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FACULTY OF SCIENCE
COMPUTER SCIENCE DEPARTMENT

Bipolar Junction Transistor-Part2-

L1 Computer Engineering
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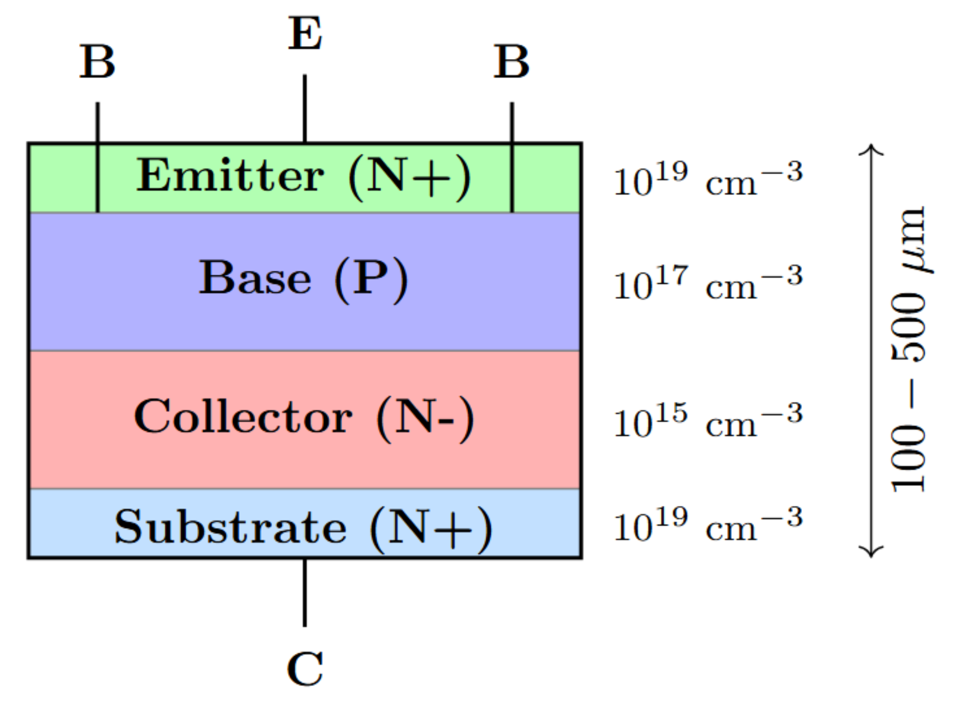
1. Recap

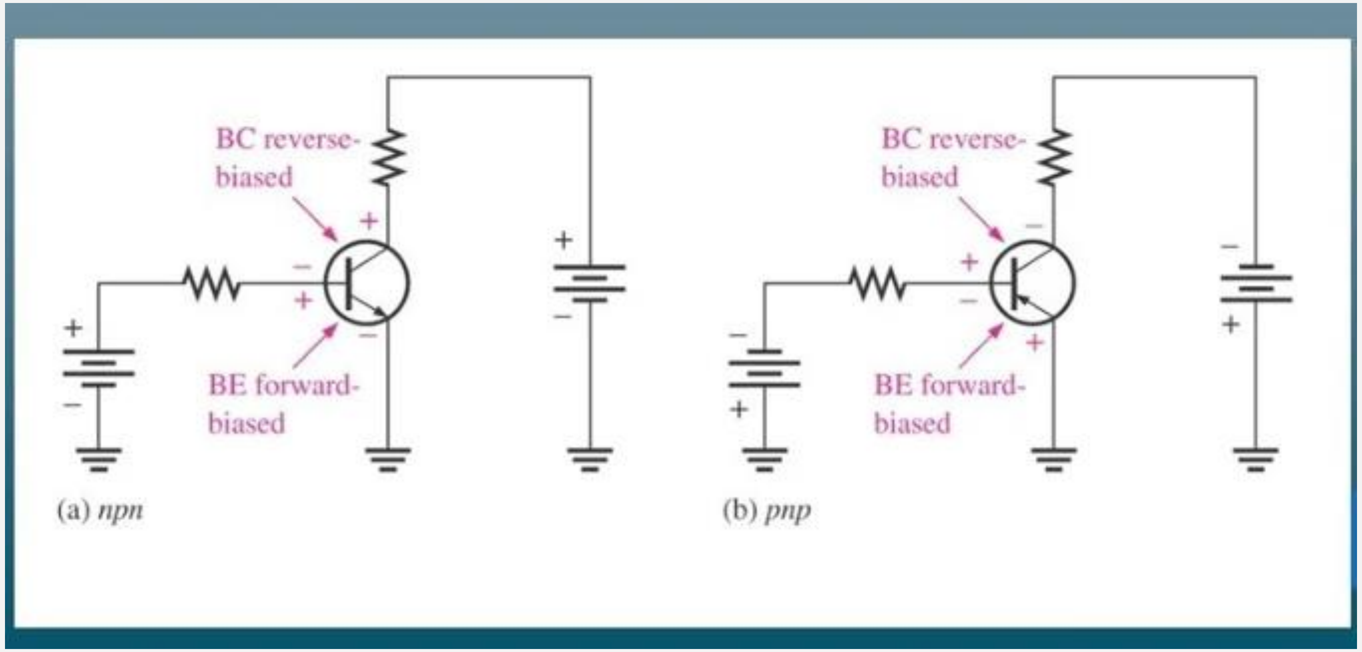


- The BJT is constructed with three doped semiconductor regions separated by two pn junctions.
- A Bipolar Junction Transistor (BJT) is a three-terminal device: Base (B), Emitter (E), Collector (C).
- Two types: NPN and PNP.
- The pn junction joining the base region and the emitter region called: the base-emitter junction
- The pn junction joining the base region and the collector region called: the base-collector junction
- The base region is lightly doped and very thin compared to the heavily doped emitter and the moderately doped collector region.
- Main function: current amplification

2. BJT Operation

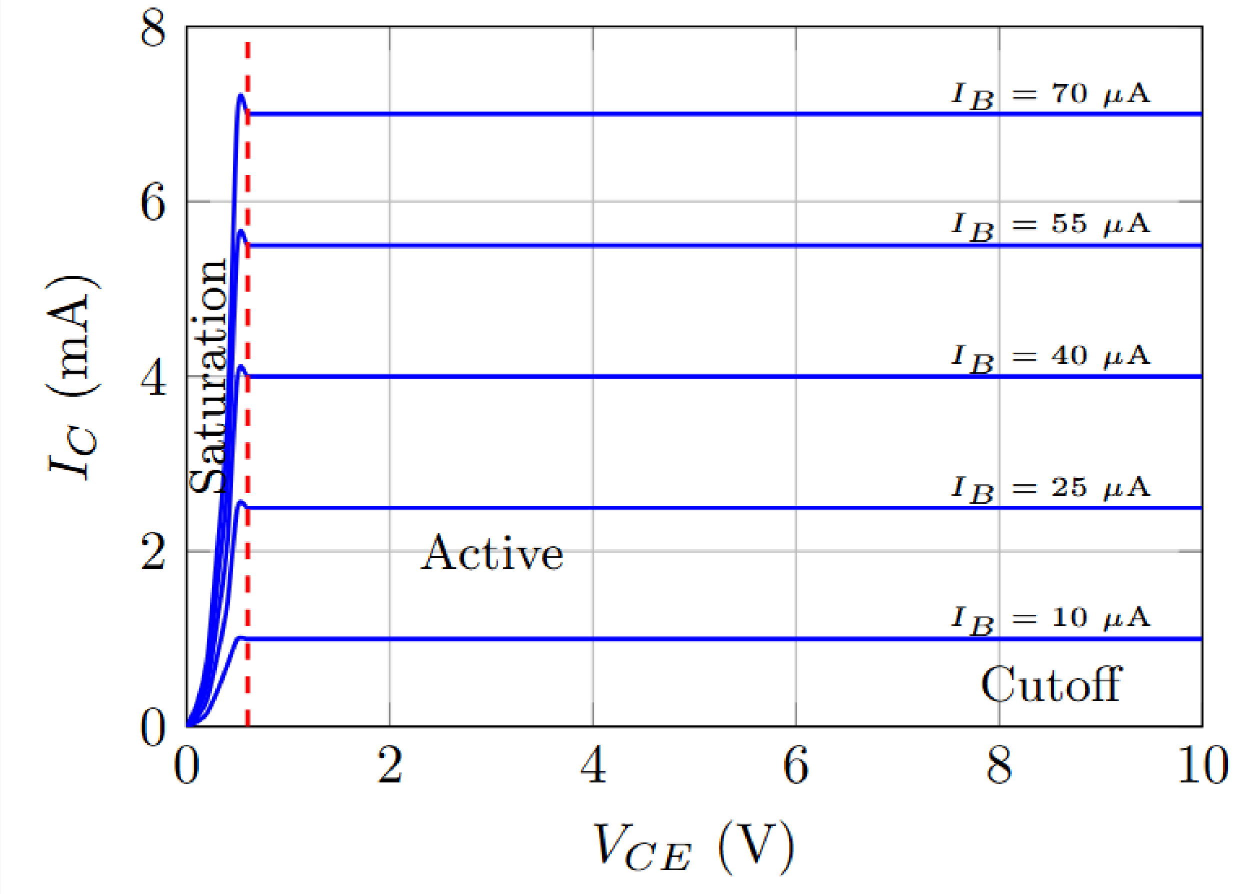
To opérate thetransistor properly, the two pn junction must be correctly biased with external DC voltajes.

The figure shown the proper bias arrangement for both NPN and PNP transistor for active operation as an amplifier.



Operations modes are:

- **Cut-off Mode**
  - VBE<VBE(th)≈0.7 V
  - IB=0, IC≈ICBO (leakage)
  - Transistor acts as open switch
- **Active Mode**
  - VBE>0.7 V, VCE>VCE(sat)
  - IC=β IB
  - Linear amplification region
- **Saturation Mode**
  - High IB, VCE<VCE(sat)
  - IC<βIB (current limited by load)
  - Transistor acts as closed switch



3. BJT characteristics & parameters.

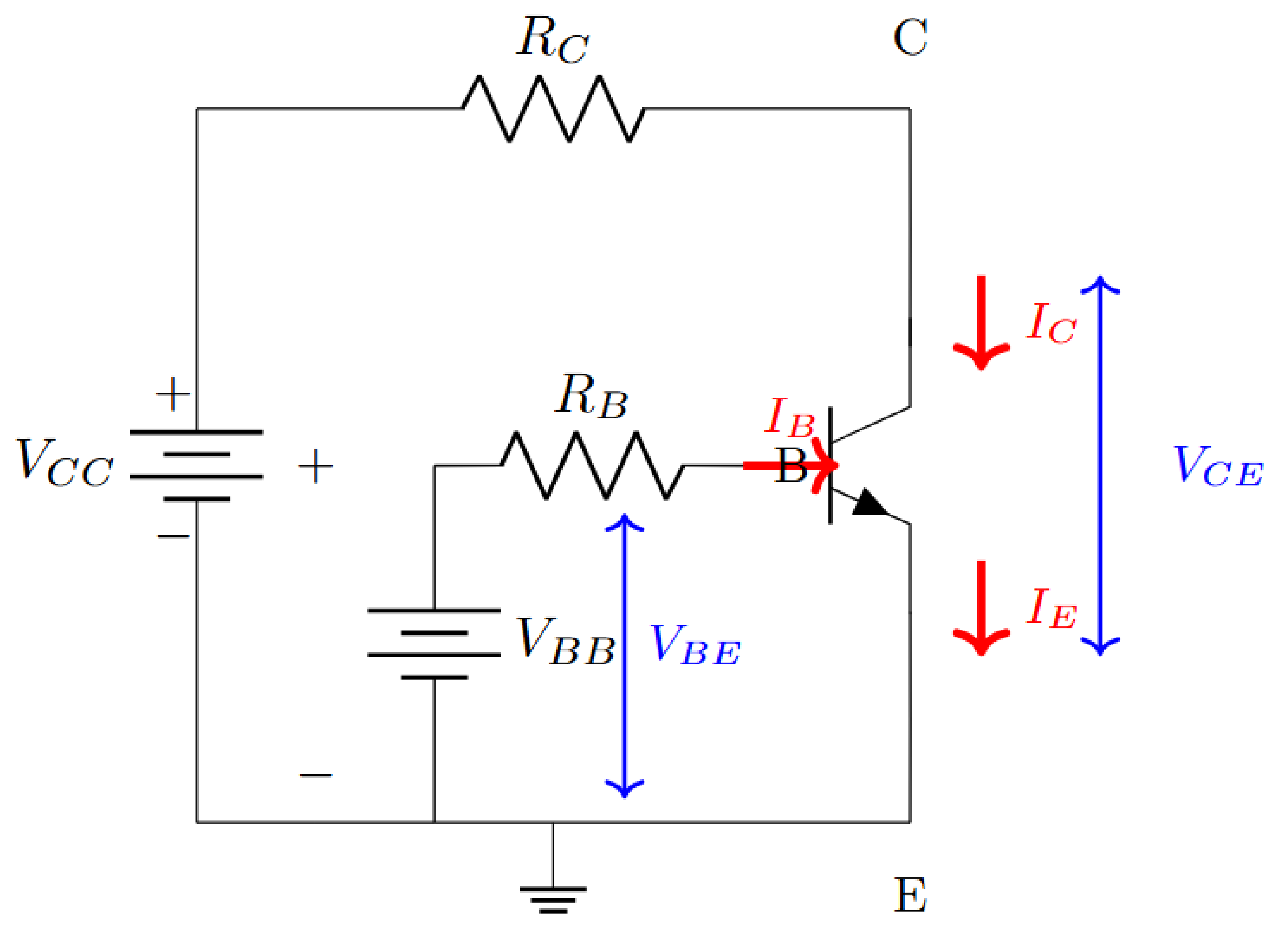
Current relationships

IE=IB+IC

IC=β.IB+ICBO

α=IC/IE=β/β+1

β=α/1−α
β: current gain (typically 50–300)



3.1. Static characteristics

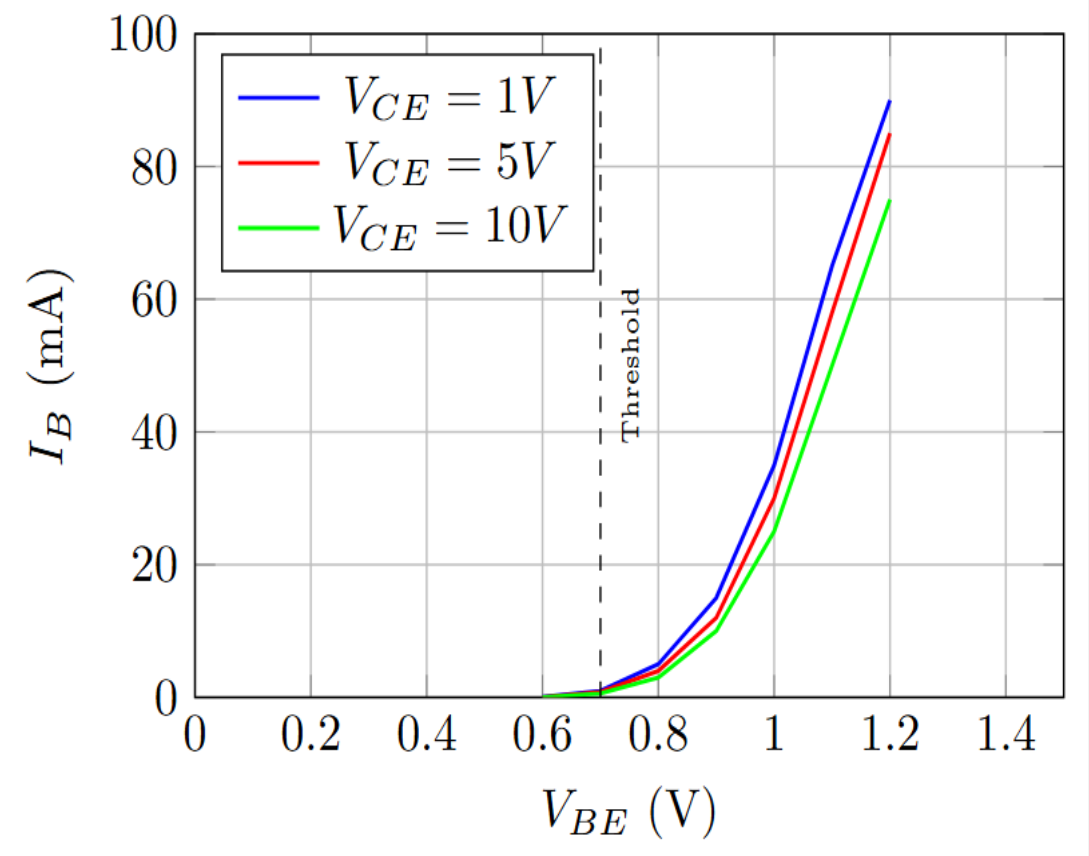
Input Characteristics (VBE vs IB).

Key Features:

- Exponential relationship (diode-like)
- IB=ISeVBE/VT
- Temperature dependent
- VBE decreases ~2 mV∘C−1
- Different for various VCE values

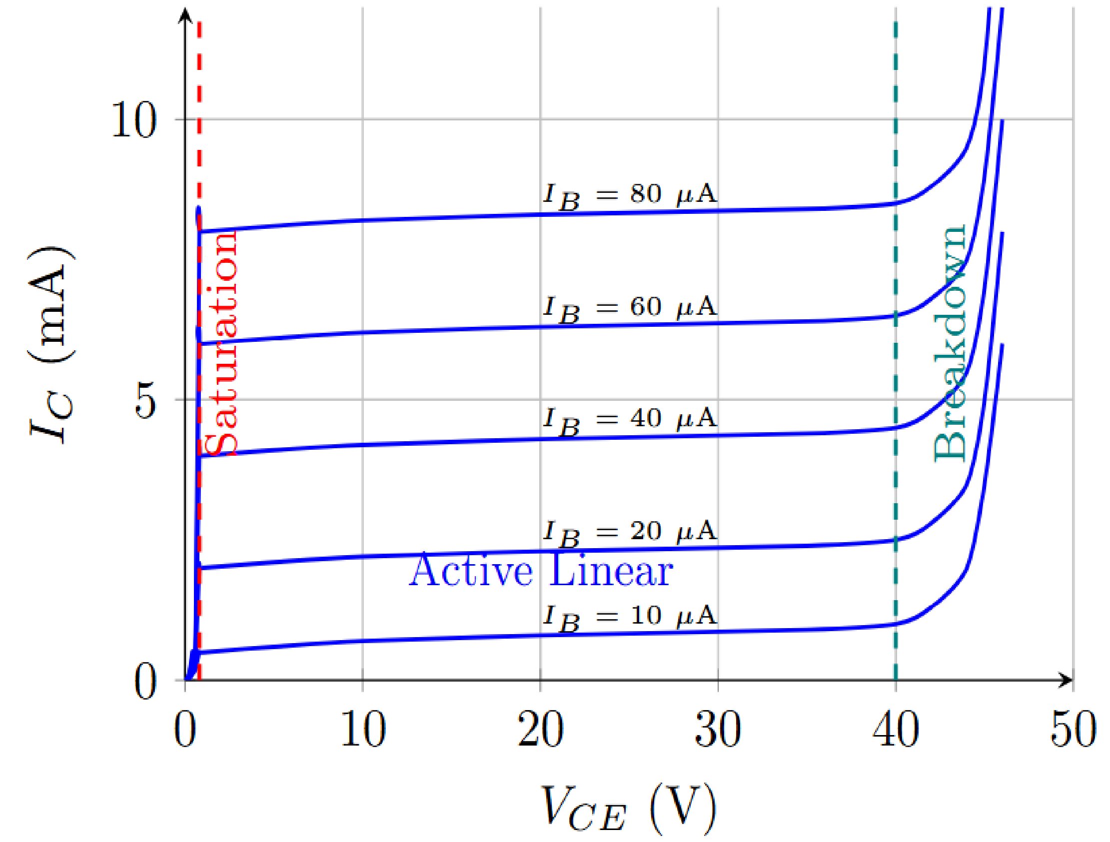
Practical Implications:

- Base drive design critical
- Temperature compensation needed
- Current limiting resistors required

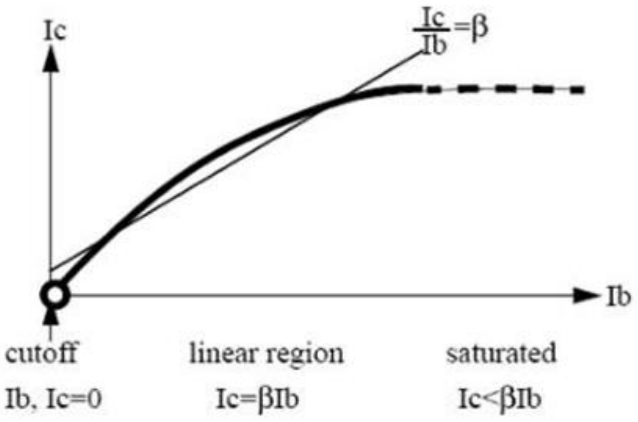


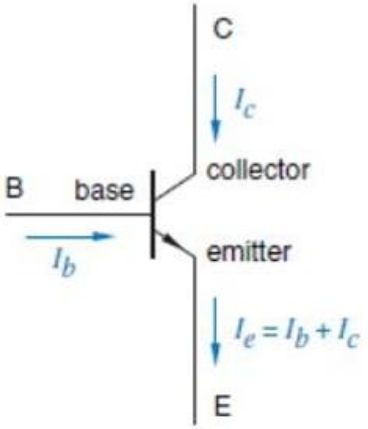
Output Characteristics (IC vs VCE)

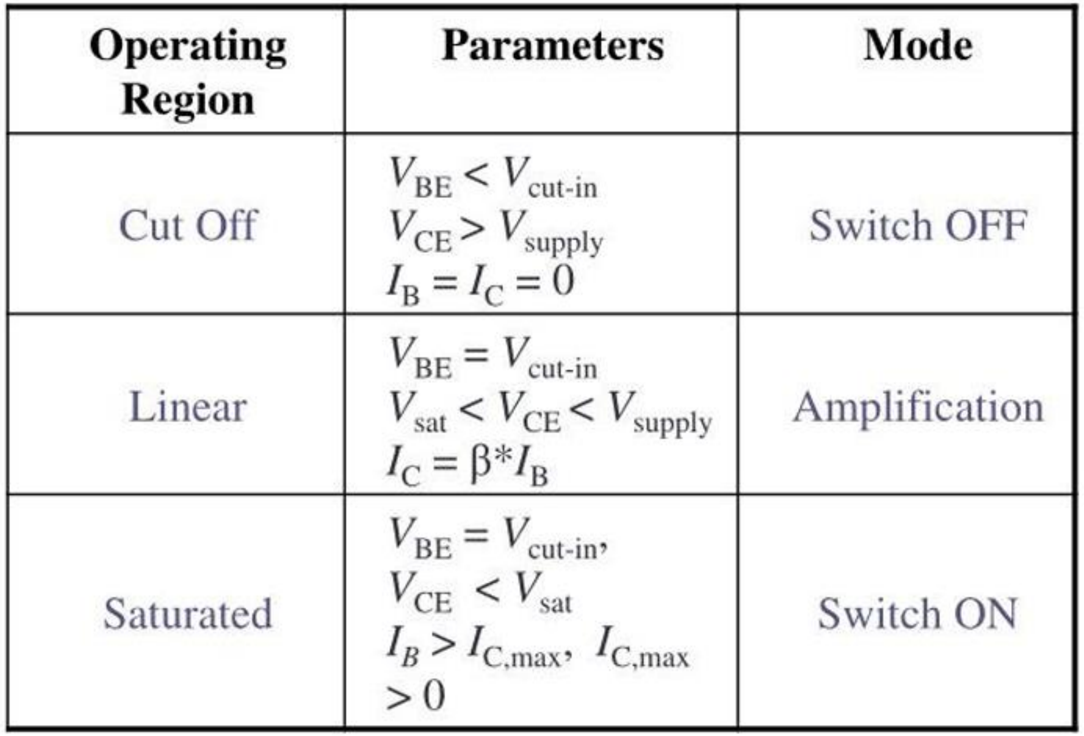
- **Saturation** (VCE<1 V):
  - Steep rise in IC
  - Low VCE(sat) desirable
  - Switching applications
- **Active** (VCE>1 V):
  - Constant IC for given IB
  - IC=βIB
  - Slight positive slope (Early effect)
- **Breakdown:**
  - VCE>BVCEO
  - Avalanche multiplication
  - Destructive if not current limited



Summary







Operating Region	Parameters	Mode
Cut Off	$V_{BE} < V_{cut\text{-}in}$ $V_{CE} > V_{supply}$ $I_B = I_C = 0$	Switch OFF
Linear	$V_{BE} = V_{cut\text{-}in}$ $V_{sat} < V_{CE} < V_{supply}$ $I_C = \beta * I_B$	Amplification
Saturated	$V_{BE} = V_{cut\text{-}in},$ $V_{CE} < V_{sat}$ $I_B > I_{C,max}, \; I_{C,max} > 0$	Switch ON

3.2. Dynamic characteristics

Switching Behavior Overview

Key Challenges:

- Minority carrier storage in base
- Charge removal during turn-off
- Slow switching compared to MOSFETs
- Turn-off time ≫ Turn-on time

Switching Times:

- t_d: Delay time (10 ns–50 ns)
- t_r: Rise time (50 ns–200 ns)
- t_s: Storage time (100 ns–500 ns)
- t_f: Fall time (50 ns–200 ns)

4. Thermal management

Temperature Effects:

- β increases with temperature (positive temperature coefficient)
- VBE decreases at −2 mV °C^{-1}
- Leakage current doubles every 10 °C
- Thermal runaway risk in parallel devices

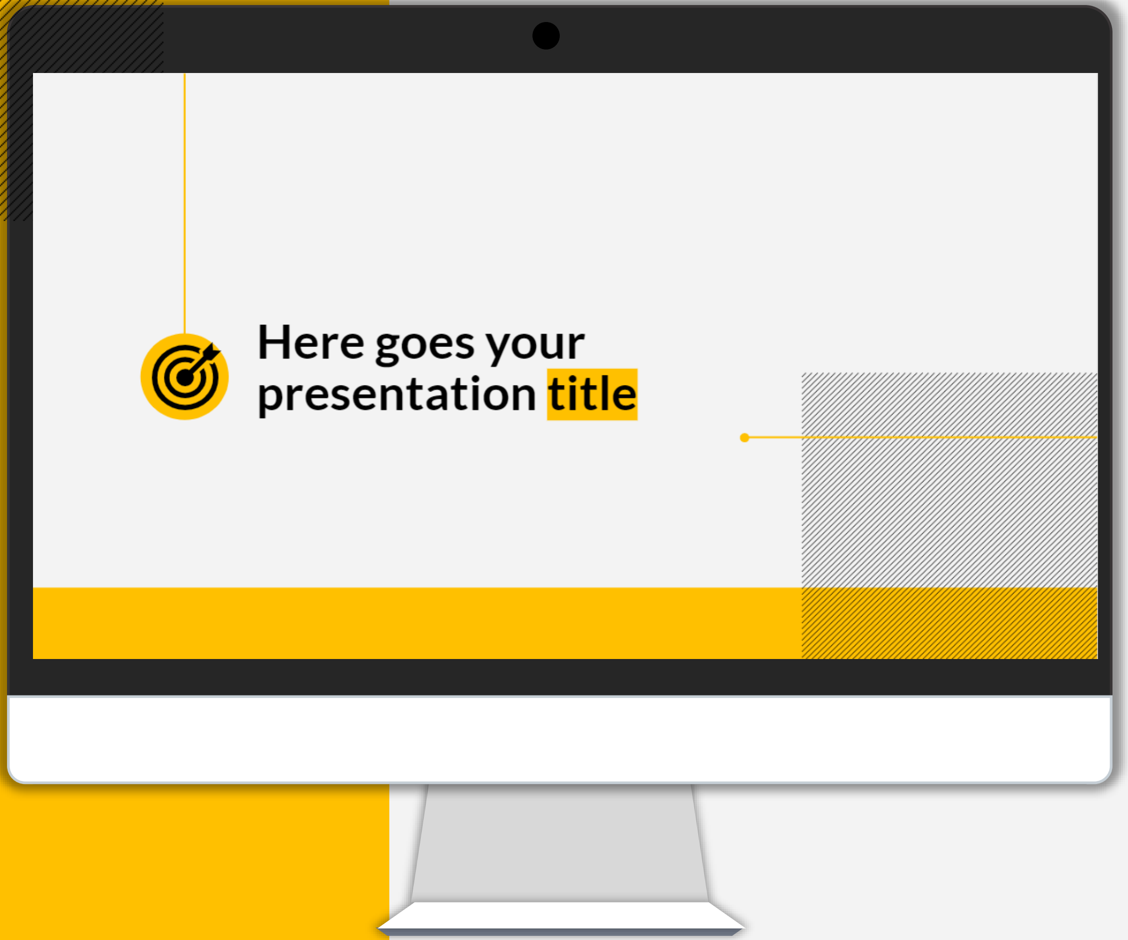
Protection Methods:

- Temperature sensors (thermistors, RTDs)
- Thermal shutdown circuits
- Current limiting
- Overtemperature indicators

Derating Guidelines:

- Power derating: 2 mW °C^{-1}–5 mW °C^{-1} above 25 °C
- Current derating with temperature
- Voltage derating at high temperatures
- Frequency derating for switching applications

5. Advantages & Limitations



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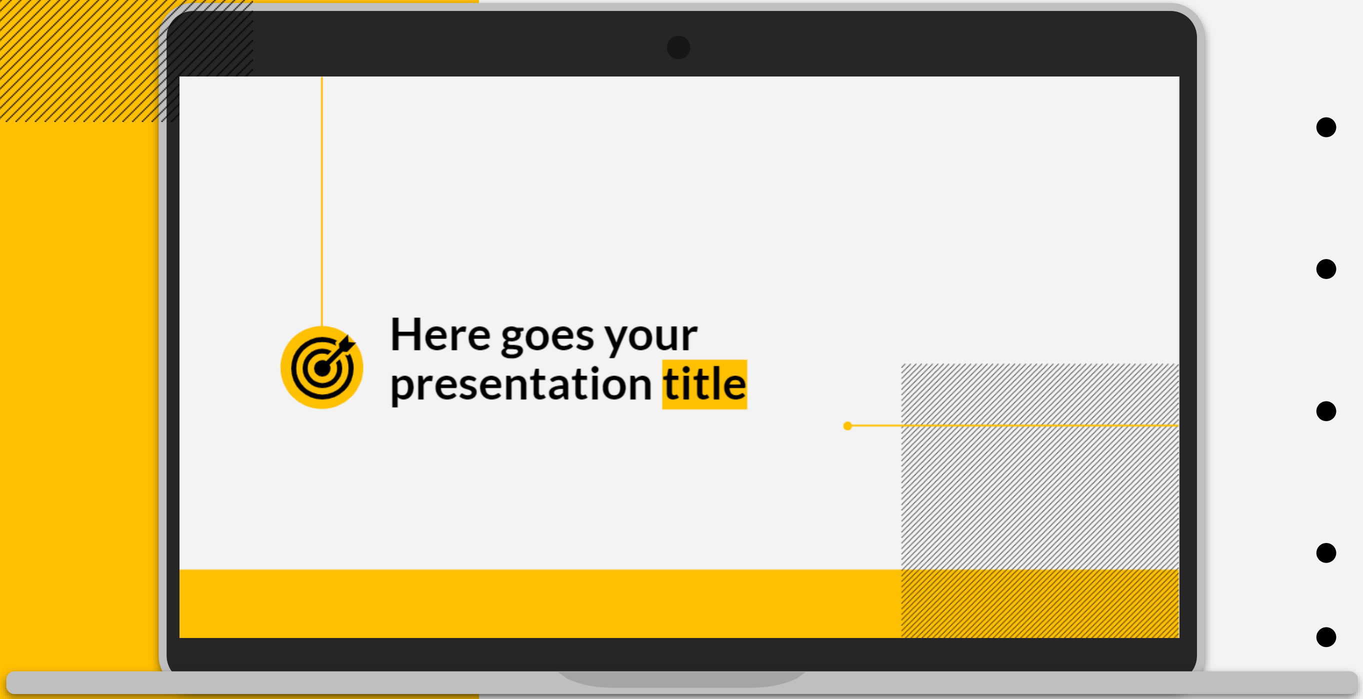
Advantages.

- High current handling capability
- Good linearity in active region
- Mature technology with proven reliability
- Cost-effective for medium power applications
- Easy parallel operation with ballast resistors



Limitations.

- Slower switching compared to MOSFETs
- Requires continuous base drive current
- Storage time limits switching frequency
- Second breakdown susceptibility
- Temperature-dependent characteristics

6. Future Outlook

Challenges:

Competition from MOSFETs and IGBTs
Limited switching frequency capability
Base drive complexity
Thermal management requirements
Second breakdown limitations

Future Developments:

SiC and GaN alternatives dominating
Specialized applications focus
Improved manufacturing for cost reduction
Enhanced packaging technologies
Smart power integration

Thank you!