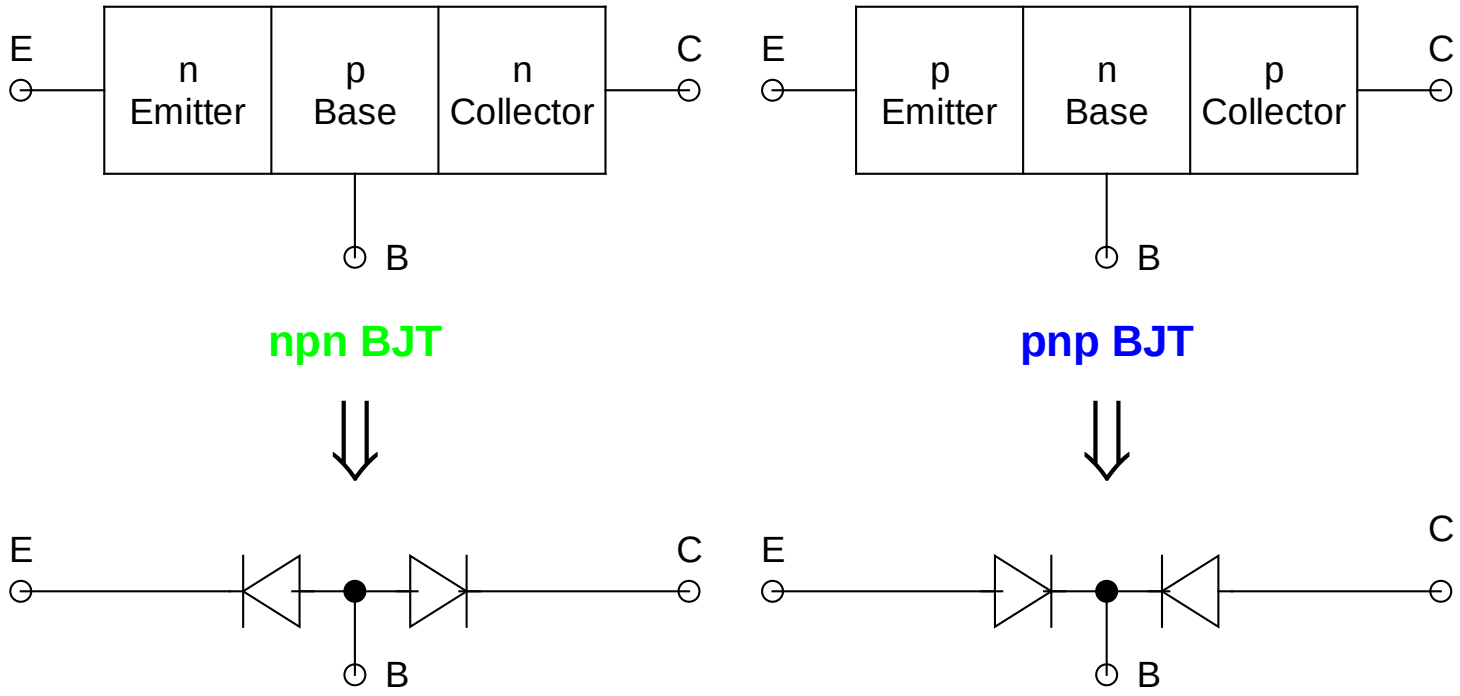
BIPOLAR JUNCTION TRANSISTOR (BJT)

- Basically two ***back-to-back diodes***

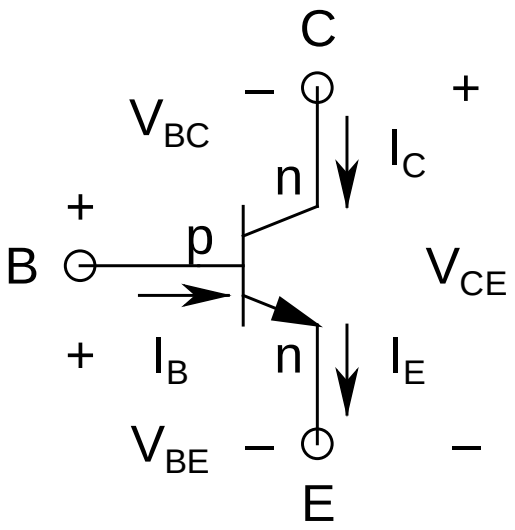


- Name originates from ***transfer of resistor***

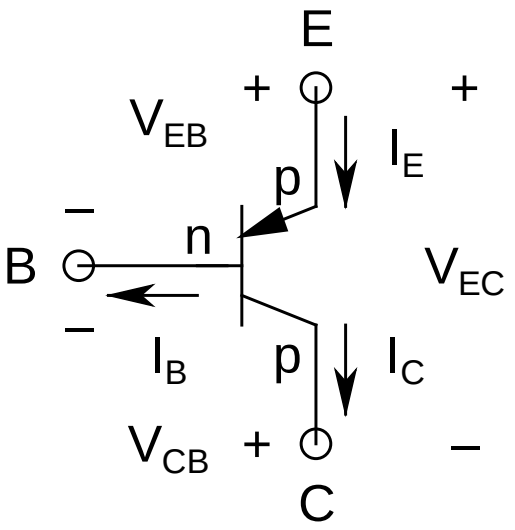
- ***Three-Layer/Terminal*** [***Emitter*** (E), ***Base*** (B), ***Collector*** (C)] ***Two-Junction*** [***Base-Emitter*** (BE), ***Base-Collector*** (BC)] device
- Current through ***two terminals*** (E and C) can be ***controlled*** by the current through the ***third terminal*** (B)
  - ***Current controlled device***
- ***Bipolar device***
  - ***Both electrons and holes*** participate in **current conduction**

- ***Active device***
  - Capable of producing ***voltage/current/power gain***
- ***Two basic usage***:
  - **Amplification** (***Analog Circuits***)
  - **Switching** (***Digital Circuits***)
- ***Two Types*:**
  - ***npn***
  - ***pnp***
- ***Immensely important device***

Symbols and Current-Voltage Conventions



npn

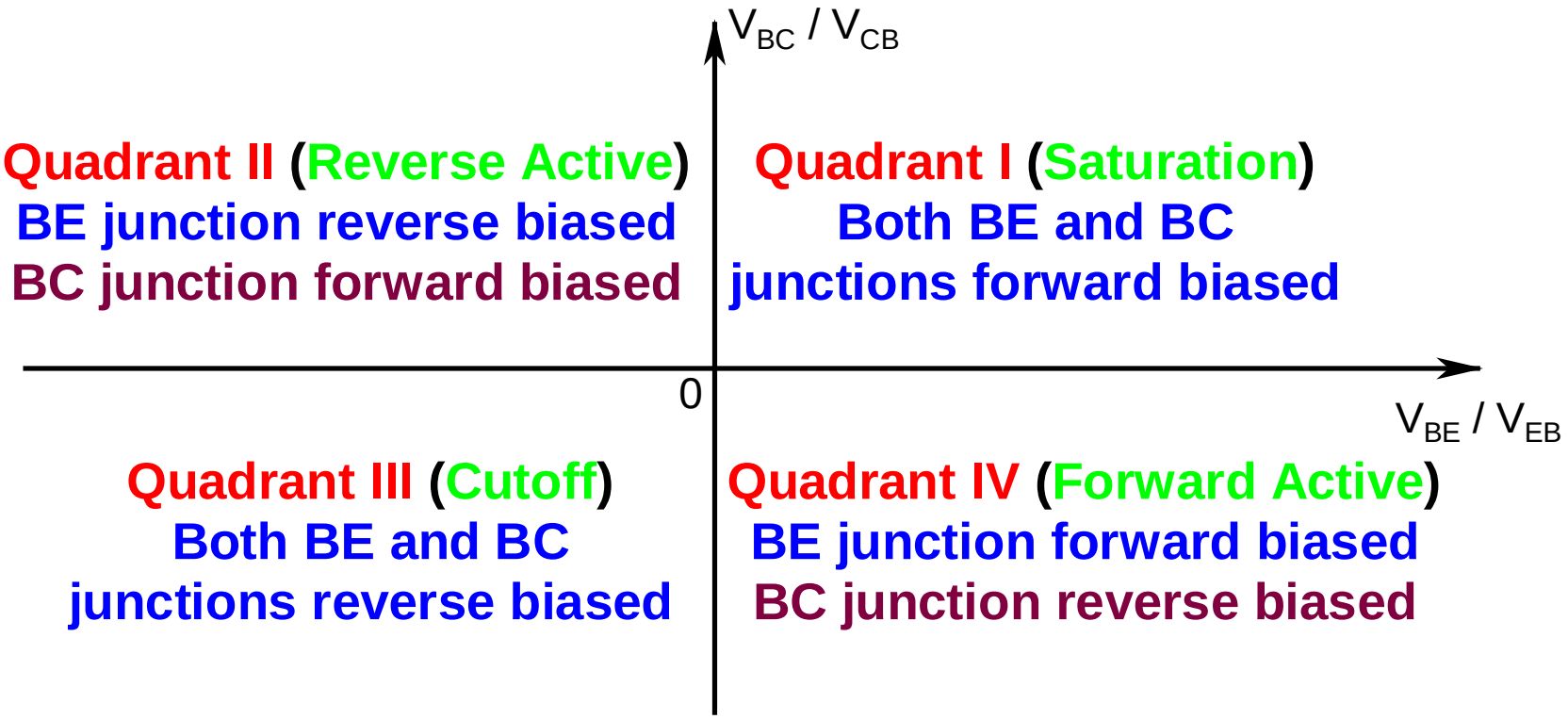


pnp

- ***Voltage Convention***:
  - ***p-side first***:
    - ***Sign of the voltage*** immediately lets us know the ***biasing state*** (***forward or reverse***)
  - ***npn***: V_{BE} (***base-emitter voltage***), V_{BC} (***base-collector voltage***), and V_{CE} (***collector-emitter voltage***)
  - ***pnp***: V_{EB} (***emitter-base voltage***), V_{CB} (***collector-base voltage***), and V_{EC} (***emitter-collector voltage***)
  - **Note**: ***Collector-Emitter is NOT a junction***

- ***Current Convention***:
  - ***npn***:
    - I_C *and* I_B *flow in*, I_E *flows out*
  - ***pnp***:
    - I_E *flows in*, I_C *and* I_B *flow out*
- ***Applying KCL***, treating the whole BJT as a ***big node***, for ***both npn and pnp***:
  - $I_E = I_C + I_B$
  - ***Extremely important KCL for the BJT***

Modes of Operation

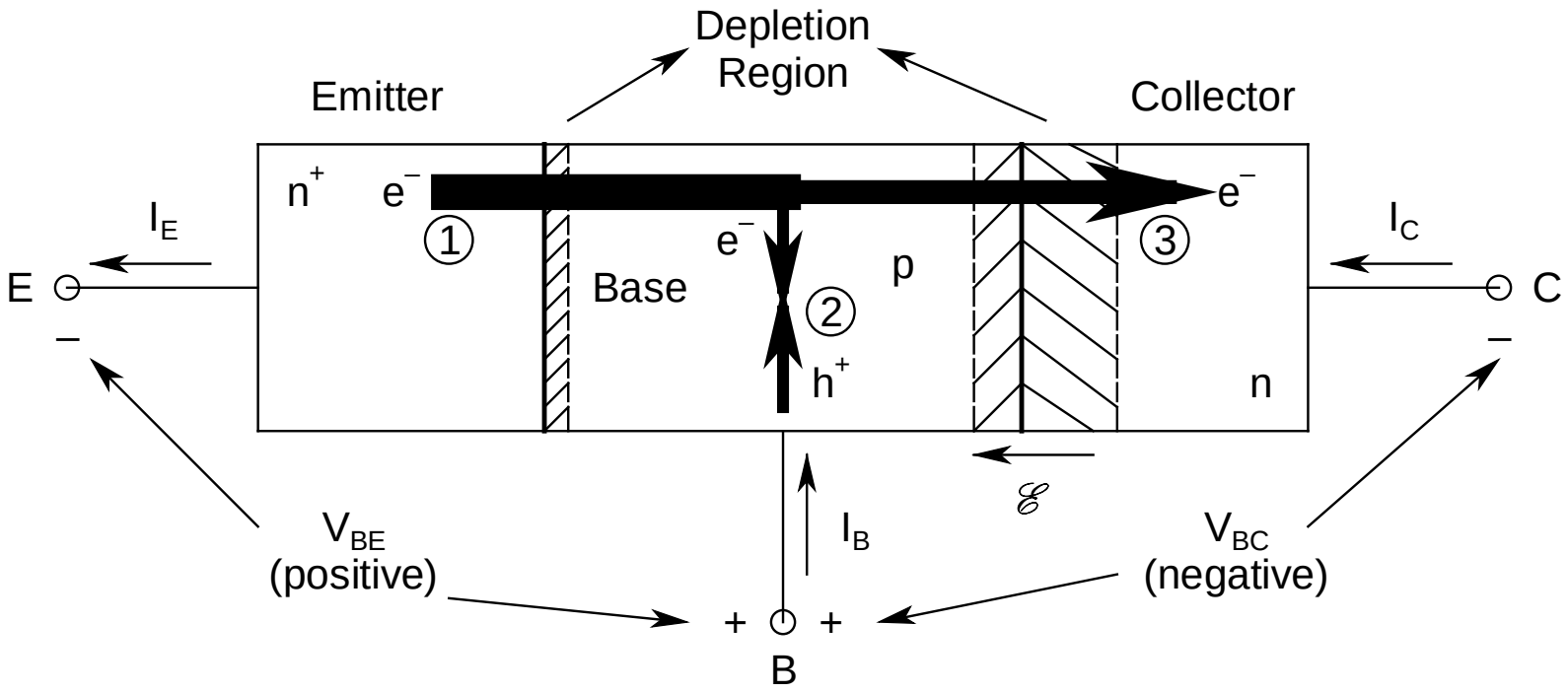


Quadrants III and IV: Analog Domain

Quadrants I and III: Digital Domain

Quadrant II: Finds use only in TTL circuits

Operation in the Forward Active (FA) Mode



①**Injection Comp.** ② **Recombination Comp.** ③**Collection Comp.**

- ***BE junction forward biased, BC junction reverse biased***
- ***Emitter injects electrons to base***
  - ***Supplied by the external terminal to maintain charge neutrality in emitter***
    - ***Emitter current (I_E) flows out of the device through the emitter terminal***
- ***Base injects holes to emitter***
  - ***This component is reduced as much as possible by doping emitter very heavily***

- Injected electrons ***diffuse*** through the base due to ***concentration gradient***
  - At the same time, some of them ***recombine*** with the ***holes*** in the ***base***
  - Supplied by the ***external terminal*** to maintain ***charge neutrality*** in ***base***
    - ***Base current*** (I_B) ***flows into the device through the base terminal***
- Electrons that ***survived recombination*** will reach the ***base edge*** of the ***BC depletion region***

- Note the ***direction*** of the ***electric field*** ($\mathscr{E}$) present in the ***BC depletion region***
- This ***field*** will ***sweep*** the ***survived electrons*** to the ***collector***
  - ➢ These ***electrons*** will ***flow out*** of the ***collector terminal***
    - ***Collector current*** (I_C) ***flows into the device through the collector terminal***
- ***Base Control***:
  - ➢ A ***small change*** in I_B can cause a ***large change*** in $I_C \Rightarrow$ ***Transistor action***

- For a ***good transistor***, the ***ratio*** I_C/I_B should be ***as large as possible***
- Can be ***achieved*** by ***reducing*** the ***chances of recombination*** in the ***base***
- ***Two ways***:
  - ***Reduce base doping*** $\Rightarrow$ ***Limits supply of holes*** $\Rightarrow$ ***Reduces recombination***
  - ***Reduce base width*** $\Rightarrow$ ***Reduces amount of time electrons spend in base*** $\Rightarrow$ ***Reduces recombination***