from Section C that a thermistor is really a resistor, the value of which changes with temperature. One useful kind of thermistor has a resistance which decreases with temperature rise; it is known as a negative temperature-coefficient (ntc) thermistor. The appearance of these thermistors is shown in Section C, and you will remember that they are in rod, wire, or bead form. They have different resistance values (usually quoted for 25°C), the choice depending on the application required.

In the circuit to be described, the temperature change of the thermistor is used to control the switching of a relay. The relay contacts are used to switch on and off the current to an electric heater, and some of this heat provides the essential feedback common to all control circuits. The block diagram of figure 2 "The principle of a thermal control circuit" shows the essential requirements for a thermal-control circuit, or thermostat.

THE CIRCUIT

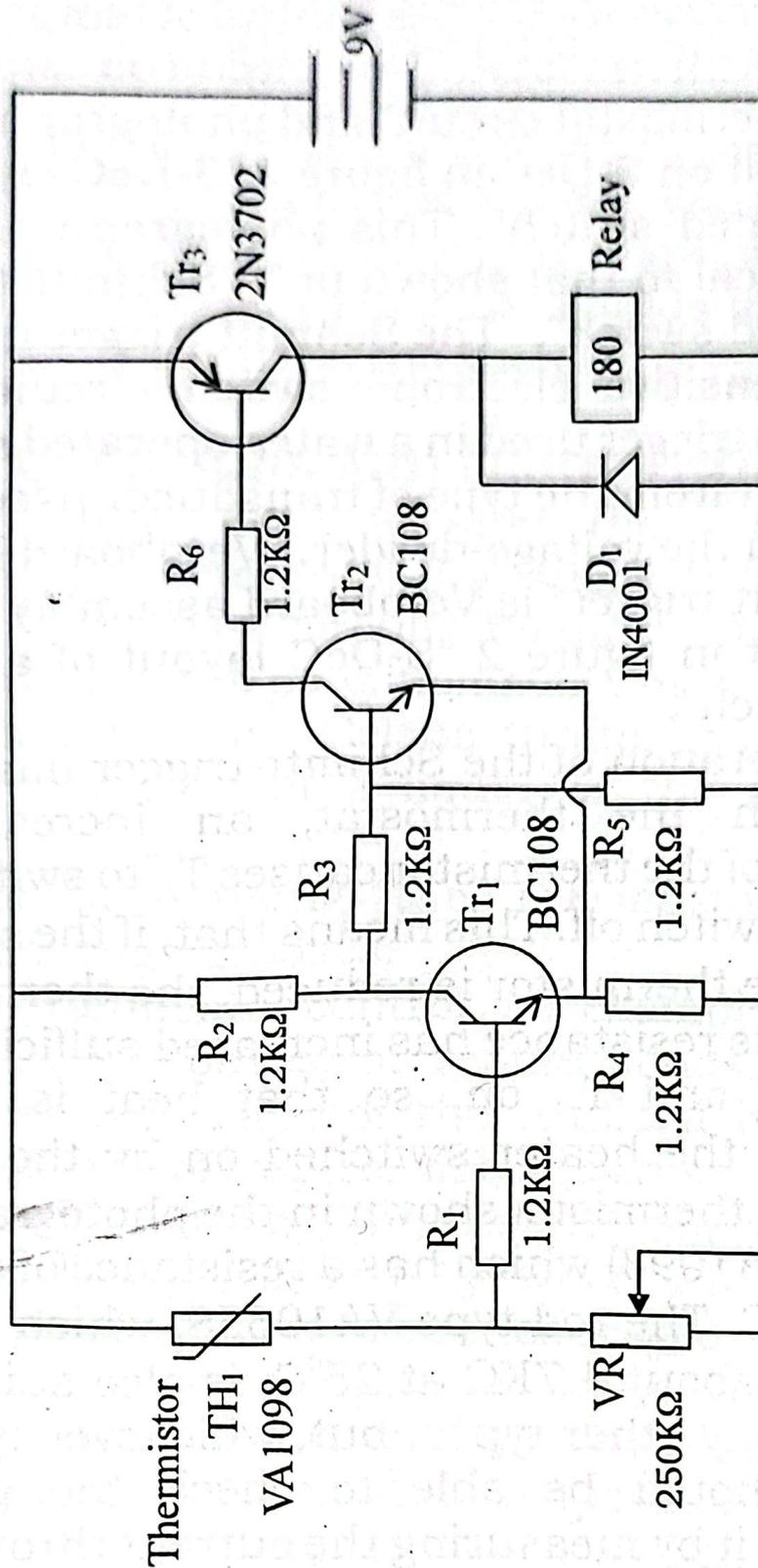


Fig.2 A thermostat circuit

A Schmitt-trigger circuit might be provided the necessary precise control of temperature required of a thermostat. This circuit is shown in figure 2 "A thermostat circuit" and photograph of the control circuit on S-DeC in figure 2 "S-DeC layout of a heat-operated switch". This photograph shows a layout identical to that shown in "A Schmitt-trigger circuit in a light-operated switch", "The Schmitt trigger used in a pressure-sensitive electronic-switch circuit" and "The Schmitt trigger used in a water-operated electronic-switch circuit", apart from the type of transducer used and its position in the voltage-divider. "Veroboard layout of the Schmitt trigger" is Veroboard assembly on S-DeC layout in figure 2 "S-DeC layout of a heat-operated switch".

The operation of the Schmitt-trigger has been described. In the thermostat, an increase in temperature of the thermistor causes T_{r1} to switch on and so T_{r3} to switch off. This means that, if the source of heat for the thermistor is reduced, the thermistor cools; when its resistance has increased sufficiently, T_{r1} turns off and T_{r3} on, so that heat is again generated by the heater switched on by the contacts. The thermistor shown in the photograph is a disc type (VA1098) which has a resistance of about $1.5K\Omega$ at $25^{\circ}C$. The rod type VA1065S, which has a resistance of about $4.7K\Omega$ at $25^{\circ}C$, is also suitable as well as many other types; but, whichever type is used, you should be able to check the power dissipation in it by measuring the current through it and the voltage across under operating conditions.

to ensure that it is not dissipating more than the permitted maximum. These maxima are listed in the catalogues of the suppliers of thermistors.

When connections are made to the normally-closed contacts of the mains relay, you must heed the warning given, concerning care with mains insulation, especially since the liquids to be heated are invariably electrical conductors.

QUESTIONS AND SUGGESTIONS

1. You may need to alter the value of the potentiometer from that suggested in figure 2 "A thermostat circuit" if a different thermistor is used. This potentiometer would have a dial calibrated in Celsius units, so that the temperature of a liquid or the air can be adjusted.
2. Consider using the thermostat for the following purposes:
 - a. environmental control, for example of animal nursery houses, or reptile ponds, of insect-breeding cages, of the artificial hatching of eggs, and of tropical-fish aquaria;
 - b. for maintaining a constant temperature in greenhouse, especially when the growth of tropical plants is to be encouraged;
 - c. in plant-propagation beds where soil temperature must be steadily maintained;
 - d. to maintain a constant temperature in a water bath in which, for example apparatus is assembled for the measurement of the viscosity of a liquid; or in calorimetric

- measurements which require the calorimeter to be surrounded by a water bath;
- e. to control the operation of a central-heating system;
 - f. fire control, where the thermistor triggers opening of water vents if unusually high temperatures are detected by the thermistor.

A BATTERY ELIMINATOR

INTRODUCTION

When transistors began to replace valves as the active components of electronic circuits, the thing that people appreciated was that electronic equipment became really portable and could at last be made to slip into the pocket. It wasn't only because transistors themselves were small; it was mainly because transistorized circuits required low-voltage batteries. Gone were the bulky "high-tension" and "low-tension" batteries of vacuum tube circuits.

To those people who can clearly remember electronic equipment before transistors, the change in the miniaturization of electronic equipment has been remarkable. Radios which are built into the frames of spectacles and televisions which can rest in the palm of the hand are two examples which demonstrate the trend towards miniaturization. Without small-scale electronics, the extraordinary advances in computer technology and space exploration would certainly not have been possible.

One of the drawbacks of portable, battery-powered equipment is the need for a battery.

operated radios is that batteries have to be bought. Also, although distortion as the battery wears out is not the problem it used to be, the output from a transistor radio does get weaker. One solution is to buy a radio which has the facility to recharge its internal batteries from the mains; another is to have a radio which can operate from mains or battery. This project describes a circuit which could be used to construct a battery eliminator unit giving a 9V output and sufficient power to operate a portable radio so that the inconvenience and cost of replacing batteries may at least be reduced. But, of course, this is a set-back for the radio is no longer truly portable.

THE CIRCUIT

This is shown in figure 3 below, parts of which you should recognize. For instance, the transformer, the two diodes D_1 and D_2 , and the electrolytic capacitor C_1 make up a full-wave rectifier. The transformer is chosen with care paid to three essentials:

- It has a centre-tapped secondary winding so that full-wave rectification requires two diodes, not four;

- The voltage available at its secondary terminals is a few volts higher than the d.c. output which is required this enables a voltage-stabilizing circuit to be included;

- The secondary of the transformer is rated to carry a current greater than that which is to be drawn from the circuit.

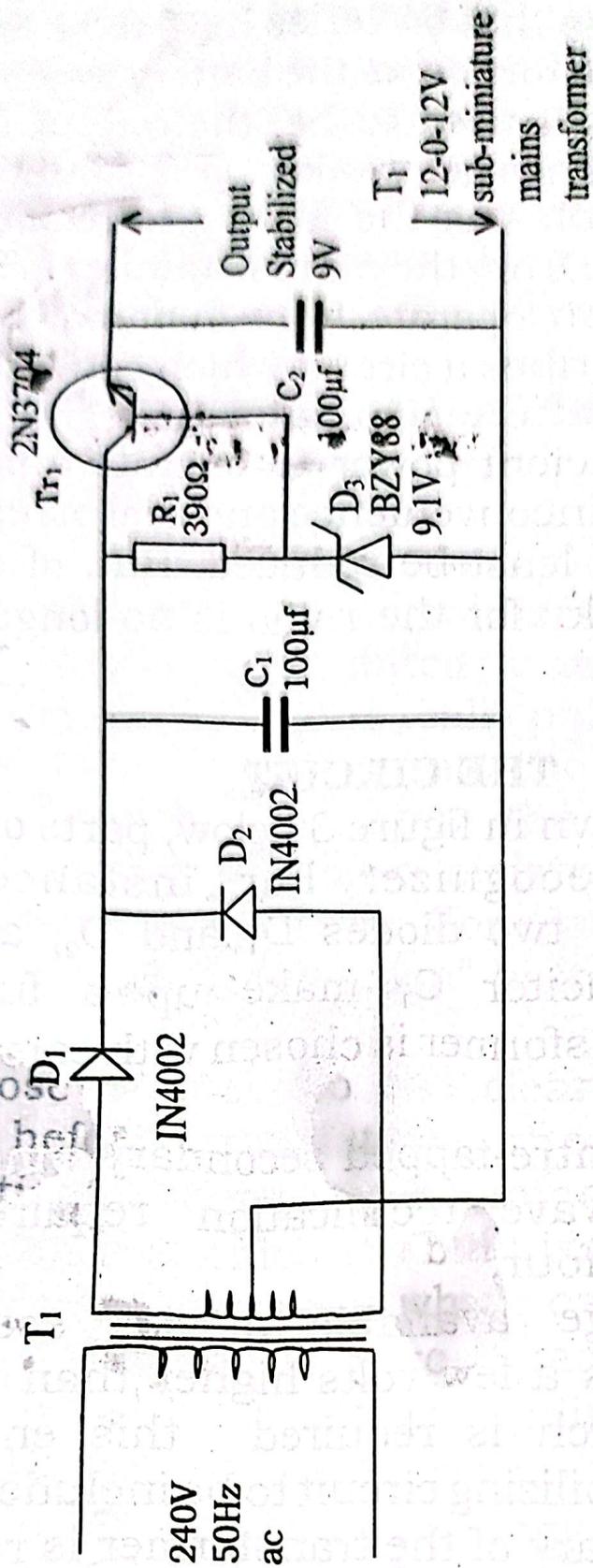


Fig.3 Stabilized power supply

The simple voltage-stabilizer has been described briefly, and a fuller explanation of the operation of this circuit is given in Note D. Note that a 9.1V zener is used to maintain a constant voltage at the base of the transistor. This transistor should be able to pass the maximum current which may be drawn from the circuit. The 2N3704 has an $I_{c(max)}$ of about 800mA, so clearly a transistor with a lower rating would also be suitable. C₂ provides further smoothing of the stabilized output.

QUESTIONS AND SUGGESTIONS

With careful layout and design, it should be possible to make an eliminator as shown in figure 3 "Appearance of a 9V battery eliminator", which could replace the battery. Fit terminals so that contact terminals of the radio may be attached to the eliminator as they are to the battery.

A Veroboard assembly of the circuit of figure 3 above is showing in figure "The 9V eliminator circuit assembled on Veroboard". Care should be taken when wiring the mains lead to the transformer to ensure that shorts will not occur. If the unit is to be contained in a metal box, then the earth lead from the mains should be connected to the metal case. This ensures that any faulty wiring resulting in the live (brown or red) wire touching the box immediately causes the mains fuse to blow.

Measure the voltage at the output of the eliminator and the base of the negative line. why is the latter smaller than the former?

4. Connect a $5K\Omega$ potentiometer across output with maximum resistance circuit. Also connect a voltmeter in with the potentiometer. Decrease the resistance and observe the variation output voltage. When the load voltage to drop, switch off; otherwise damage transistor or transformer may result.
5. The eliminator may be used to power other than a portable radio the photog timer unit, for instance, or the thermostat.

A METAL-LOCATOR

INTRODUCTION

This may be surprising to learn that a detector has applications other than ordinary. Although there are obvious and vital reasons being able to detect arms and buried mines in troubled times, the fortune hunter or archaeologist has a clear interest in an instrument which helps him to find coins during ancient and modern metallic bric-a-brac of a bygone age. Britain in particular has a rich history stretching far back to the metal-working culture which was responsible for the building of Stonehenge around 2000BC. Prehistoric man-occupied Britain has left behind numerous ancient towns, roads, boundary kilns and the many of which have still to be investigated by archaeologists.

The archaeology apart, there are often everyday reasons why a metal-locator would

useful to find lost keys and other personal property, for instance. But suppose you wanted to find the positions of hidden nails in second-hand timber before sawing it; or to locate the path of electrical wiring or conduit before a wall is drilled; or to trace the path of water pipes under the ground; or to decide whether or not an animal has swallowed the ring you have kept.

THE CIRCUIT

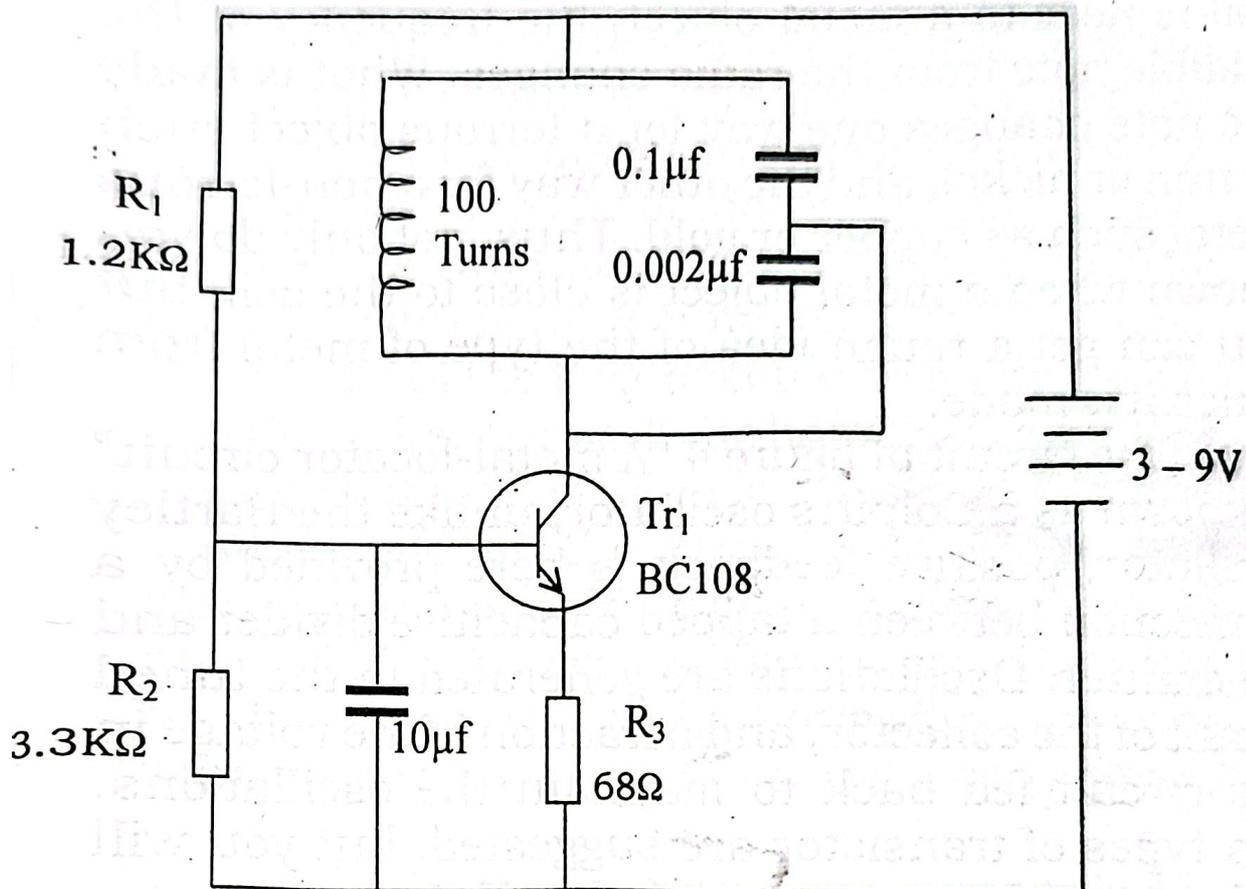


Fig. 4 A metal locator

The circuit of figure 4 "A metal-locator circuit" is simpler than most because part of the complete detector system is a transistor-radio receiver. The

Circuit is the radio-transmitter part of the system produces a steady carrier wave (an unmodulated radio wave), the frequency of which is around frequencies corresponding to the medium picked up by a radio. This carrier wave interferes ("beats") with the carrier wave transmitted station on the medium-wave band, to produce an audible note. If this was all that happened, the circuit would be worthless; but the circuit is common with most metal-locator circuits, is sensitive to the presence of metal near the coil. If the coil is near to a metal object, the frequency of the audible note from the radio changes. What is the note changes one way for a ferrous object such as iron or nickel, and the other way for a non-ferrous metal such as copper or gold. Thus, not only do you know when a metal object is close to the coil, you can get a rough idea of the type of metal from which it is made.

The circuit of figure 4 "A metal-locator circuit" is known as a Colpitts oscillator; unlike the Hartley oscillator, positive feedback is here provided by a connection between a tapped capacitive divider and the emitter. Oscillations are generated in the tuned circuit of the collector, and a fraction of the voltage of this circuit fed back to maintain the oscillation. Two types of transistor are suggested, but you will find that other types are suitable if you make sure that they are radio frequency types. C_3 is a decoupling capacitor and ensures that the base is effectively grounded for feedback signals. The values of C_1 and C_2 required for oscillations to be maintained are given in an equation.

QUESTIONS AND SUGGESTIONS

1. As shown in figure 4 "The appearance of the prototype metal-locator", one way of enclosing the circuit is to assemble it in a plastics "transparency box". A 3V supply provided by two 1.5V "penlight" cells drives the circuit. An on-off switch is fitted to the box, and two leads are taken from it to the coil.
2. The coil consists of about 100 turns of about 28s.w.g enameled-copper wire wound on a plastics or other non-metallic former. One suggestion for a former is indicated by figure 4 "The appearance of the prototype metal-locator". A thermoplastics tube is heat-formed to produce a ring of not less than 15cm diameter. A saw cut is made round the ring so that the wire can be wound inside it. Similarly, the handle of the locator could be made from a plastics tube. Through the handle of this tube, a wire is threaded to make contact with the positive line of the circuit. This wire will increase the sound from the radio if it is plugged into the serial socket, but you may not need to do this since just wrapping the wire round the radio should produce a loud enough note.
3. Switch on the radio, and tune to stations in the medium-or long-wave band. You should hear a whistle as you tune across a station, but choose a station for which the whistle is loudest and one where the interference from speech or music is minimal. The note should

not change in pitch as you tune across the bandwidth of the station. Test the locator by bringing up various kinds of metal objects in an experiment so that you know how ferrous and non-ferrous objects alter the pitch of the note. You will soon learn how to distinguish between copper and iron articles, for instance.

4. If the whistle that you hear is not very strong or if it is too high or too low, adjustment of the frequency should be made. Alternatively, you may make a small alteration to the values of C_1 and C_2 .

AN ICE ALARM

INTRODUCTION

Pure water freezes at 0°C , however, water containing dissolved impurities, such as salts, has a lower freezing-point, which could be -3°C , for instance. Common salt is sprinkled on roads and pavements during icy weather to reduce the possibility of ice forming as the air temperature falls below 0°C .

Of course, an ordinary liquid-in-glass thermometer will tell you when the air temperature has fallen to zero degrees Celsius; but these thermometers are not only fragile they also need to be looked at closely in order to read them. The advantage of all electrical thermometers is that a temperature reading can be obtained at a distance from the temperature sensor. In this project, two circuits are described which give

visual indication that the air temperature has reached the freezing-point of pure water whether ice will form on the water depends upon the purity of the water. One obvious application is in the car, where a warning signal on the dashboard would, it is hoped, make the driver proceed with caution. It should be appreciated, however, that there are times when the air could be just above 0°C while ice still forms on the road surface.

THE CIRCUIT

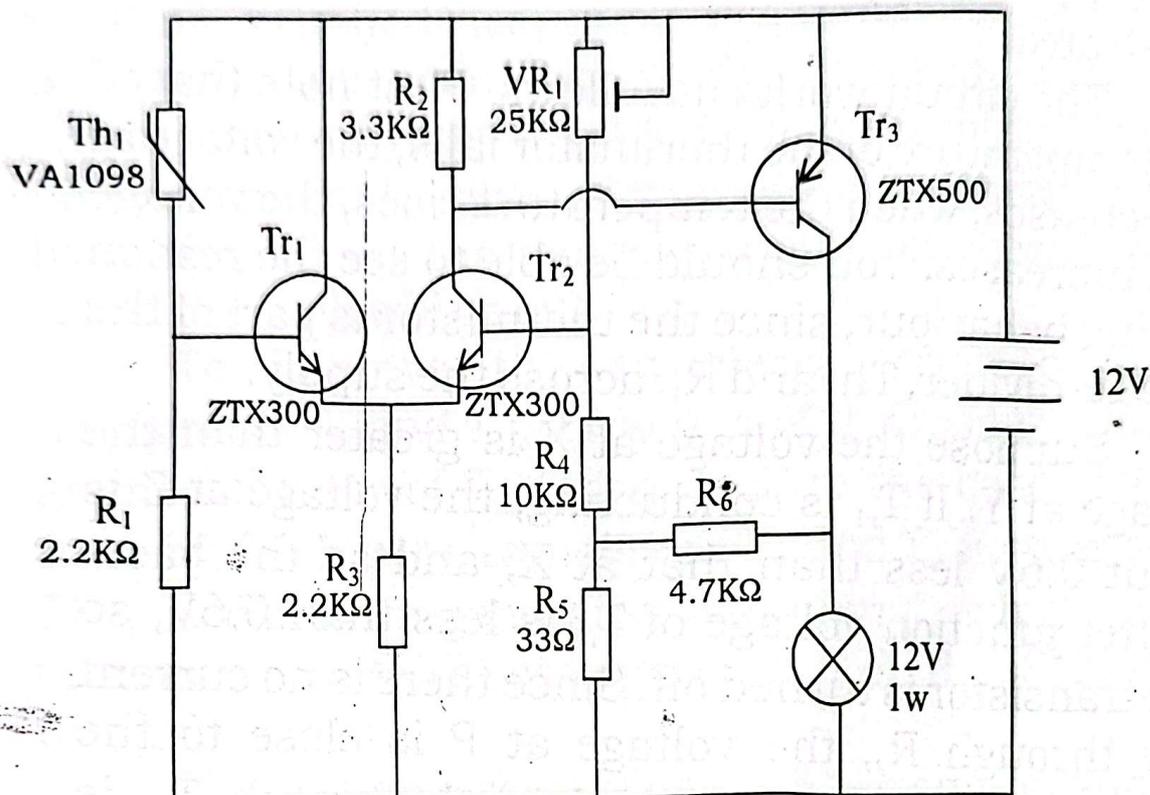


Fig.5 A basic temperature alarm circuit

In figure 5 above, "A basic temperature-alarm circuit" should be assembled on S-DeC, so that you can more easily understand its operation. This circuit causes the bulb to light when the

temperature of the thermistor has reached 0°C operation in a car, the circuit will work from the battery supply; but for test purposes a 9V supply may be used and the bulb be replaced by a 6V, 60 type. Figure shows two types of thermistor which are recommended for the alarm circuit, but other types are suitable. The circuit operates best if the value of R_1 is approximately equal to the resistance of the thermistor at the temperature at which you want the bulb to light. But take care that the thermistor is not dissipating more than the permitted maximum power; this is 0.6W for the two thermistors illustrated.

The circuit works as follows. First note that as the temperature of the thermistor falls, the voltage at X decreases; when the temperature rises, the voltage at X increases. You should be able to see the reason for this behaviour, since the thermistor is part of the voltage-divider, T_{h1} and R_1 , across the supply.

Suppose the voltage at X is greater than the voltage at Y. If T_{r1} is conducting, the voltage at Z is about 0.6V less than that at X; and so the base-emitter junction voltage of T_{r2} is less than 0.6V, this transistor is turned off. Since there is no current flow through R_2 , the voltage at P is close to the positive supply voltage (12V in this case); T_{r3} is biased off (it is a pnp transistor), and the bulb is off.

Suppose the voltage at X is less than the voltage at Y. the voltage at Z will take the higher of these two voltages, less the 0.6V for the base-emitter junctions. T_{r1} will be off and T_{r2} on. Current flows

through R_2 the base of T_{r2} goes negative; T_{r2} switches off and the bulb lights. When the voltages at X and Y are equal, both transistors are biased on. Thus T_{r2} turns on as soon as the thermistor temperature reaches the preset value.

The voltage divider made up of VR_1 and R_1 (and R_2 , but this is small) enables you to set the temperature for which the bulb lights. In order to set the value of VR_1 so that the bulb lights as the thermistor reaches 0°C , the thermistor must first be sealed in a water-tight cover. It is then immersed in melting crushed ice, which should be at 0°C although this can be easily checked with a thermometer if you wish. VR_1 is then slowly adjusted so that the bulb lights. Now remove the thermistor from the ice. As the temperature of the thermistor rises, the bulb will go out.

To improve the switching action of the transistors T_{r2} and T_{r3} , a fraction of the rising voltage at the collector of T_{r3} is fed back to the base of T_{r2} , thereby driving the transistors T_{r2} and T_{r3} further on. This is called "regenerative switching", which you remember was an essential part of the Schmitt trigger.

The add-on circuit of figure 5 "An add-on audio alarm" will provide an audible warning note rising in pitch as the preset temperature is reached as the indicator light comes on, the note is heard. This add-on circuit was incorporated in the unit shown in figure 5 "An assembled unit for measuring temperature" and made use of a miniature

...so that the plastic slide box circuit...
 ...modification, a spindle potentiometer...
 ...replace the preset potentiometer in the circuit...
 ...a basic temperature-alarm circuit.

HIGH-VOLTAGE SUPPLY CIRCUIT

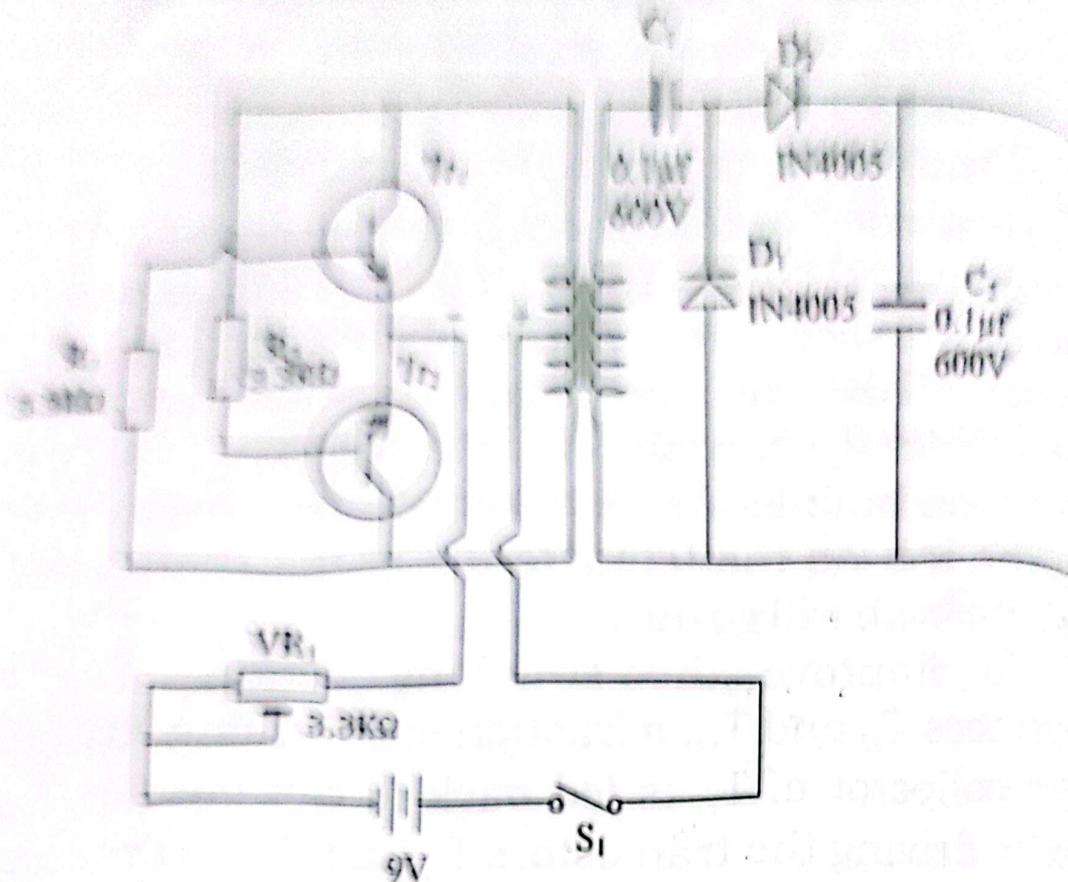


Fig.6 HIGH-VOLTAGE SUPPLY CIRCUIT

The figure 6 "High-voltage supply circuit" consists of a d.c. to a.c. converter, or "inverter". The first part is required so that a transformer may be used to step-up the voltage, and the second part so that the output from the transformer can be doubled.

and rectified to give a d.c. voltage of about 420V. The action of the voltage-doubler has been described in Section F.

The two transistors in the d.c.-to-a.c. converter operate in a simple resistance-coupled circuit. This circuit is self-oscillating. When the switch S_1 is closed, inevitable inequalities in the characteristics of the transistors and in the inductance of the two halves of the two transformer windings cause one transistor to conduct more heavily than the other. Suppose T_{r1} begins to conduct. Its collector voltage falls as the current rises in the upper half of the transformer winding. T_{r2} is driven off by the base-emitter bias provided by means of R_2 . Positive feedback provided by an induced e.m.f. in the lower half of the winding drives T_{r1} quickly into saturation. Once T_{r1} becomes bottomed, feedback ceases, since the transformer saturates and T_{r1} returns to the off state. But, because of the symmetry of the circuit, the state of the circuit with T_{r1} bottomed and T_{r2} cut off cannot be maintained. The magnetic field which has been established in the upper half of the winding now collapses, and an induced e.m.f. drives T_{r2} on. Now the lower winding carries an increasing current until T_{r2} is bottomed. The cycle repeats itself, each

transistor alternately "providing" pulses of current through alternate halves of the primary winding. Thus 6V switched across each half of the primary winding produces about 220V across the secondary for the transformer suggested.

The plateau of the MX168 is shown in figure 6 "Count rate versus tube voltage for MX168 Geiger tube"; it is the range of voltage over which the counting rate of the tube is approximately constant. Since the plateau is about 80V wide for the MX168, the voltage applied to the circuit range from perhaps 370V to 450V. VR_1 in figure 6 "High-voltage supply circuit" allows you to adjust the voltage.

QUESTIONS AND SUGGESTIONS

1. Other switching transistors could be used in this circuit for instance the ZTX50 (remember this is a pnp type)
2. In the completed unit shown in figure 6 "One version of a complete Geiger-counter unit", the circuit was assembled on Veroboard and the 2000 ohm earpiece was mounted inside the box. If required, the box can be held to the ear. Should the unit be operated in a noisy environment.
3. With one of the tubes suggested, a background count rate of approximately 45 per minute was heard. The count rate depends partly on the

THE TRANSISTORIZED SOUND-SWITCH CIRCUIT

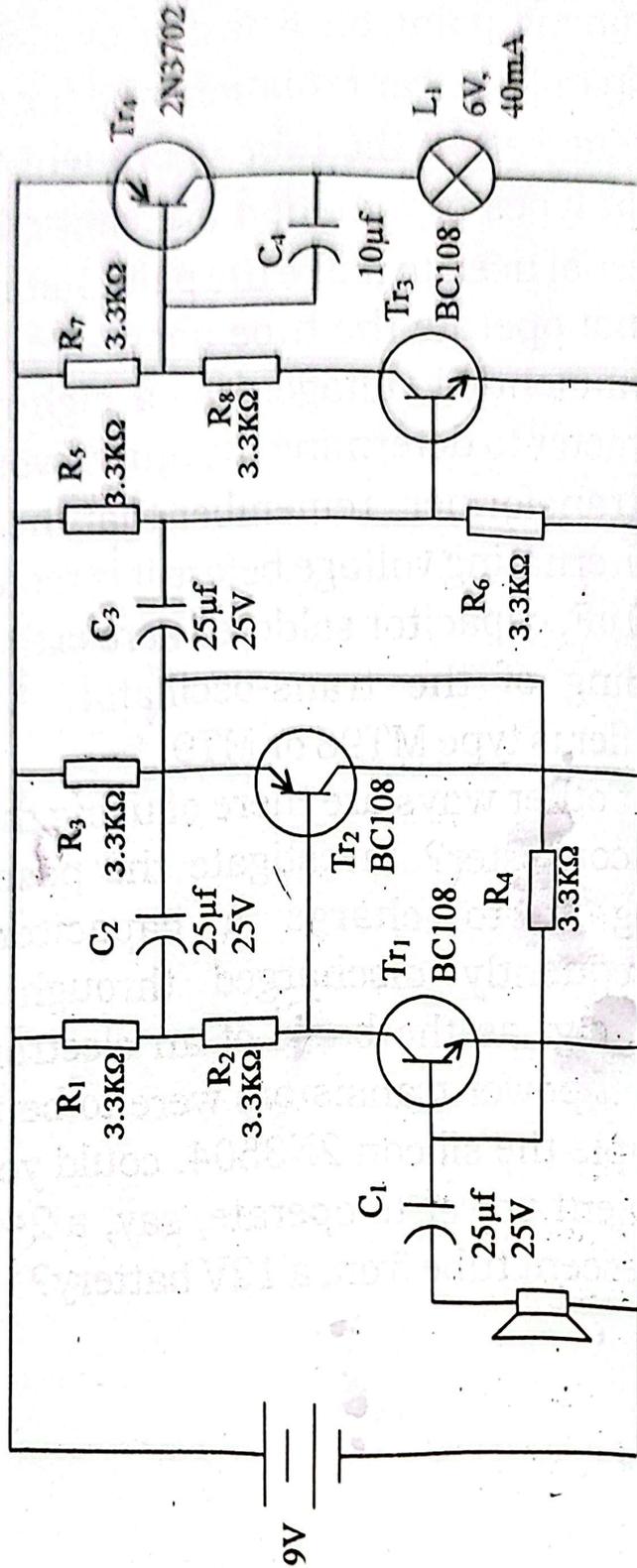


Fig.7 Transistorized sound switch circuit

You will notice from the figure 7 "transistorized sound-switch circuit" that the part of the circuit on the first S-DeC is the two-transistor amplifier used in previous projects (for instance, the intercom and radio). The output from this amplifier operates a two-transistor switch on the second S-DeC.

The second part of the sound-switch circuit works like this. When the speaker receives sound waves, the output across the points X and Y consists of voltage changes which are the amplified electrical signals corresponding to the sound waves. The two resistors R_5 and R_6 are arranged as a voltage-divider so that, when there is no signal input to T_{r3} , this transistor is just turned off. This means that the base-emitter voltage is close to 0.6V. The varying voltage is now impressed on this steady base voltage so that the voltage at X goes above and below 0.6V. As the graph of figure "Signal variations from an amplifier" is intended to show, only those parts of the signal which drive the base to greater than 0.6V switch the transistor on.

Transistor T_{r4} is a pnp transistor, and R_6 holds this transistor off. But, when T_{r3} begins to conduct, the current flow through R_7 and R_6 lowers the voltage at the base of T_{r4} so that this transistor turns on and the bulb lights.

The purpose of C_4 is to hold on T_{r4} a little longer than T_{r3} ; that is, even though T_{r3} has turned off and

C_4 has discharged while T_{r4} is conducting, current continues to flow through L_1 for a short time as C_4 charges up again through R_{s2} .

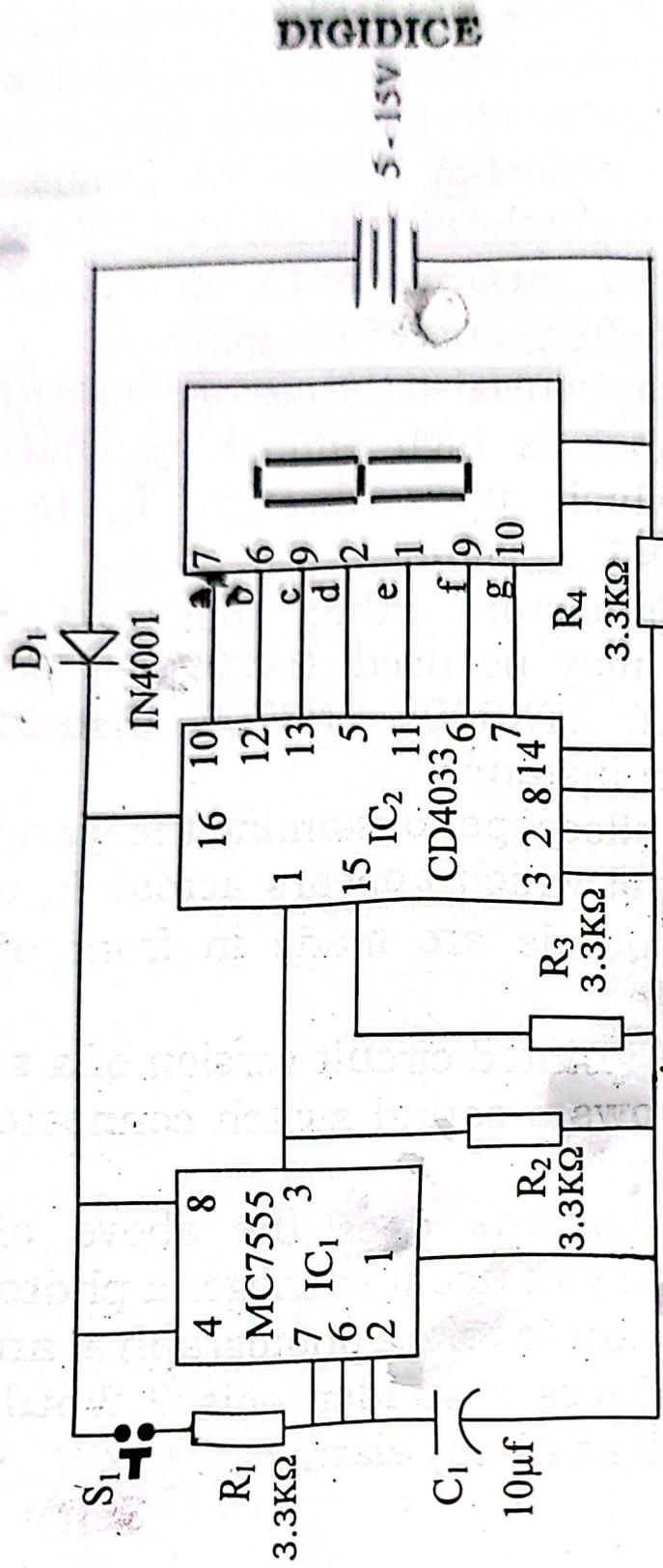
You will notice that, when you first switch the supply to the circuit, the bulb lights for a short time; this is caused by current flowing through L_1 and the bulb as the capacitor charges. C_4 is useful when a relay replaces the capacitor, since the relay holds on for a little longer than the time for which T_{r4} and T_{r3} are switched on.

QUESTIONS AND SUGGESTIONS

1. An 80 ohm moving-coil loudspeaker, as used in previous project, is suggested for the microphone, since this matches the low input impedance of the amplifier. A crystal microphone works in the circuit, but it has a high impedance and so the response of the circuit will not be as good.
2. The S-DeC arrangement makes it easy to adjust the value of R_8 so that T_{r3} is just on the point of conducting without a signal at the point X. To do this, connect a 10mA meter in series with the emitter of T_{r3} so that it only just begins to show a reading as R_8 is adjusted.
3. The sensitivity of the circuit may be increased by means of the one-transistor pre-amplifier shown in figure 7 "A pre-amplifier circuit". If the circuit becomes unstable with this

addition, so that the bulb comes on even though the microphone is not receiving sound, then this can usually be cured by connecting a large-value capacitor across the positive-to-negative lines of the circuit at least $100\mu\text{F}$ will do. Nearby mains-operated electrical equipment often causes instability.

4. When a relay is used in the circuit, ensure that its resistance is high enough to limit the current which flows through T_{r4} to the transistor's $I_{c(\text{max})}$ value.
5. Silicon transistors other than the ones suggested may be used: 2N2926 or BC108 instead of ZTX300: 2N3702 instead of ZTX500, for instance.
6. Use an oscilloscope to examine the waveform of the signal which appears across R_8 when different sounds are made in front of the microphone.
7. Figure 7 "A printed circuit version of a sound switch" shows a sound switch connected on printed circuit.
8. What applications does the above circuit have? Could you use it to trigger a photoflash when you want to take a photograph of an event which produces a sudden noise? Would the circuit work as a baby alarm?



ig.8. Digidice

The circuit described here is that of a simple digitizer. The circuit is based on two low-cost CMOS ICs.

IC₁, (MC7555), which is wired as a clock pulse generator, generates pulses which are fed to IC₂ (CD4033). The frequency of these pulses is dependent upon R₁ and C₁, IC₂ counts these pulses, and accordingly displays a digit between 0 and 9, on the common-cathode display DISI (LT543).

As long as S₁ is pressed, IC₁ continues to generate the clock pulse, and the digit 8 is displayed.

When S₁ is switched off, any number between 0 and 9 is randomly selected and displayed by DISI. D₁ is used to protect the current from any damage due to the reverse battery connection. The current being based on CMOS ICs, can safely be operated from a power supply voltage ranging from 5 to 15V.

The circuit would cost around one thousand naira.

PARTS LIST

Semiconductors

IC₁ MC7555

IC₂ CD4033

DISI LT543

DI IN4001

Capacitors 0.01 μ F

Resistors

R₁ 47K

R₂ 220K

R₃
S₁

470K
Push Button Switch

CIRCUIT A

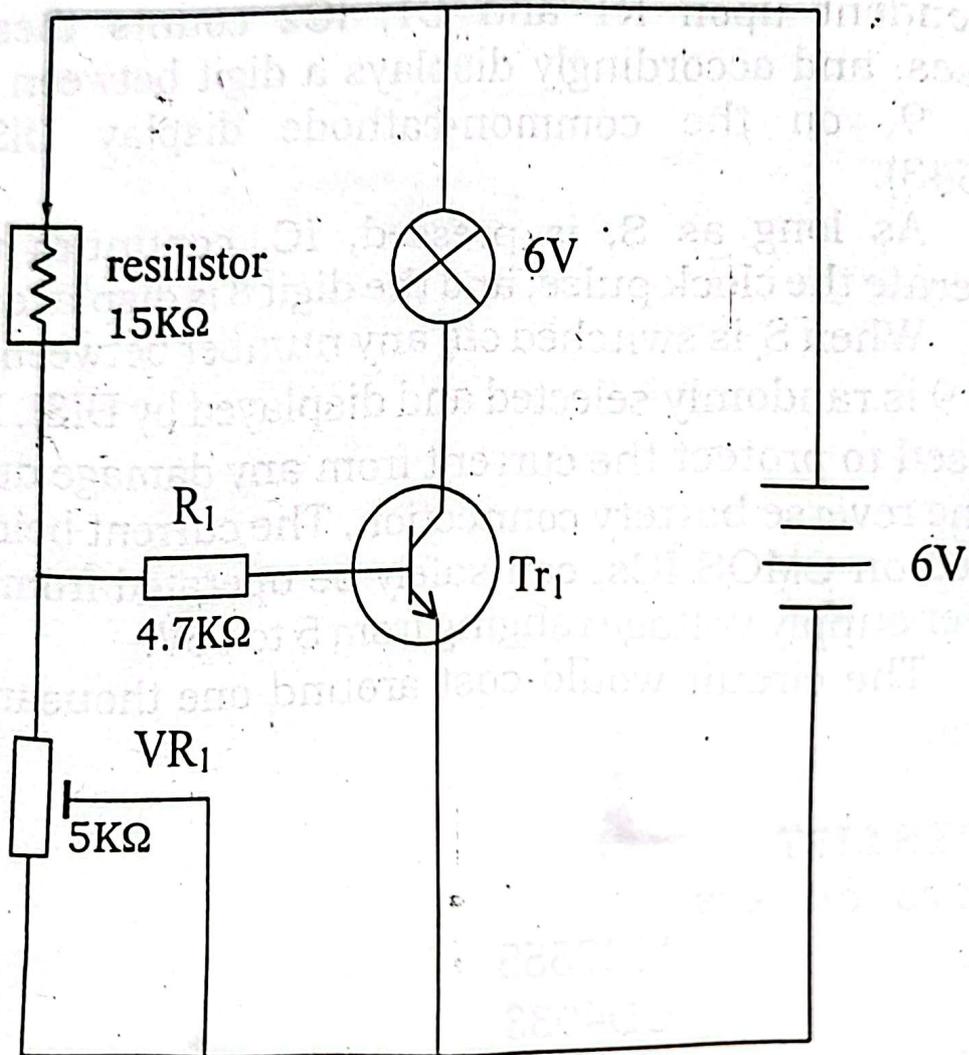


Fig.9

CIRCUIT B

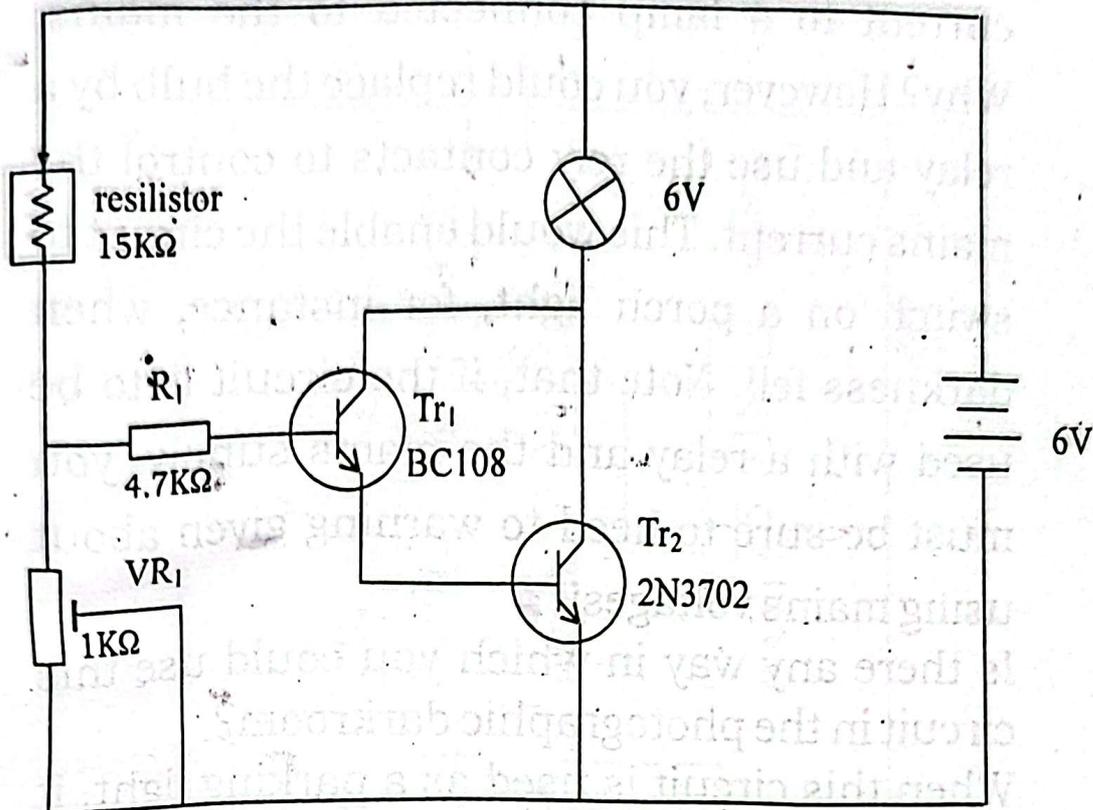


Fig. 10

1. Assuming that T_{r1} and T_{r2} are equivalent to a single transistor, use a milliammeter to find the d.c. current gain of the circuit. Compare this the d.c. current gain of Circuit A. Is Circuit B better than Circuit A for the point of view of current gain?
2. The values of the components of Circuit B enable it to be used on a circuit as a parking light. Figure 10 "A printed-circuit layout for a parking light" shows a completed parking-light circuit mounted on printed-circuit board.

You must not use this circuit to switch on current to a lamp connected to the mains. Why? However, you could replace the bulb by a relay and use the relay contacts to control the mains current. This would enable the circuit to switch on a porch light, for instance, when darkness fell. Note that, if the circuit is to be used with a relay and the mains supply, you must be sure to heed to warning given about using mains voltages!

Is there any way in which you could use this circuit in the photographic darkroom?

When this circuit is used as a parking light, it is essential that the light is not switched off when the light from passing cars falls briefly onto the photocell. C_1 , of high value, is included to damp the action of these lights; it absorbs any current changes in the potential-divider caused by sudden changes in illumination of the photocell.

Interchange the photocell and potentiometer. What is the effect on the photocell of an increase in illumination?

CIRCUIT C

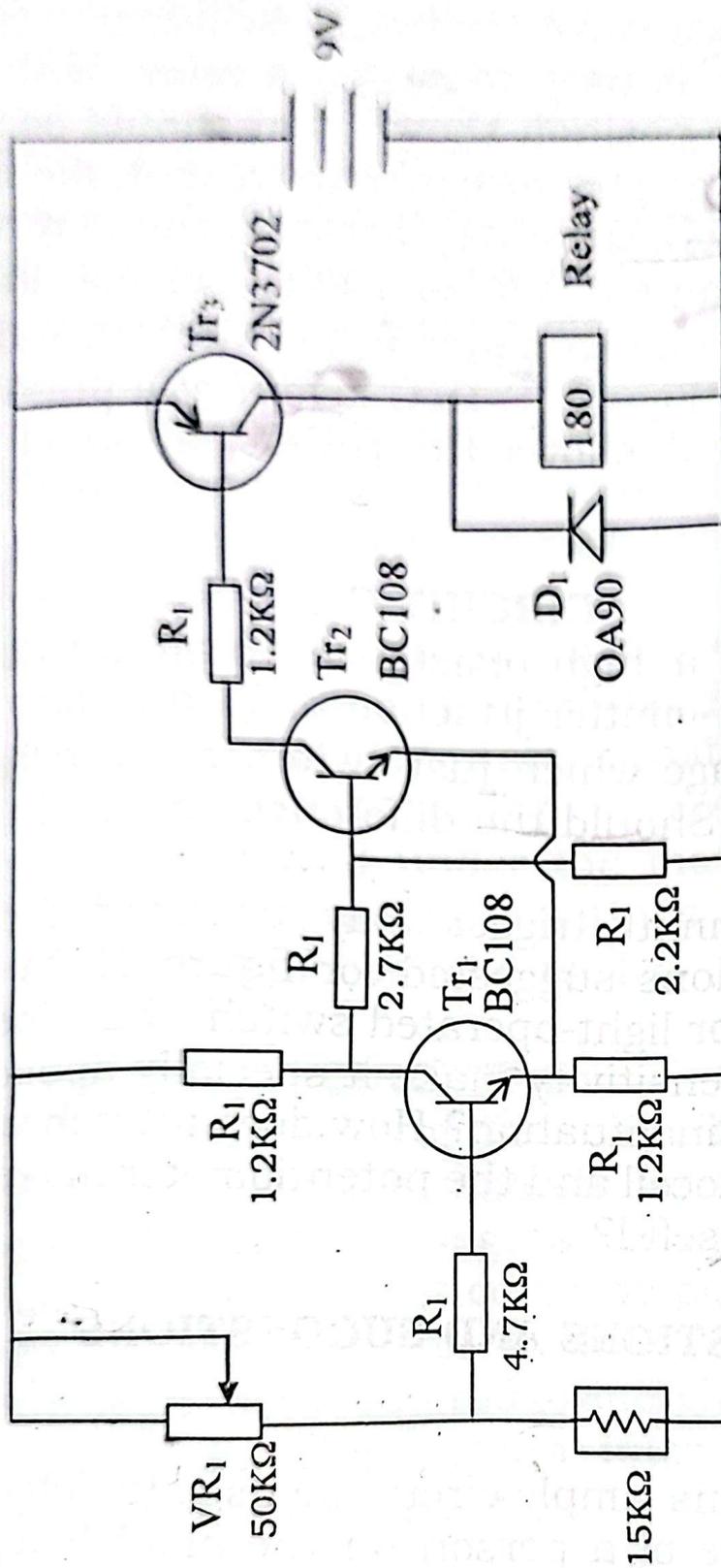


Fig. 11 Pressure sensitive electronic switch

This is shown in Figure 17. The Schmitt trigger circuit is a pressure-sensitive automatic switch circuit. The Schmitt trigger is used to switch a relay. With the potentiometer in the position shown, you should be able to adjust the pressure increased on it, the relay will go on. For more sensitive operation you may need to increase the value of V_R to $100k\Omega$, so that just a small pressure change cause T_1 to switch off and the relay to go on. Figure "S-DeC layout of a pressure-operated switch" shows the S-DeC layout of this circuit.

CIRCUIT C

Connect a high-resistance voltmeter across the base-emitter junction of T_1 , and measure the voltage which just switches the relay on and off. Should the difference be small? (See Note C)

The Schmitt trigger may be used for the applications suggested for figure 10 "A two-transistor light-operated switch", but does its higher sensitivity make it specially applicable for certain situation? How does interchanging the photocell and the potentiometer make this circuit useful?

QUESTIONS AND SUGGESTIONS

CIRCUIT A

Could this simple circuit be used to detect the presence of a person on the mat? If a relay replaced the bulb, how could the circuit be arranged to ring an electric bell?

2. What is the usefulness of the circuit if the resistor and the potentiometer are interchanged?

CIRCUIT B

1. This is a more sensitive circuit than that of figure "One-transistor pressure-operated switch". With T_{12} of the type shown, the circuit will switch on a greater load than that of the bulb illustrated. Could this circuit be used to sound an alarm when someone sits on a seat? Perhaps it might be used so that a car thief sounds the car horn as soon as he sits in the driver's seat?
2. It is suggested that you consider using this circuit in a pram. If the pram is left unattended for a while, a switch is set so that the circuit is ready to detect a drop of pressure on a resistor placed under the mattress. If the baby is lifted, an alarm sounds perhaps the "wailer" circuit could be used.

CIRCUIT C

The greater sensitivity of this circuit to pressure changes makes it more suitable for detecting the presence of smaller weights. For instance, a resistor in this circuit it could be placed under a valuable show-case item. In this application, a pressure decrease is required to energize the relay or to light a bulb; this means interchanging the resistor and the potentiometer.

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