Bipolar Junction Diode

Applications

1. Amplifier : Make a weak signal strong. The function is called gain and basically shows how much stronger the output signal is compared to the input. The three types of gains are voltage gain, power gain, and current gain.
2. Oscillator
3. Switch

BJT is bipolar. Both holes and electrons participate in the current flow through the device.

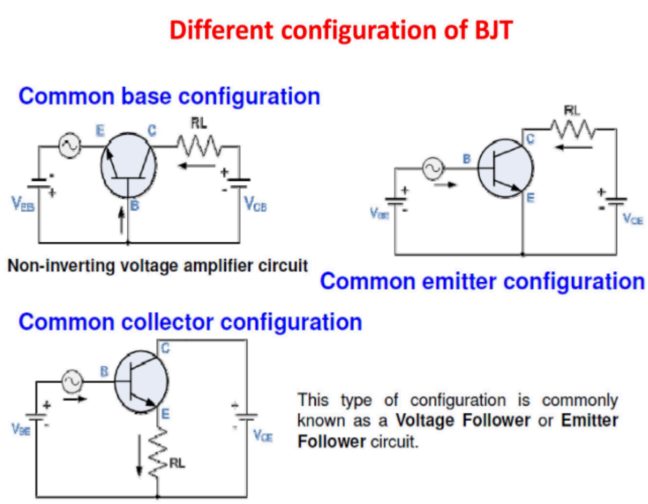
Doping variation:
$D_e > D_c > D_b$

Components

1. Emitter
    a. The emitter is **heavily doped** to provide a large number of charge carriers (electrons in NPN or holes in PNP).
    b. When a **voltage** is applied between the **emitter** and **base**, the **emitter** injects these charge carriers into the **base**.
        i. The **collector** in an **NPN transistor** is also **N-type**, but it's **lightly doped** compared to the **emitter**.
        ii. The **base**, which is **P-type**, is very thin and has fewer holes than the **emitter** has electrons.
        iii. When electrons from the **emitter** are injected into the **base**, the **base** has only a few holes to accept them.
        iv. Most of the **electrons** from the emitter **don't recombine** with holes in the base; instead, they are **attracted by the positive voltage** at the **collector**.
2. Base
    a. The base is very thin and lightly doped (in an NPN transistor, it’s P-type).
    b. It controls the flow of electrons from the emitter to the collector.
3. Collector
    a. The collector is also N-type (in an NPN transistor), but it’s lightly doped and has a larger area compared to the emitter.
    b. The base allows electrons from the emitter to flow into the collector, and most of these electrons do not recombine in the base.
    c. The positive voltage at the collector attracts the electrons from the base, pulling them through the base and into the collector.
    d. The collector then collects these electrons, which is the output current (called collector current).
    e. The **collector** collects the electrons (or holes, in the case of PNP) and sends them out as the **output current**, which is much larger than the small current that controls it at the base.

Regions/Modes of Operation of BJT

1. **Cutoff mode:**
    - No base current → transistor is **off**.
    - No current flows from collector to emitter.
    - Like a faucet where the knob isn't turned at all → no water flows.
2. **Forward Active Mode:**
    - A small base current flows (by applying a small **voltage** between the **base** and **emitter**.) → transistor is **on**.
    - Current flows from collector to emitter, controlled by the base.
    - The transistor amplifies or switches current.
    - Like turning the faucet knob slightly → water flows based on how much you turn.
3. **Saturation Mode:**
    - In **saturation mode**, the transistor is fully "on."
    - The base current is large enough that the collector-emitter voltage is very small.
    - The transistor acts like a closed switch, allowing **maximum possible** current to flow from the collector to emitter.
    - Even after increasing base current, there is no change in output at the emitter.
    - **The base current is high when voltage between base and emitter is high**
    - It's like turning the faucet all the way open — full current flows through.
4. **Reverse Active Mode (or Inverse Active Mode):**
    - In **reverse active mode**, the transistor is still "on," but in the opposite direction.
    - The **collector** and **emitter** are swapped: **collector becomes the emitter** and **emitter becomes the collector**. (voltage difference is applied between collector and base, instead of base and emitter)
    - The **base** current flows in the opposite direction compared to forward active mode.
    - The transistor is not efficient in this mode and is rarely used, as it has poor current gain.
    - Current moves from emitter to collector
    - The current is still amplified, but less efficiently.



5.2 BJT EEEE-MBZ/

In common base configuration

- Input is applied to the emitter, and the current flows from the emitter to the base.
- Output is taken from the collector, where the amplified current flows.
- The base is common to both input and output, hence the name common base

Common emitter configuration

- Input signal is applied between the base and emitter.
- The emitter is often connected to ground or a fixed voltage, making it the common point for both input and output.
- The output signal is taken from the collector.

Common collector configuration

- Input signal is applied between the base and collector.
- The collector is the common terminal (usually grounded).
- The output signal is taken from the emitter.

$$r_i = \frac{\Delta V_{BE}}{\Delta I_B} \text{ at constant } V_{CE}$$

1. Vbe is directly proportional to ib
2. **Input characteristic:** When vbe is approaching 0.7, IB is also zero. this implies that just below .7 vbe, IB remains zero and just after .7V of vbe IB increases rapidly.
3. **Output characteristics:** When VCE increases the collector current increases slightly.
    a. The value of IC is directly proportional to the VCE at constant base current.
    b. The value of Beta also increases
    c. the collector base junction of the transistor is always in forward bias
    d. The saturation region is when VCE is less than 0.5 volt
    e. Beta = ic/ib

Region of operation	Emitter Base Junction	Collector - Base Junction
Cut-off	Reverse Bias	Reverse Bias
Active	Forward Bias	Reverse Bias
Saturation	Forward Bias	Forward Bias

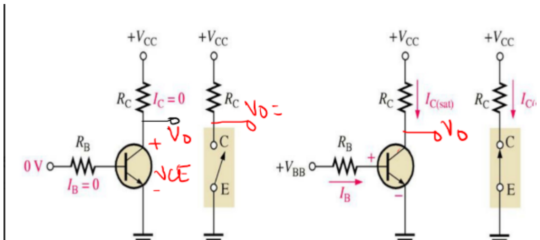
With biasing certain current and voltage conditions are established, called as DC operating point or quiescent point. Operating Point may shift because of changes in transistor parameters. Beta, IC, and VBE are temperature dependent. Ic = collector current and ICO = collector leakage current
S = stability factor

$$S = \frac{\Delta Ic}{\Delta ICO} \text{ when } VBE \text{ and } \beta \text{ are constant, CE Config}$$

$$S = \frac{\Delta Ic}{\Delta VBE} \text{ when } ICO \text{ and } \beta \text{ are constant}$$

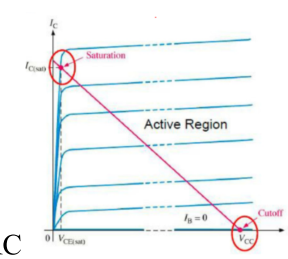
$$S = \frac{\Delta Ic}{\Delta \beta} \text{ when } ICO \text{ and } VBE \text{ are constant}$$

1. Transistor as switch
    a. Cutoff and saturation for off and on.
    b. In cutoff, vce= vcc (supply voltage)
    c. In saturation, vce = 0

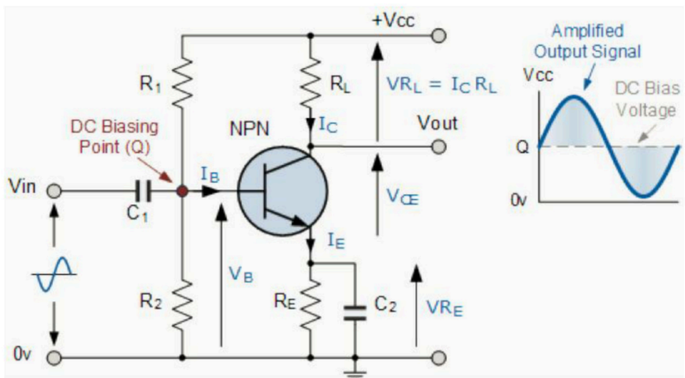


(a) Cutoff — open switch (b) Saturation — closed switch

VCE = VCC - ICRC



2. Single stage CE amplifier//redo
    a. BJT as a Switch: Turns current "ON" or "OFF" in saturation or cutoff.
    b. Active Region for Amplification: Applies a small AC signal with a DC bias to keep the transistor in its active region for amplification.
    c. Class A Amplifier: The base is biased so the transistor operates between cutoff and saturation, amplifying both parts of the signal. Otherwise, only half would be amplified.
    d. Q-point: The point where VCE is set to let the transistor amplify signals.
    e. Load Line: Shows possible points where the transistor can operate with different base currents.
    f. The Q-point ensures the transistor amplifies signals correctly.



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