وزارة التعليـم العالـي و البحـث العلمـي

DEMOCRATIC AND POPULAR REPUBLIC OF ALGERIA

Ministry of Higher Education and Scientific Research

National Polytechnic School of Oran Maurice AUDIN

المدرســة الوطنية المتعددة التقنيات
بوهران- موريس أودان

Department of Preparatory Education in Science and Technology

General Electronics

LAB MANUAL

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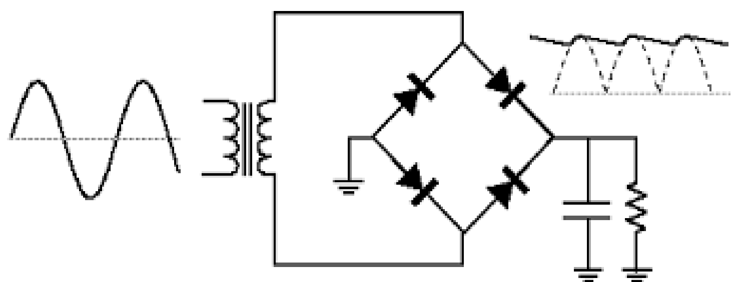

This laboratory manual is intended for second-year preparatory students within the Department of Preparatory Education in Science and Technology (PEST, 4th Semester) at the National Polytechnic School (NPS) of Oran Maurice AUDIN

Academic Year 2025 / 2026

Preface

This laboratory manual, **"General Electronics,"** has been carefully crafted to offer students a comprehensive and engaging practical learning experience. Tailored specifically for second-year students in the Department of Preparatory Education in Science and Technology (PEST, 4th Semester) at the National Polytechnic School of Oran Maurice AUDIN (ENPO-MA), this manual aligns with the official "General Electronics" curriculum. It serves as an invaluable resource not only for preparatory engineering students but also for anyone looking to build a solid foundation in experimental electronics.

Synthesizing proven pedagogical approaches and standard technical references, this guidebook bridges classroom theory and hands-on laboratory reality. The curriculum focuses on the fundamentals of semiconductor devices, guiding students from basic device physics to practical circuit implementation. Through these experiments, students will analyze the behavior of p-n junctions, explore foundational diode applications in wave shaping and rectification, evaluate the operational modes and current-gain parameters of Bipolar Junction Transistors (BJTs) and Junction Field-Effect Transistor (JFET).

The manual is organized into three core laboratory investigations :

- **Experiment No. 1 : Diode Characteristics**
- **Experiment No. 2 : Rectification**
- **Experiment No. 3 : Capacitor Filtering**
- **Experiment No. 4 : The Bipolaire Transistor : Operation and Characteristics**
- **Experiment No. 5 : The Junction Field-Effect Transistor (JFET)**

To streamline laboratory workflow and reporting, each instruction set includes a built-in datasheet template. Students can use these dedicated sections to record data and perform calculations, allowing the manual to double as a direct laboratory report.

We trust that this manual will foster a deeper, more intuitive understanding of active electronic devices and empower students to confidently apply theoretical principles to real-world hardware.

Experiment No. 1: Diode Characteristics

1. Objectives :

- To understand the behavior of a P-N junction diode and a Zener diode.
- To experimentally plot the current-voltage characteristics curve in both forward and reverse bias.
- determine the characteristic parameters: threshold voltage (V_s), dynamic resistance (R_d), and Zener voltage (V_z).
- interpret the results using equivalent models (ideal diode, simplified model with threshold, and piecewise linear model with threshold and resistance).

2. Required Equipment:

- One variable DC power supply (0 – 30 V).
- Two multimeters (one configured as a Voltmeter, the other as an Ammeter).
- a breadboard and connecting wires.
- One current-limiting resistor R = 1 kΩ (or 220 Ω).
- One Silicon rectifying diode (e.g., 1N4007 or 1N4148).
- One Zener diode (e.g., nominal Zener voltage around 4.7 V or 6.2 V).

Theoretical Part

1. Physics of the P-N Junction:

A semiconductor diode is an asymmetrical passive two-terminal device formed by the junction of two regions within the same crystal (usually Silicon) that are doped differently:

- **The P region:** doped with acceptor atoms, exhibiting a high concentration of holes (positive charges).
- **The N region:** doped with donor atoms, exhibiting a high concentration of free electrons (negative charges).

When these two regions are brought into contact, a diffusion process occurs: majority carriers cross the junction and recombine. This movement leaves uncompensated fixed ions on both sides of the junction. This region, depleted of mobile carriers, is called the **Space Charge Region (SCR)** or **depletion region**. The fixed charges create an internal electric field that opposes further diffusion and generates an internal potential barrier, denoted as V_s (threshold voltage), which is approximately 0.6V to 0.7V for Silicon at room temperature.

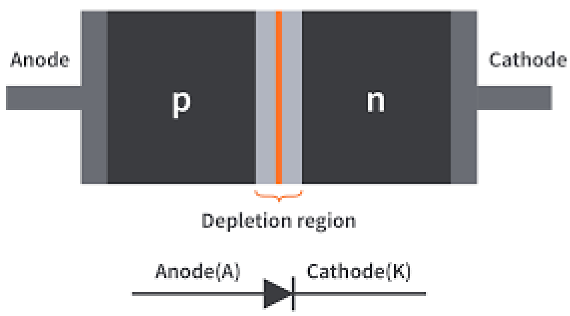

Figure 1.1 : The P-N Junction

2. Current-Voltage Characteristics:

The electrical behavior of an ideal semiconductor junction is governed by the Shockley equation:

$$I = I_s.\left(e^{\frac{V}{n.V_T}-1}\right)$$

Where I_s is the reverse saturation current (extremely low, in the nanoampere range) et n is the ideality factor (typically between 1 and 2), and V_T is the thermal voltage (≈26 mV at 25°C).

In practice, the actual characteristic curve I = f(V) has three distinct zones :

a. **The forward-bias region** (V > 0) :

- If V < V_s, the current reman negligible, almost zero.
- If V > V_s, the potential barrier is overcome. The current then increases exponentially, and the diode conducts

b. **The reverse-bias region** (V < 0)**:** The current is limited to the reverse saturation current I_s. It is so small that it is considered virtually zero in practice. The diode is blocked (off).

c. **The breakdown region** (V << 0) : If the reverse voltage exceeds the critical breakdown value (VB), the reverse current in a conventional rectifying diode increases destructively due to thermal effects.

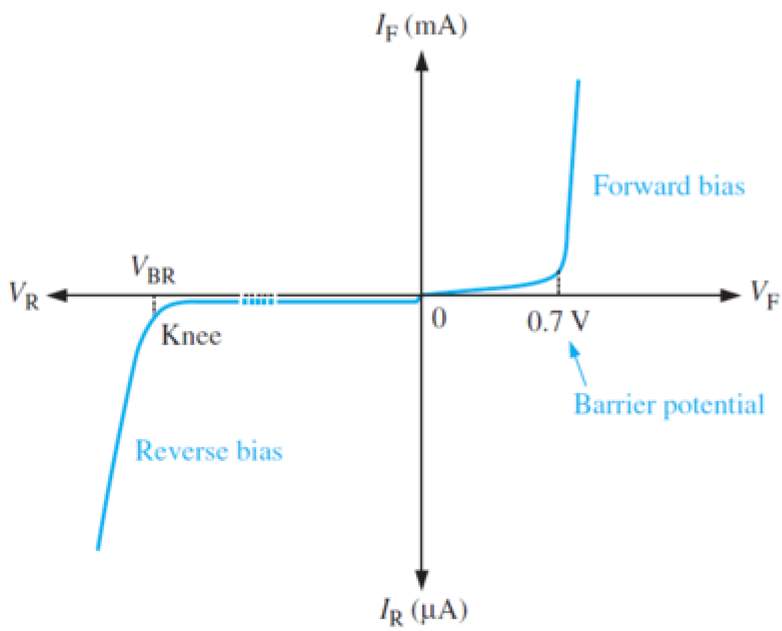

Figure 1.2 : Real diode – characteristics

3. Diode Electrical Modeling

To simplify the study of electronic circuits, the real exponential curve is replaced by three piecewise linear models:

- **Ideal Diode Model:** The threshold voltage V_s and internal resistance are neglected .
  - *Forward bias:* Equivalent to a closed switch (V = 0).

- *Reverse bias:* Equivalent to an open switch (I = 0).

- **Simplified Model with Threshold Voltage:** The threshold voltage V_s.
  - *Forward bias:* Equivalent to an electromotive force (e.m.f.) of value V_s.
  - *Reverse bias:* Equivalent to an open switch (I = 0).

- **Piecewise Linear Model (Threshold + Dynamic Resistance):**

  Forward bias: Equivalent to an e.m.f. V_s in series with a low dynamic resistance R_d. Ohm's law becomes $V = V_s + R_d.I$.
  - The dynamic resistance is calculated graphically in its linear conduction region using the following ratio:

$$R_d = \frac{\Delta V}{\Delta I}$$

which corresponds to the inverse of the slope of the I = f(V) characteristic curve

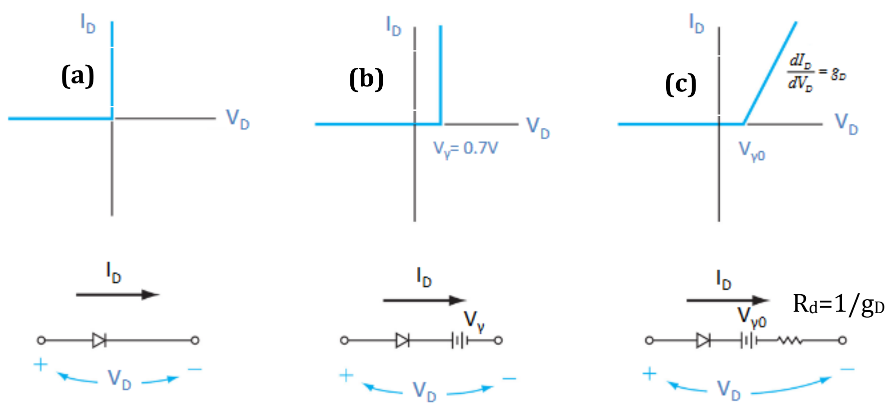

Figure 1.3 : Diode approximation models : ideal switch (a), offset-voltage (b), piecewise-linear with R_d (c)

4. Special Case : The Zener Diode

- The Zener diode is designed with heavier doping to operate reversibly, stably, and non-destructively within the reverse breakdown region

- **In Forward Bias: It behaves exactly like a conventional diode** ($V_s \approx 0,7V$).

- **In Reverse Bias: As soon as the applied reverse voltage reaches the nominal breakdown value**$|V_Z|$ (Zener Voltage), the reverse current increases sharply. The diode then maintains a highly stable voltage across its terminals, almost independent of variations in the circuit current

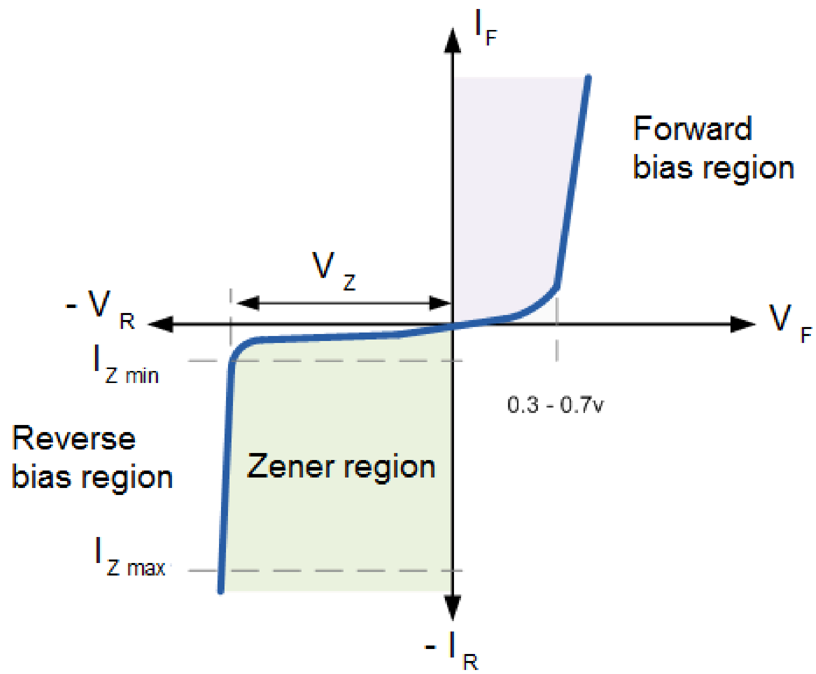

Figure 1.4 : Characteristics of Zener Diode

Major Application: Owing to this distinctive characteristic in reverse bias, the Zener diode is the component of choice for voltage regulation and overvoltage protection.

Practical Part

Part A: Characteristics of the Junction Diode :

1. **Forward Bias :**

- Consider the diagram shown in the Figure 1.5, where R is a resistor with a value of R = 1kΩ

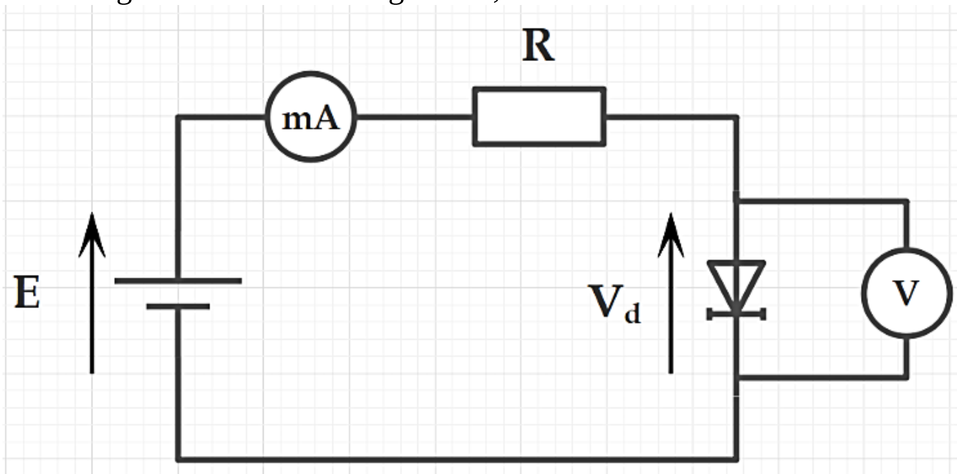

Figure 1.5

a. **Circuit Assembly:** Proceed with setting up the circuit. Ensure all components are properly connected, paying particular attention to the orientation of the diode.

N.B.: **Note the importance of correctly managing the multimeter inputs for proper operation of the milliammeter and voltmeter**.

b. **Data Acquisition:** Vary the voltage delivered by the generator from 0 to 10 V, while simultaneously recording the values of the current I_d and the voltage V_d.

Fill in the following tables with the obtained values:

E(mV)	0	100	200	300	400	500	600	700	800	900
V_d(mV)										
I(mA)										

E(V)	1	2	3	5	10
V_d(mV)					
I(mA)					

c. **Analysis of Results**:

— Formulate a comment on the behavior of the diode across the tested range of voltages, highlighting any significant observations.

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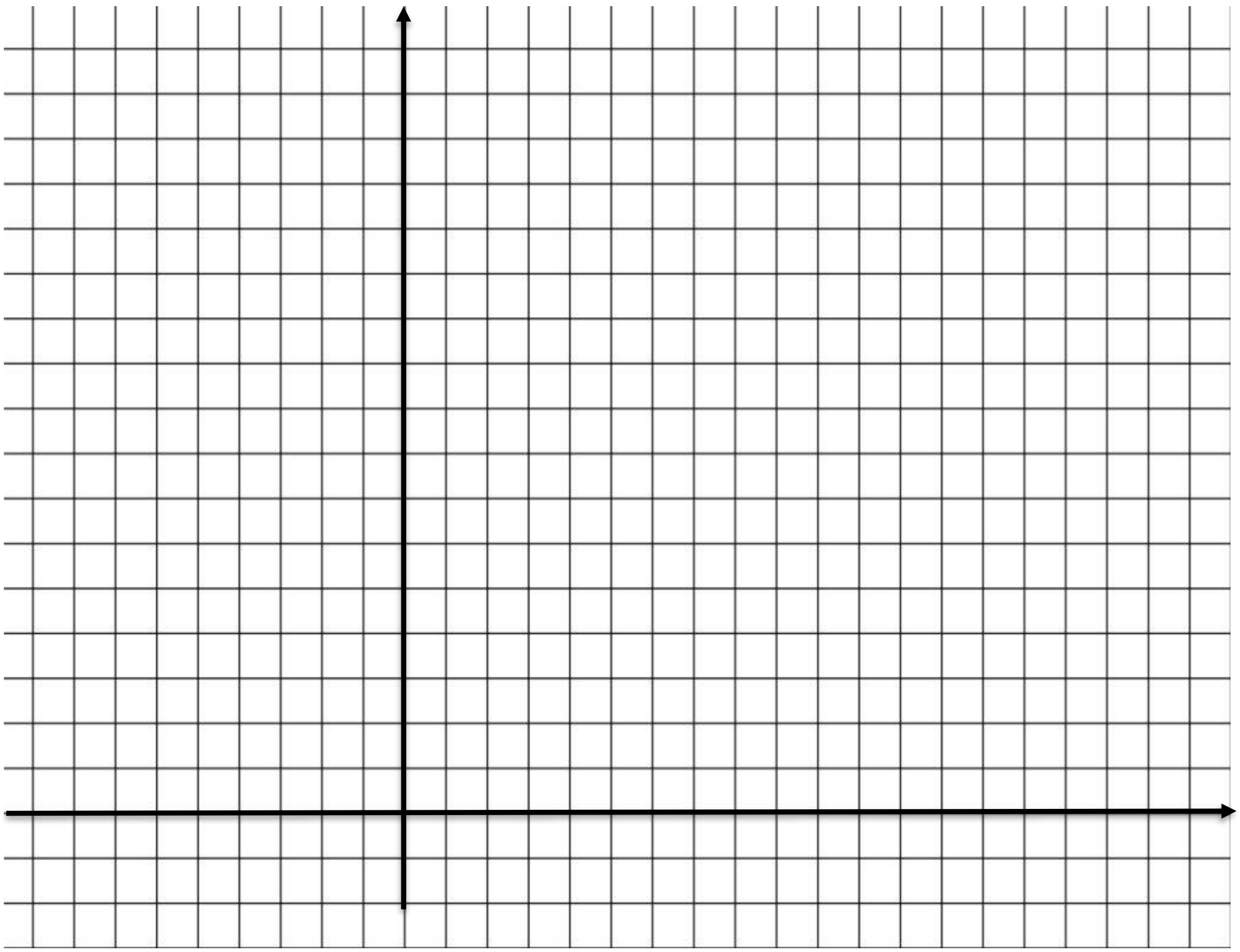
— Use the values from the first table to plot the characteristic curve I=f(V) of the diode on millimeter graph paper:



— Graphically estimate the threshold voltage of this diode V_S = …………

— Graphically determine the dynamic resistance of the diode R_d = …………

— Write the equation of the load line, then represent it graphically for E=7V.

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2. Reverse Bias

- **Manipulation:** Reconnect the diode by reversing its polarity with respect to the previous setup.
- **Data Acquisition:** Record the values of the voltage Vd (V) for different values of the input voltage and the I(µA)in the following table:

E(V)	1	2	4	10
V_d(V)				
I(µA)				

- Formulate a comment on the behavior of the diode across the tested voltage range, highlighting any significant observations.

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- Plot these values on the same graph as the one previously constructed.
- What happens if you continue to increase the supply voltage significantly?

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— Provide a physical interpretation for this phenomenon:

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Conclusion

State the conditions required on E for the diode to become conducting:

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………

Part B: Characteristics of the Zener Diode

Replace the Silicon diode with the Zener diode.

1. **In Forward Bias:** Perform a few quick measurements to verify if its behavior is identical to that of a conventional diode.
2. **In Reverse Bias:** Wire the Zener diode in reverse configuration (Cathode connected to the positive side through the protective resistor R). Vary the generator voltage from 0 to 12V. Fill in the following table (take closer data points as soon as the ammeter shows that the current begins to increase significantly):

V_d(V)	0	-2	-4	-6
I(mA)				

- On millimeter graph paper or using software (Excel, Python, Regressi), plot the characteristic curve $I_D = f(V_D)$ for the Zener diode.
- Graphically determine the forward threshold voltage V_s and the reverse Zener voltage.
- Calculate the dynamic resistance of the diode within the Zener breakdown region (R_Z).

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Explain why this component is used for voltage regulation.

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Experiment No. 2: Rectification

1. Objectives :

- To understand and analyze the operation of half-wave and full-wave (bridge) rectifier circuits.
- study the effect of a smoothing capacitor on the output voltage (filtering).
- observe waveforms on an oscilloscope and measure key parameters: peak voltage (V_p), DC voltage (V_{DC}), and ripple voltage (V_r).

2. Required Equipment (Matériel requis) :

- 1 AC Power Supply
- 4 Diodes (e.g., 1N4007).
- 1 Load Resistor (R =1kΩ).
- 1 Digital Oscilloscope.
- 1 Digital Multimeter (DMM).
- Breadboard and connecting wires.

Theoretical Part

1. Half-Wave Rectification

A half-wave rectifier allows only the positive half-cycles of the AC input voltage to pass to the load, blocking the negative half-cycles. The ideal DC output voltage is given by:

$$V_{DC} = \frac{V_m}{\pi} \approx 0.318. V_m$$

(where V_m is the peak value of the input voltage minus the diode drop V_s).

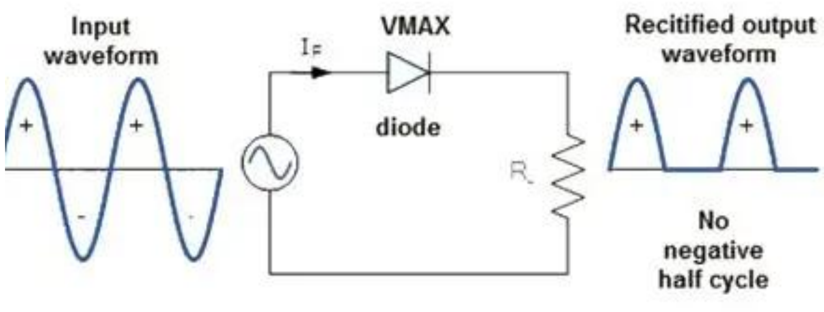


Figure 2.1 : Half-Wave Rectification

2. Full-Wave Bridge Rectification

A full-wave bridge rectifier uses four diodes arranged in a bridge configuration (Graetz Bridge) to convert both half-cycles of the AC input into a single polarity at the output. The DC output voltage is higher and smoother than the half-wave rectifier:

$$V_{DC} = \frac{2. V_m}{\pi} \approx 0.636. V_m$$

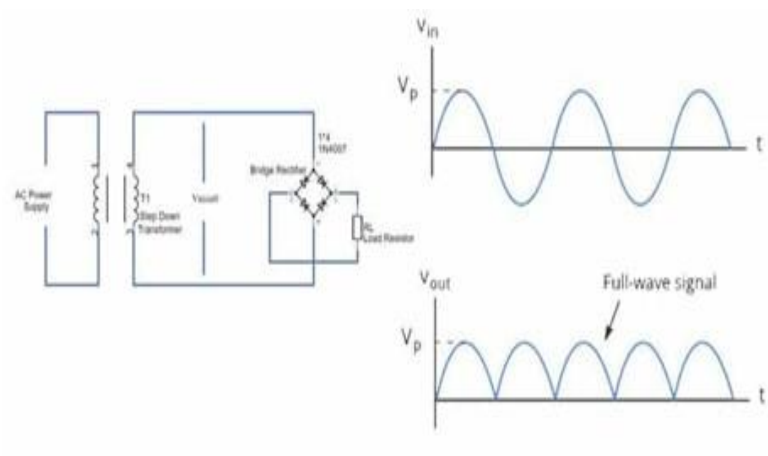


Figure 2.2 : Full-Wave Bridge Rectification

Practical Part

1. **Half-Wave Rectification:**

Circuit Assembly: Construct the circuit as indicated in the accompanying schematic diagram (Figure 2.3). The supply voltage *e*(*t*) is provided $e(t)=\mathbf{2}\sin(\mathbf{2000}\pi t)$ with a frequency of *f*=………………

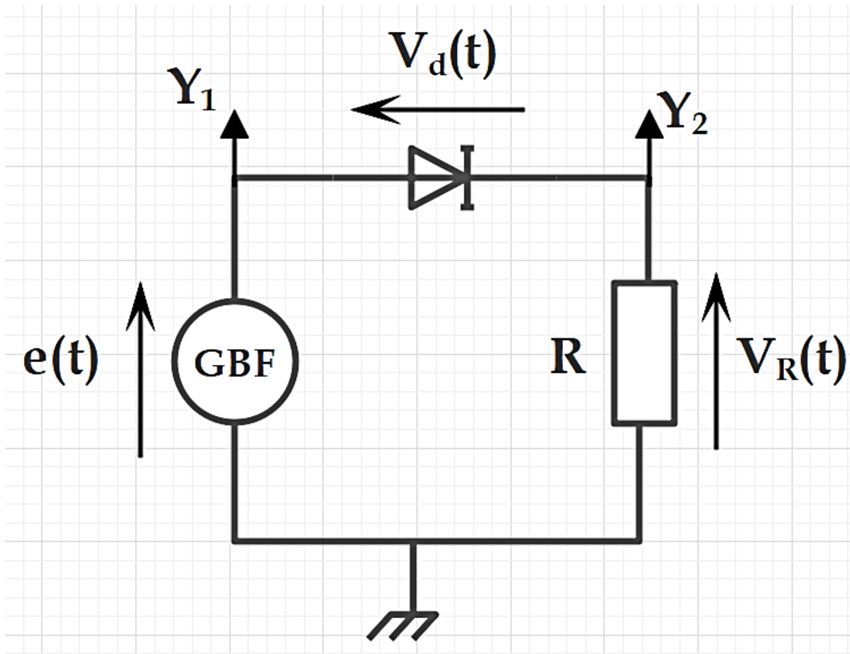


Figure 2.3

a. **Voltage Observations:** Simultaneously visualize the input voltage *e*(*t*) and the output voltage $V_R(t)$ on the oscilloscope.

Identify the maximum peak value of *e*(*t*) (*Em*) and its period (*Te*):

E_m=…………………..…, T_e=………………………

Note also the maximum value of $V_R(t)$ (V_m) and its period (T_R):

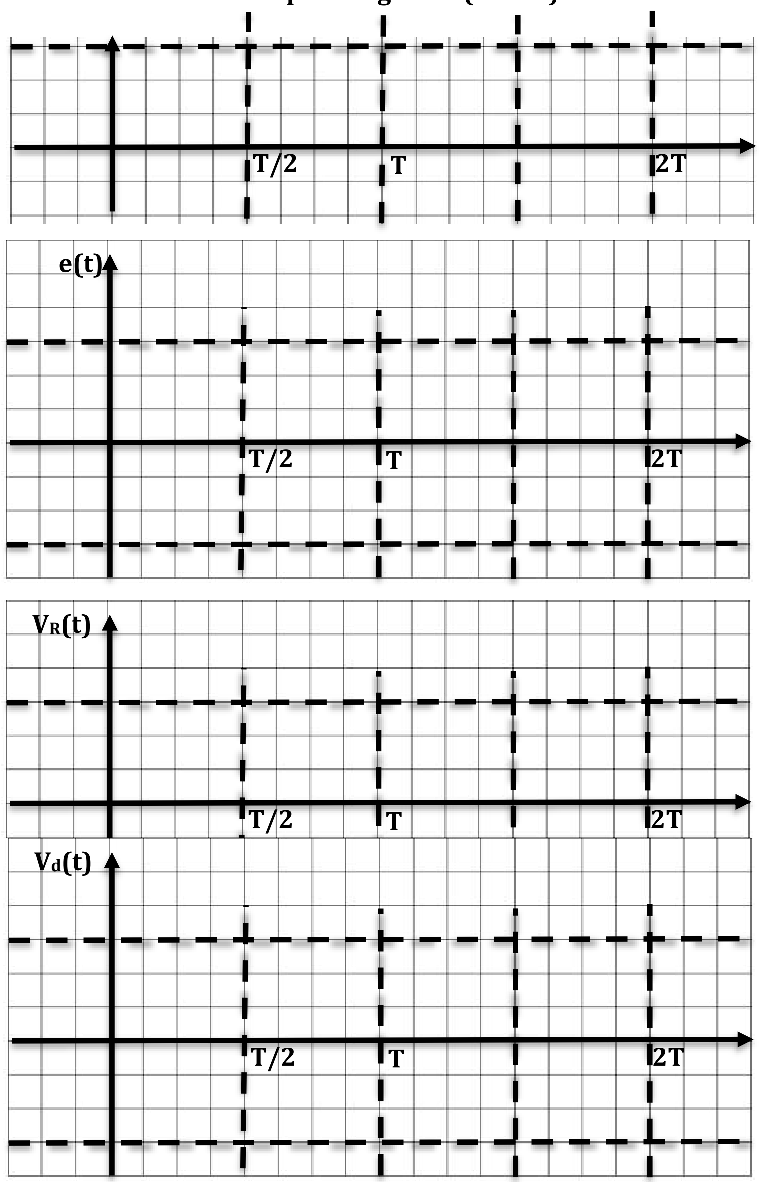
V_m=……..…...…, T_R=………………

Deduce the expression for the threshold voltage *VS* of the diode and give its value:

V_s=………….. ……………………………………………………

- **Qualitative Plots & Analysis:** Reproduce qualitatively the observed curves of $e(t)$ and $V_R(t)$, then deduce the curve of the diode voltage $V_d(t)$ and identify the state of operation (blocked blq or conducting pst) of the diode for each half-period $0<t<T/2$ and $T/2<t<2T$

Diode operating state (0 ou 1)



Deduce the expressions for $V_R(t)$ as a function of $e(t)$ and $V_d(t)$ for the following half-periods:

$0<t<\frac{T}{2}$: ………………………………………...	$\frac{T}{2}<t<T$: ………………………………………...

2. Full-Wave Bridge Rectification:

— **Circuit Assembly:** Build the circuit shown in the diagram (Figure 2.4). $e(t) = \mathbf{2}\sin(\mathbf{2000}\pi t)$

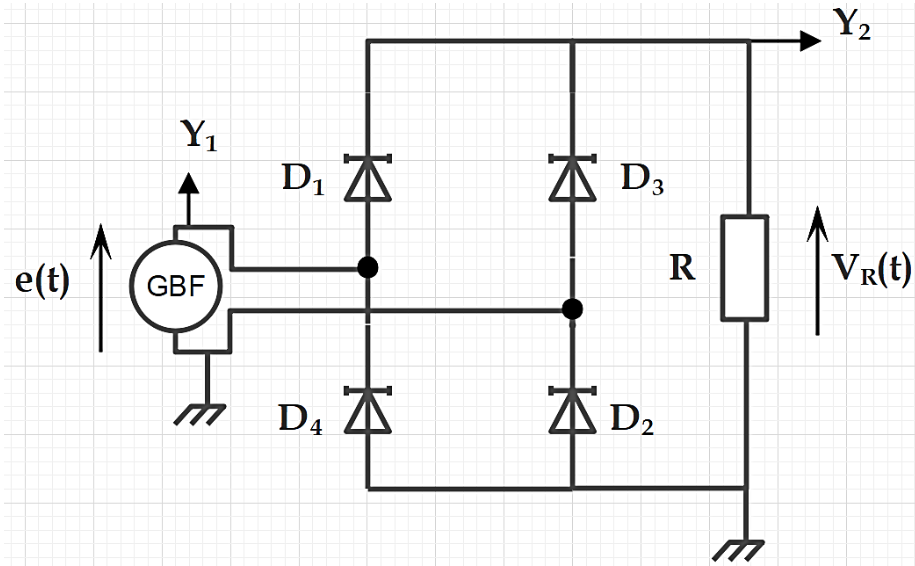


Figure 2.4

Voltage Observations : Observe the AC supply voltage *e*(*t*), and then the rectified output voltage $V_R(t)$ on the oscilloscope.

- **IMPORTANT NOTE :** Never simultaneously visualize the input voltage and the output voltage in the case of a Graetz bridge rectifier. They must be measured individually, one after the other. Why?

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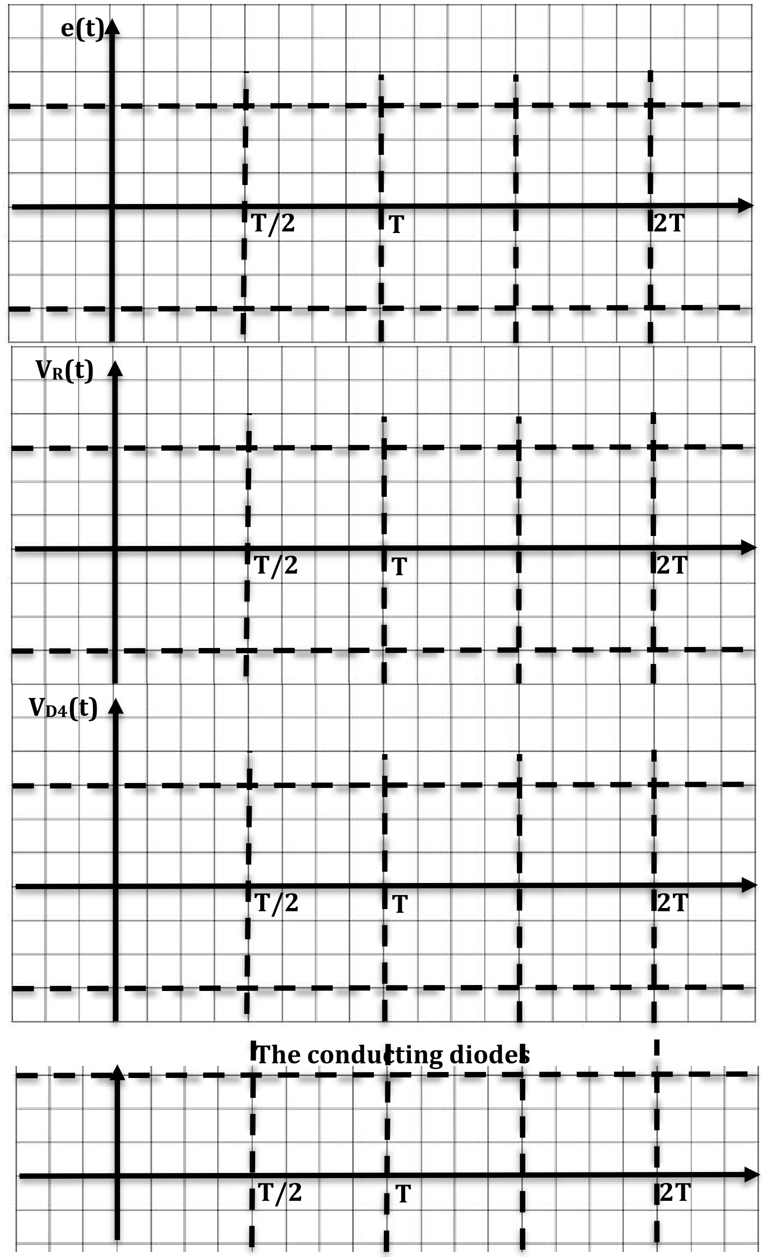
Measurements: Record: V_m=……………… , T_R=………………

Graphical Analysis: Reproduce qualitatively the observed curves of *e*(*t*) and *VR*(*t*), then deduce the voltage across a blocked diode *VD*4(*t*) and identify which diodes are conducting (pst) during each half-period $0<t<T/2$ and $T/2<t<T$.



Conclusion: Give the literal expression and then calculate the total threshold voltage drop across the conducting diode path:

V_S=……………………

Experiment No. 3: Capacitor Filtering

1. Objectives :

- To understand and analyze the operation of a smoothing capacitor in converting a pulsating DC voltage into a steady, continuous DC voltage.
- study the effect of the time constant (τ = R.C) on filtering efficiency by comparing different capacitance values (10µF and 100µF).
- To master oscilloscope measurement techniques using **AC coupling** to isolate, zoom in on, and accurately measure the peak-to-peak ripple voltage ($V_{r(p-p)}$).
- To evaluate and compare filtering performance across both half-wave and full-wave rectification configurations.
- measure and contrast key parameters, specifically the average DC output voltage (V_{DC}) using a digital multimeter (DMM) and the ripple voltage (V_r) using an oscilloscope.
- validate theoretical models by calculating the theoretical ripple factor (γ) and comparing it with experimental results.

2. Required Equipment (Matériel requis) :

- 1 AC Power Supply
- 4 Diodes (e.g., 1N4007).
- 1 Load Resistor (R =1kΩ).
- Electrolytic Capacitors (C = 10µF and C = 100µF).
- 1 Digital Oscilloscope.
- 1 Digital Multimeter (DMM).
- Breadboard and connecting wires.

Theoretical Part

To convert the pulsating DC voltage into a steady DC voltage, a smoothing capacitor C is connected in parallel with the load resistor R. The capacitor charges during the peak of the input voltage and slowly discharges through the resistor when the input drops, reducing the voltage fluctuations (ripple voltage, V_r).

When connected in parallel with a load resistor at the output of a rectifier, a capacitor acts as an energy storage device.

- **During the rising edge of the rectified voltage:** The capacitor charges quickly through the conducting diodes up to the peak voltage (V_m).
- **During the falling edge and zero-crossing zones:** The diodes become reverse-biased (turn off), and the capacitor slowly discharges its stored energy into the load resistor R.

This continuous cycle of fast charging and slow discharging smooths out the severe fluctuations of the pulsating DC, resulting in a steadier DC output. The remaining small fluctuation is called the **Ripple Voltage** ($V_{r(p-p)}$).

The efficiency of this filtering depends directly on the time constant:

$\tau = R.C$

If τ is much larger than the period of the signal (T), the discharge is slow, and the output voltage stays high, closer to the peak value.

The Ripple Factor (γ) :

The quality of the filtering is quantified by the ripple factor (γ). The lower the ripple factor, the better the filter. Mathematically, it is defined as:

$$\gamma = \frac{1}{2\sqrt{3}.f.R.C}$$

(Where f is the frequency of the rectified signal: 50 Hz or 60 Hz for half-wave, and 100 Hz or 120 Hz for full-wave).

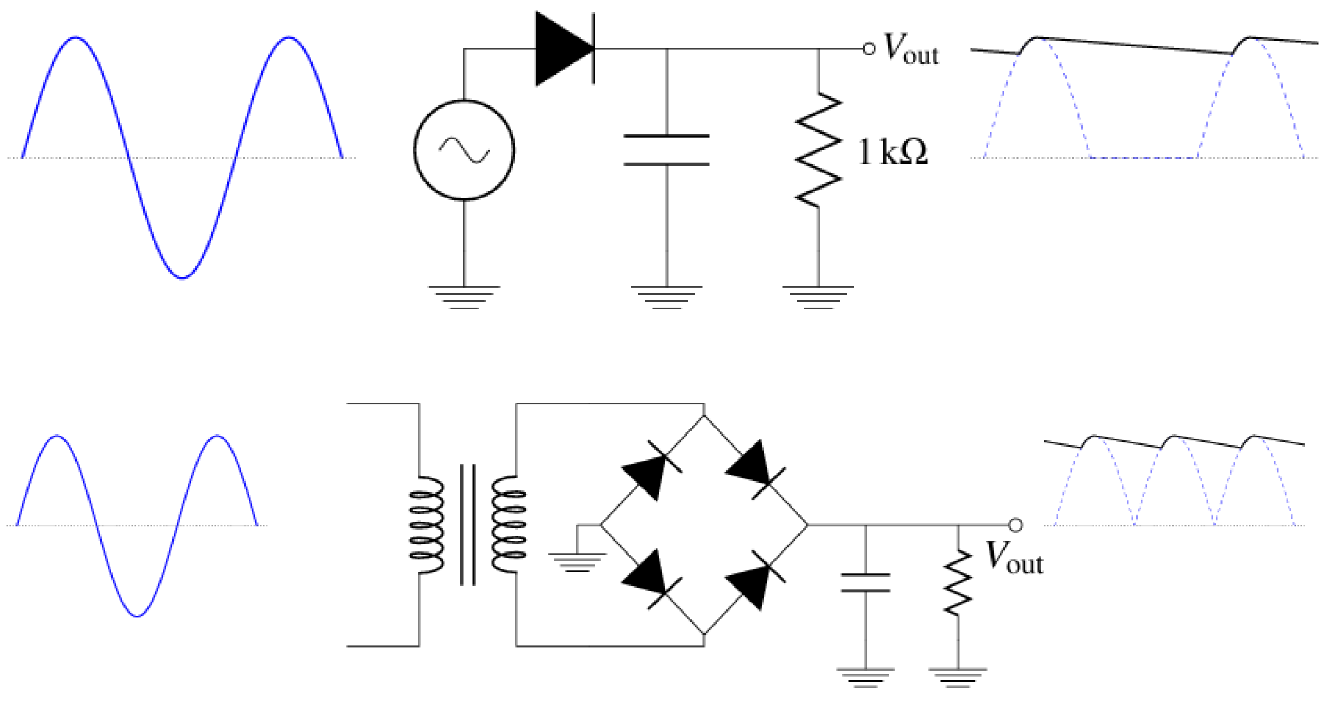


Figure 3.1 : ***half-wave, and full-wave*** **with capacitor filtering**

Practical Part

Part A: Filtering on a Half-Wave Rectifier

1. Rebuild the half-wave rectifier circuit from Experiment 2 using one diode (1N4007) and a load resistor R = 1kΩ.

2. Connect an electrolytic capacitor C = 10µF in parallel with the resistor R (Figure 3.2).

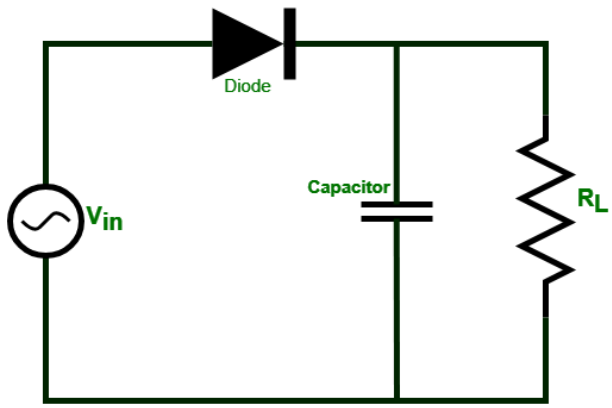


Figure 3.2

3. Observe the new output waveform on the oscilloscope.
4. To measure the ripple voltage accurately: Switch the oscilloscope channel setting from **DC coupling to AC coupling**. Increase the vertical sensitivity (Volts/Div) to zoom in on the ripple waveform. Measure the peak-to-peak ripple voltage ($V_{r(p-p)}$).
5. Switch the oscilloscope back to **DC coupling** and measure the average DC output voltage (V_{DC}) using the digital multimeter (DMM).
6. Replace the 10µF capacitor with a 100µF capacitor and repeat the measurements.

Part B: Filtering on a Full-Wave Bridge Rectifier

1. Assemble the full-wave Graetz bridge rectifier circuit using 4 diodes and the load resistor R = 1kΩ.

2. Connect the 10µF capacitor in parallel with R (respecting polarity) (Figure 3.3).

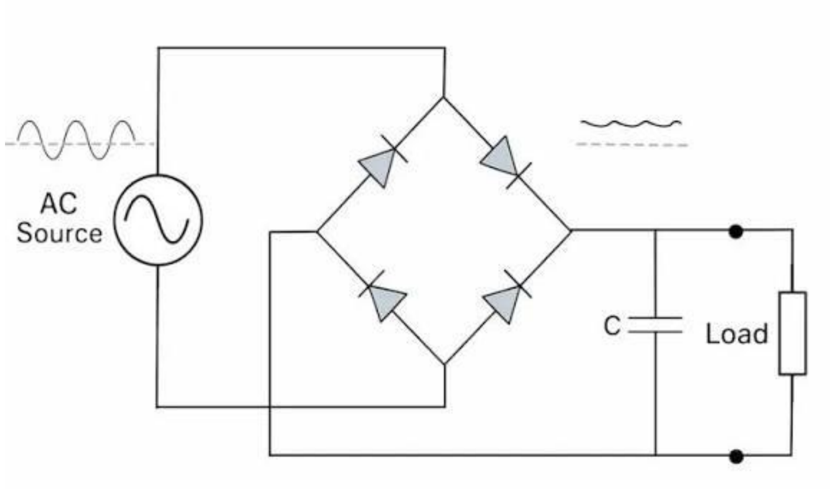


Figure 3.3

3. Observe the waveform. Use AC coupling to measure $V_{r(p-p)}$ and the DMM in DC mode to measure V_{DC}.

4. Replace it with the 100µF capacitor and complete your measurements.

5. Fill out the following comparative table based on your observations:

Rectifier Type	Capacitor Value (C)	Output Waveform Shape	V_{DC} (Measured with DMM)	$V_{r(p-p)}$ (Ripple Voltage)
Half-Wave	**No Capacitor**			
Half-Wave	**10µF**			
Half-Wave	**100µF**			
Full-Wave	**No Capacitor**			
Full -Wave	**10µF**			
Full -Wave	**100µF**			

1. Analyze the effect of the capacitor value (C) on both the ripple voltage (V_r) and the average DC output voltage (V_{DC}). What happens when C increases? Why?

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2. Compare the filtering efficiency of the 10μF capacitor in the Half-Wave circuit versus the Full-Wave circuit. Explain why the same capacitor performs significantly better in a full-wave rectifier configuration *(Hint: consider the time available for the capacitor to discharge)*.

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3. Calculate the theoretical ripple factor γ for both the 10μF and 100μF capacitors in the Full-Wave configuration using the formula: $\gamma = \frac{1}{2\sqrt{3}.f.R.C}$. Compare these values with your experimental observations.

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Experiment No. 4: The Bipolar Transistor: Operation and Characteristics

1. **Objectives**

- To understand the working principle of a bipolar junction transistor.
- To identify the different operating regions: cutoff, saturation, and active region.
- study the input and output characteristics of the transistor by plotting and analyzing the curves $I_C=f(V_{CE})$ and $I_B=f(V_{BE})$.
- determine fundamental parameters such as the current gain (β).
- To experimentally verify the relationship between currents: $IC \approx \beta \cdot IB$.
- become familiar with using laboratory measurement instruments (multimeter, power supplies, etc.).

2. Required Equipment

- A DC power supply generator.
- Two digital multimeters.
- Two resistors: 1 kΩ or 10 kΩ.
- One BJT transistor (BD137 or BC140).
- Breadboard, banana-to-banana cables, and multimeter probes.

Theoretical Part

1. Introduction :

After exploring the diode, it is time to dive into a much more versatile component : the transistor. These elements play a crucial role in the design of modern electronic circuits found in computers, phones, and a multitude of other electronic systems in our daily lives. To give you an idea, current generations of microprocessors can integrate up to nearly a billion transistors. They are used in a variety of configurations, including filters, voltage regulators, or amplifiers.

Physically, transistors are three-terminal components across which electric voltages can be applied.

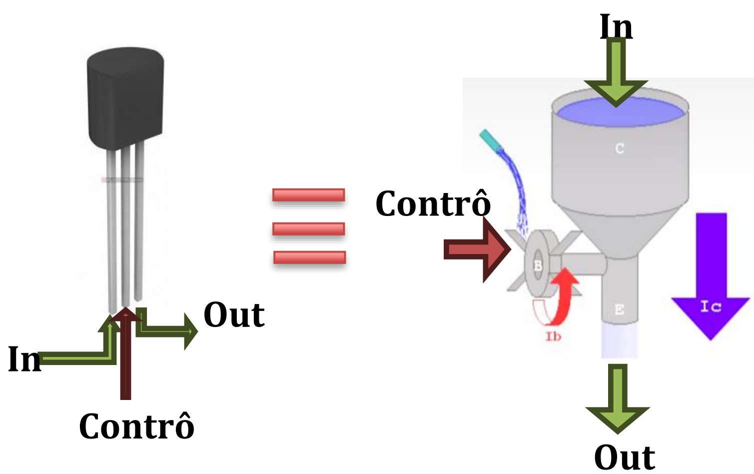
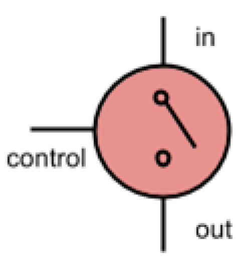
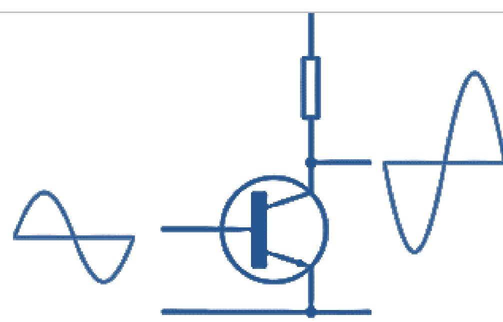


Figure 4.1: The Transistor

Their primary applications are divided into two main categories: as **switches** or as **amplifiers**.

	
A transistor serves as a controllable switch	**A bipolar transistor operates as a current/voltage amplifier: it amplifies the current sent to its base**

Most commonly, they are used as **controlled switches**, meaning switches whose state is governed by their third terminal. They act as open or closed switches depending on what signal is applied to this control terminal.

Alternatively, they can function as **amplifiers**. In this mode, they amplify the voltage or the current passing through them. Their amplification capability is determined by the voltage and current applied to the third pin. More specifically, bipolar transistors are current amplifiers: they receive a small current on their input pin and produce an amplified version of it at the output pin. The amplification coefficient depends directly on the parameters applied to the control pin.

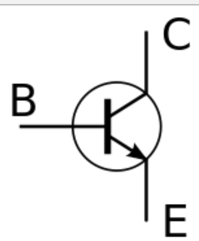
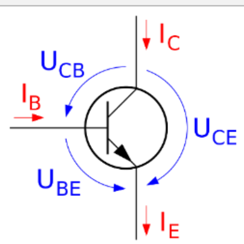
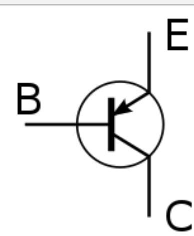
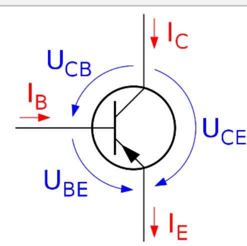
There are various types of transistors, the two main classes being **Bipolar Junction Transistors (BJT)** and **Field-Effect Transistors (FET)**. In this lab experiment, we will limit our study to BJT transistors.

2. NPN and PNP Transistors :

There are two distinct polarities of bipolar junction transistors: **NPN** and **PNP**. The primary distinction lies in the direction of the schematic arrow: it points outward from the base for NPN types and inward toward the base for PNP types.

The three pins making up a bipolar transistor are as follows:

- **The Base (B):** Controls the flow of current through the component.
- **The Collector (C):** The pin through which the current enters the bipolar transistor.
- **The Emitter (E):** The pin through which the current leaves the component, as well as the output signal.

Transistor NPN		**Transistor PNP**	
			
Symbol	**Voltage and current representations**	**Symbol**	**Voltage and current representations**

3. The Physics of a Bipolar Transistor:

You will have noticed that the terms NPN and PNP bring to mind P-N junctions. This is no coincidence: every BJT is made up of two P-N junctions connected in series. Since a P-N junction is a diode, a transistor can be considered—apart from a few details—as being composed of two diodes connected in series in opposite directions**.**

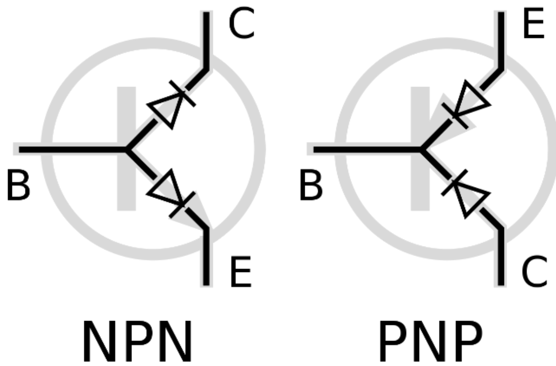


Figure 4.2: Internal diodes of a BJT transistor.

The assembly results in a group of three semiconductor pieces placed side-by-side. For NPN transistors, a P-doped region is found between two N-doped regions. For PNP transistors, it is the exact opposite: an N-doped region is located between two P-doped regions. Each pin is connected directly to a specific semiconductor section: the left pin is connected to the emitter, the middle pin is connected to the base, and the right pin is connected to the collector. A transistor therefore has two junctions: one between the emitter and the base, and another between the base and the collector

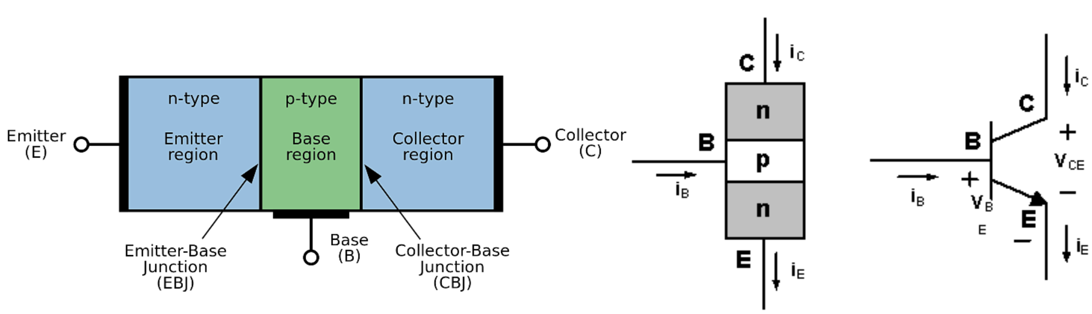


Figure 4.3: Pinout and schematic symbol of a bipolar transistor

4. Characteristics of the NPN Bipolar Transistor :

The operation of the NPN bipolar transistor is characterized by curves that link the electrical quantities defined previously. Since I_E and V_{CB} can be deduced from the other four variables, it is standard practice to consider the characteristics curves relating I_B, I_C, V_{BE}, and V_{CE} (Figure 4.4).

We have:

$$I_E = I_C + I_B$$

and : $I_C = \beta.I_B$ with $\beta >> 1$ in the linear operating region

The static characteristics of a bipolar transistor (Figure III.3) consist of:

- **Input Characteristics:**

$I_B = f(V_{BE})$ at a constant V_{CE}. This represents the characteristic curve of a diode with a threshold voltage of V_{BE0} = 0.6 V sim 0.7 V.

- **Voltage Transfer Characteristics:**

$V_{BE} = f(V_{CE})$ at a constant I_B.V_{BE} varies very little with changes in V_{CE}.

- **Current Transfer Characteristics:**

$I_C = f(I_B)$. The collector current IC and the base current I_B are linked by the fundamental relationship $I_C = \beta.I_B$. The coefficient β (current gain) is a intrinsic characteristic of the transistor. It is generally on the order of several tens to a few hundreds, depending on the transistor type.

- **Output Characteristics:**

$I_C = f(V_{CE})$ depends on the value of I_B, and consequently on V_{BE}, which ultimately results in a family of characteristic curves.

It is worth noting that NPN transistors are the most widely used and offer better performance characteristics.

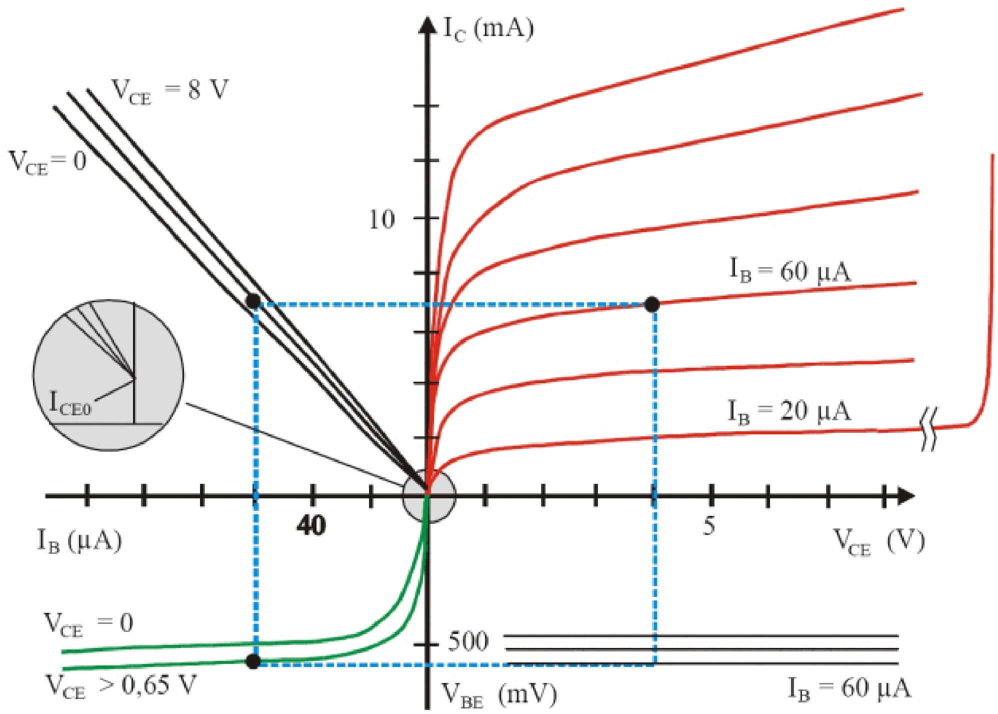


Figure 4.4: Characteristic curves diagram of an NPN transistor in common-emitter configuration

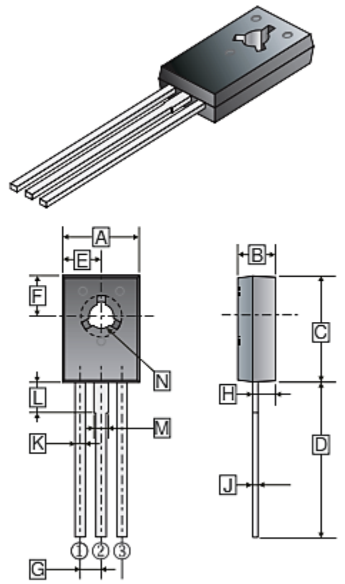
Operating Regions (Modes):

The bipolar transistor can operate in two different regions or modes:

- **The Linear Region (Amplification Mode):** In this mode, the transistor regulates and controls the amount of current passing through it.
- **The Saturation/Cutoff Region (Switching Mode):** In this case, the transistor operates in two states: either cutoff (off) or saturated (fully on). In the cutoff state, no current flows through the component. In the saturated state, the transistor allows current to pass fully from the collector to the emitter.

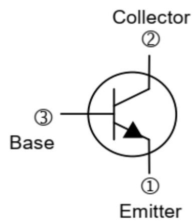
Transistor Datasheet (BD135, BD137, BD139) and (BC140, BC141)

<u>BD135, BD137, BD139 :</u>

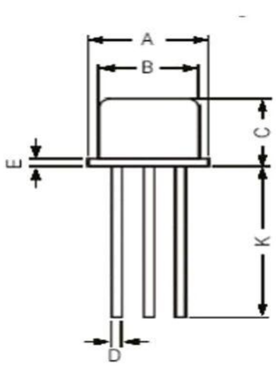


①Emitter
②Collector
③Base

REF.	Millimeter		REF.	Millimeter	
	Min.	Max.		Min.	Max.
A	7.40	7.80	H	1.10	1.50
B	2.50	2.90	J	0.45	0.60
C	10.60	11.00	K	0.66	0.86
D	15.30	15.70	L	2.10	2.30
E	3.70	3.90	M	1.17	1.37
F	3.90	4.10	N	3.00	3.20
G	2.29 TYP.				

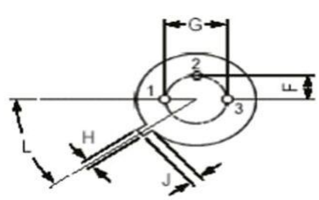


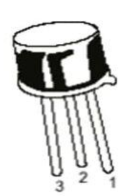
BC140, BC141



Dimension	Minimum	Maximum
A	8.50	9.39
B	7.74	8.50
C	6.09	6.60
D	0.40	0.53
E	-	0.88
F	2.41	2.66
G	4.82	5.33
H	0.71	0.86
J	0.73	1.02
K	12.70	-
L	42°	48°

Dimensions : Millimetres





Pin Configuration:
1. Emitter
2. Base
3. Collector

ABSOLUTE MAXIMUM RATINGS (T_A=25℃ unless otherwise specified)

Parameter		Symbol	Rating	Unit
Collector to Base Voltage	BD135	V_{CBO}	45	V
	BD137		60	
	BD139		80	
Collector to Emitter Voltage	BD135	V_{CEO}	45	V
	BD137		60	
	BD139		80	
Emitter to Base Voltage		V_{EBO}	5	V
Collector Current-Continuous		I_C	1.5	A
Collector Power Dissipation		P_C	1.25	W
Thermal Resistance From Junction To Ambient		$R_{\theta JA}$	100	℃ / W
Junction, Storage Temperature		T_J, T_{STG}	150, -55~150	℃

Symbol	Ratings		Value	Unit
V_{CBO}	Collector-Base Voltage $I_E = 0$	BC140	80	V
		BC141	100	
V_{CEO}	Collector-Emitter Voltage $I_B = 0$	BC140	40	V
		BC141	60	
V_{EBO}	Emitter-Base Voltage $I_C = 0$	BC140	7	V
		BC141		
I_C	Collector Current	BC140	1	A
		BC141		
I_B	Base Current	BC140	0.1	A
		BC141		
P_{tot}		@ T_{case}= < 45°	3.7	W
		@ T_{amb}= < 45°	0.65	
T_J	Junction Temperature		175	°C
T_{Stg}	Storage Temperature range		-55 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A=25℃ unless otherwise specified)

Parameter		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Collector to Base Breakdown Voltage	BD135	$V_{(BR)CBO}$	45	-	-	V	I_C=0.1mA, I_E=0
	BD137		60	-	-		
	BD139		80	-	-		
Collector to Emitter Breakdown Voltage	BD135	$V_{CEO(SUS)}$*	45	-	-	V	I_C=0.03A, I_B=0
	BD137		60	-	-		
	BD139		80	-	-		
Emitter to Base Breakdown Voltage		$V_{(BR)EBO}$	5	-	-	V	I_E=0.1mA, I_C=0
Collector Cut–Off Current		I_{CBO}	-	-	0.1	μA	V_{CB}=30V, I_E=0
Emitter Cut–Off Current		I_{EBO}	-	-	10	μA	V_{EB}=5V, I_C=0
DC Current Gain		$h_{FE(1)}$*	40	-	250		V_{CE}=2V, I_C=150mA
		$h_{FE(2)}$*	25	-	-		V_{CE}=2V, I_C=5mA
		$h_{FE(3)}$*	25	-	-		V_{CE}=2V, I_C=500mA
Collector to Emitter Saturation Voltage		$V_{CE(sat)}$*	-	-	0.5	V	I_C=500mA, I_B=50mA
Collector Output Capacitance		V_{BE}*	-	-	1	V	V_{CE}=2V, I_C=500mA

*Pulse test：pulse width≦350μs, duty cycle≦2.0%

Symbol	Ratings	Test Condition(s)		Min	Typ	Max	Unit
I_{CES}	Collector – Cutoff Current	I_E= 0 V_{CES}= 60 V	BC140	-	-	100	nA
			BC141				
		I_E= 0, V_{CES}= 60 V T_{amb} = 150°c	BC140	-	-	100	μA
			BC141				
V_{CB0}	Collector – Base Breakdown Voltage	I_C = 100 μA I_E= 0	BC140	80	-	-	V
			BC141	100	-	-	
V_{CE0} (*)	Collector – Emitter Breakdown Voltage	I_C = 30 mA I_B= 0	BC140	40	-	-	V
			BC141	60	-	-	
V_{EB0}	Emitter – Base Breakdown Voltage	I_E= 100 μA I_C= 0	BC140	7	-	-	V
			BC141				
$V_{CE(SAT)}$ (*)	Collector-Emitter saturation Voltage	I_C= 100 mA , I_B= 10 mA		-	0.1		V
		I_C= 500 mA , I_B= 50 mA		-	0.35		
		I_C= 1 A, I_B= 100 mA		-	0.6	1	
V_{BE} (*)	Base-Emitter Voltage	I_C= 1 A , V_{CE}= 1V			1.25	1.8	
h_{FE} (*)	DC Current Gain	I_C= 100 μA , V_{CE}= 1 V		-	75	-	-
			Gr 10	-	40	-	
			Gr 16	-	90	-	
		I_C= 100 mA , V_{CE}= 1 V		40	140	250	
			Gr 10	63	100	160	
			Gr 16	100	160	250	
		I_C= 1 A , V_{CE}= 1 V		-	26	-	
			Gr 10	-	20	-	
			Gr 16	-	30	-	
f_T	Transition Frequency	I_C= 50 mA , V_{CE}= 10 V		50	-	-	MH_Z
C_{CBO}	Collector – base Capacitance	I_E= 0 ;V_{CB}= 10V f = 1 MH_Z		-	12	25	pF
t_{off}	Turn-off times	I_C=100 mA I_{B1}=-I_{B2}=5 mA		-	-	850	ns
t_{on}	Turn-on times	I_C=100 mA I_{B1}=1 mA		-	-	250	ns

Practical Part

Input Characteristic I_B=f(V_{BE}) :

a. **Circuit Assembly:** Proceed to set up the circuit illustrated in the adjacent figure, where R_B=10 kΩ and R_C=100 Ω. Ensure all components are connected correctly, paying particular attention to the orientation of the transistor. Set voltage E_2 to 5 V and leave E_1 at 0 V.

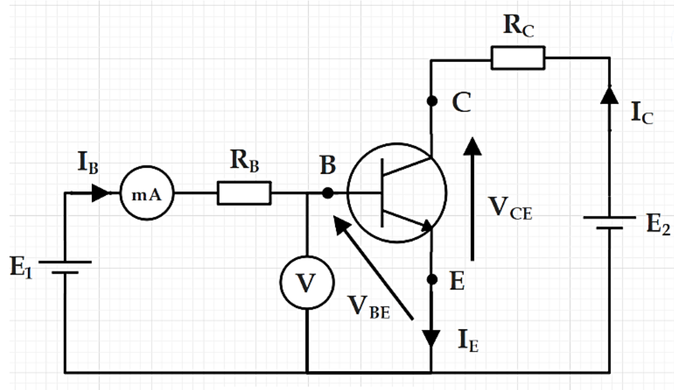


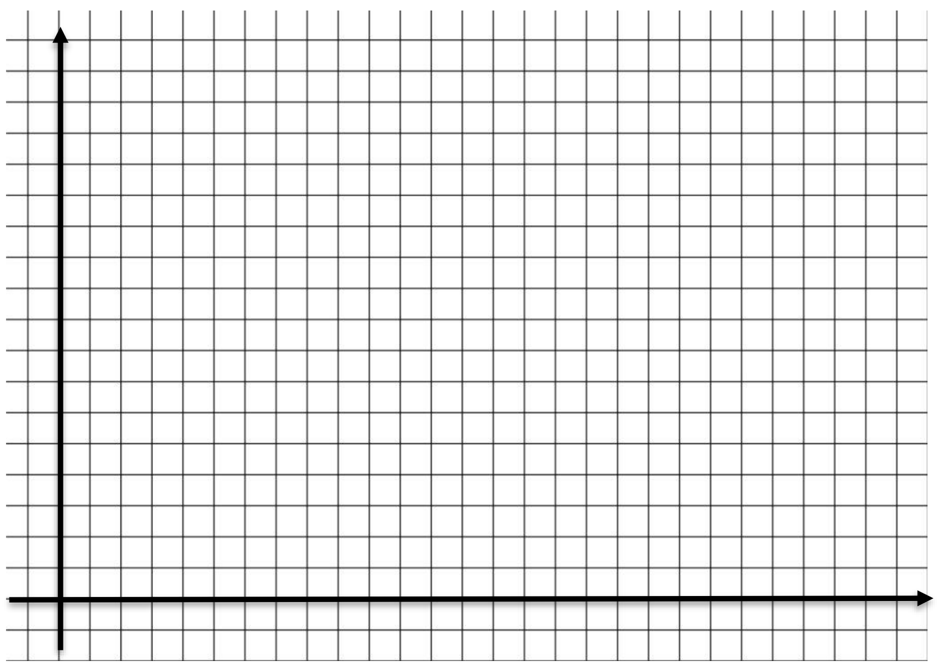
Figure 4.5

b. **Data Acquisition:** * Vary the voltage E_1 from 0 to 20 V, simultaneously recording the values of the voltage *VBE* and the current *IB*. Use the following table:

E_1(V)	0	2	4	6	8	10	12	14	16	18	20
V_{BE} (V)											
I_B (mA)											

c. **Analysis of Results:**

Plot the curve I_B=$f(V_{BE})$ and determine to which component the Base-Emitter junction can be compared



Transfer Characteristic $I_C=f(I_B)$:

a. Circuit Assembly:

Keep the same circuit setup as before, but set the multimeter to mA mode to measure I_C. Use the analog voltmeter to set the voltage V_{CE} to 3 V using E_2 and leave E_1 at 0 V.

b. Data Acquisition:

- Vary the voltage E_1 from 0 to 10 V following the values in the table below. For each value, adjust the voltage E_2 until VCE is equal to 3 V, then record the values of I_C and I_B.

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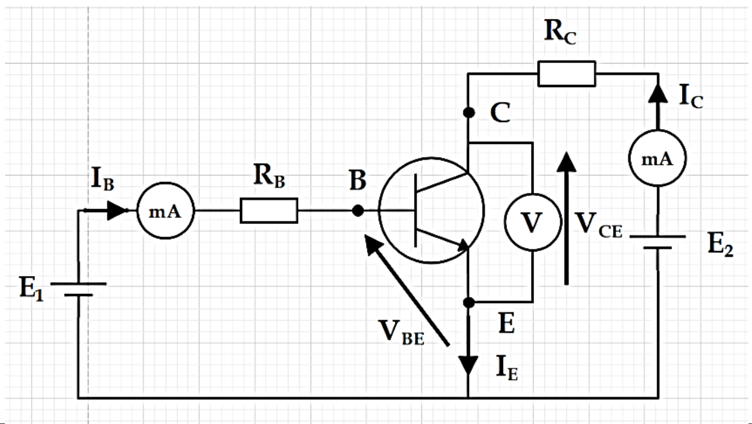
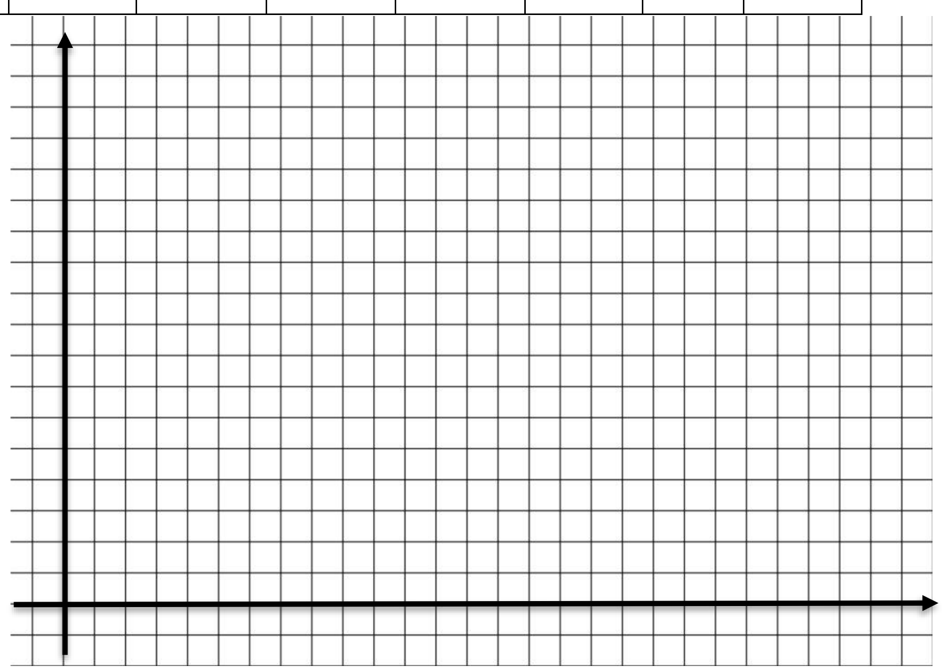


E_1(V)	0	1	2	3	4	5	6	7	8	9	10
I_B(mA)											
I_C(mA)											

c. Analysis of Results:

Plot the curve $I_C=f(I_B)$ and determine the current amplification factor β for the linear portion of the characteristic curve. Then, compare this value to the one provided by the manufacturer.



Output Characteristic $I_C=f(V_{CE})$:

1. Circuit Assembly: Keep the same circuit setup as before. By adjusting the power supply E_2, vary V_{CE} while maintaining the base current at I_B=1 mA (the base current *IB* is kept constant by adjusting the power supply E_1).

2. Data Acquisition:

- Vary the voltage V_{CE} from 0 to 10 V following the values in the table below, and simultaneously record the value of I_C.

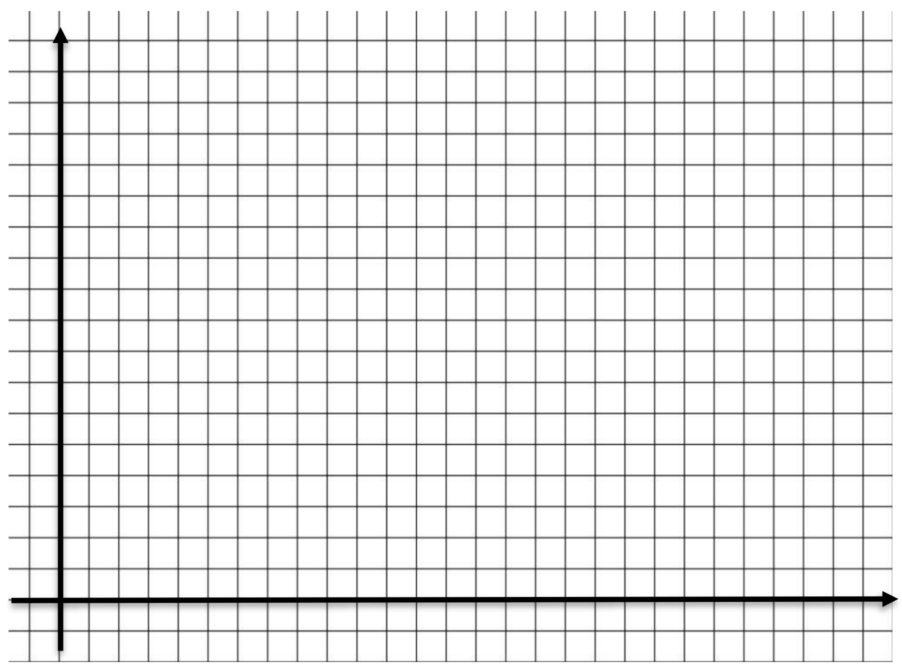
I_B=cte=1mA											
V_{CE}(V)	0	1	2	3	4	5	6	7	8	9	10
I_C(mA)											

- **Same procedure for I_B=0.5 mA**

I_B=cte=0.5mA											
V_{CE}(V)	0	1	2	3	4	5	6	7	8	9	10
I_C(mA)											

Analysis of Results :

Tracer les courbes $I_C=f(V_{CE})$ pour les deux valeurs de I_B.



Analysis of Characteristics :

1. Load Line:

- Establish the literal relationship between the collector-emitter voltage (V_{CE}), the collector resistance (R_C), the collector current (I_C), and the power supply voltage (E_2).

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The curve corresponding to the equation $I_C=f(V_{CE})$ is called the **load line** of the transistor. Plot this line on the $I_C=f(V_{CE})$ graph. Then, deduce the coordinates of the **operating point** (Q-point).

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Conclusion

In the linear (active) region, the governing equations for the transistor are:

- Relationship between I_C, I_B, and I_E: …………………………………………………

Relationship between I_C and I_B: …………………………………………………

Experiment No. 5 : The Junction Field-Effect Transistor (JFET)

1. Objectives

- investigate the physical behavior, operational principles, and terminal electrical properties of an N-channel Junction Field-Effect Transistor (JFET).
- To experimentally map and evaluate the Static Drain Characteristics ($I_D = f(V_{DS})$ at a constant V_{GS}).
- plot the Transfer Characteristic Curve ($I_D = f(V_{GS})$ at a constant VDS) in order to extract the maximum saturation current (I_{DSS}) and the pinch-off voltage (V_P).

2. Required Equipment

- N-channel JFET (e.g., 2N3819 or BF245).
- 2 Variable, Independent DC Power Supplies.
- 2 High-precision Digital Multimeters (DMMs) for current and voltage monitoring.
- 1 Current-limiting resistor ($R_D = 1\ k\Omega$).
- 1 Laboratory breadboard and jumper wires.

Theoretical Part

1. **Introduction:** In contrast to the Bipolar Junction Transistor (BJT), which acts as a current-controlled device, the Junction Field-Effect Transistor (JFET) is a voltage-controlled semiconductor device. The majority charge carrier flow through the conductive channel (Drain current, I_D) is regulated strictly by the reverse-bias voltage applied across the Gate-to-Source p-n junction (V_{GS}).

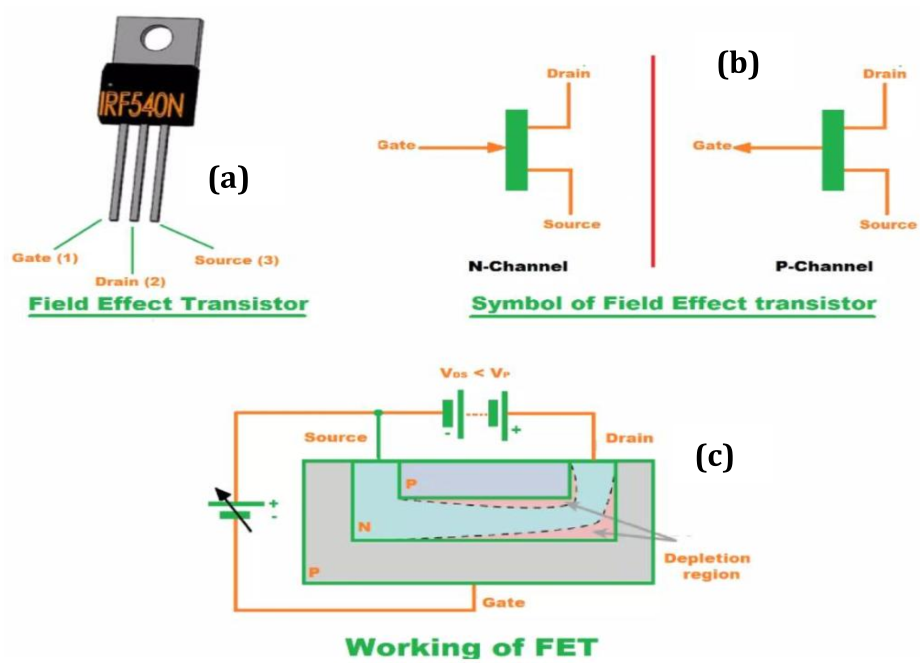


Figure 5.1 : FET (a), Symbol (b) and Working of Field-Effect Transistor (c)

2. **Fundamental Parameters and Equations:**
   a. **Saturation Drain Current (I_{DSS}):** The absolute maximum current through the channel when the gate-source voltage is zero (V_{GS} = 0 V) and the device is operating beyond the pinch-off point.
   b. **Pinch-off Voltage (V_P or V_{GS}(off)):** The exact negative gate voltage that expands the depletion regions to completely close the channel, choking the drain current down to 0 A.
   c. **Shockley's Equation:** When operating in the saturation (active) region, the control relationship between the input voltage and output current is defined by:

$$I_D = I_{DSS} \times (1 - V_{GS} / V_P)^2$$

Practical Part

Part A: Determination of Static Drain Characteristics ($I_D = f(V_{DS})$)

This section analyzes how the output channel current reacts to a changing drain-source voltage under fixed input field conditions.

1. Assemble the test circuit on the breadboard. Pay close attention to the JFET packaging pinout (Gate, Drain, Source) to avoid improper bias.

2. Adjust the first DC source to apply a negative biasing voltage to the gate terminal ($V_{GS} \leq 0$ V).

3. Connect the second variable DC source to the drain loop via the 1 kΩ series resistor to sweep the voltage V_{DS}.

4. Initialize the gate bias at $V_{GS} = 0$ V. Stepwise increase V_{DS} from 0 V up to 12 V (in 1 V increments), recording the stable value of I_D at each step.

5. Set V_{GS} to -0.5 V, -1.0 V, and -1.5 V respectively, and repeat the full voltage sweep for each curve.

Part B: Extraction of the Transfer Characteristic ($I_D = f(V_{GS})$)

This section demonstrates the transconductance effect by evaluating how the input gate voltage governs the output current while the drain is held constant inside its active plateau.

1. Stabilize the Drain-Source voltage at a constant operating point well within the saturation region (e.g., fixed $V_{DS} = 8$ V).

2. Start the sweep at $V_{GS} = 0$ V and log the maximum current value; this establishes your experimental I_{DSS}.

3. Gradually increase the negative bias at the gate terminal (V_{GS} = -0.2 V, -0.4 V, ...) until the monitored channel current drops completely to 0 mA.

4. Record this specific voltage terminal threshold as the pinch-off voltage (V_P).

5. Lab Report / Measurements Tables

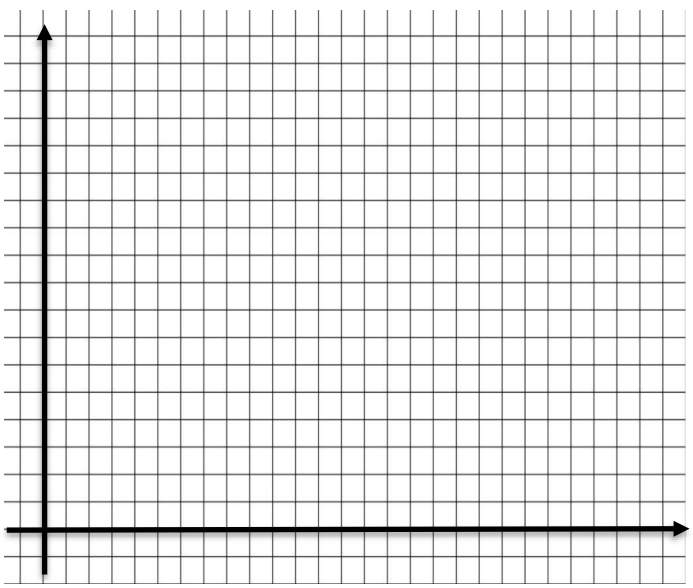
Table 1: Drain Output Characteristics (I_D in mA)

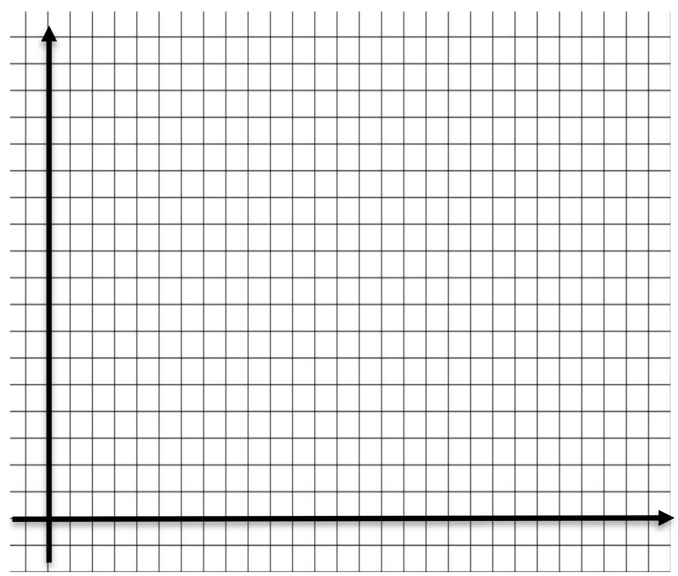
V_{DS} (V)	V_{GS}=0V	V_{GS} =-0.5V	V_{GS} =-1.0V	V_{GS} =-1.5V
0.0				
1.0				
2.0				
……				
12.0				

Table 2: Transconductance Transfer Data (at V_{DS} = 8 V)

V_{GS} (V)	0.0	-0.5	-1.0	-1.5	-2.0	...	V_P
I_D (mA)							0.0

3. From your plotted output graphs, delineate and highlight the boundaries of the three distinct operational zones: the Ohmic (Linear) region, the Saturation region, and the Breakdown zone.





4. Using the hardware-extracted constants (I_{DSS} and V_P) from Table 2, mathematically calculate I_D using Shockley's formula for V_{GS} = -1.0 V. Compare this calculated value to your empirical reading and assess the percentage error.

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