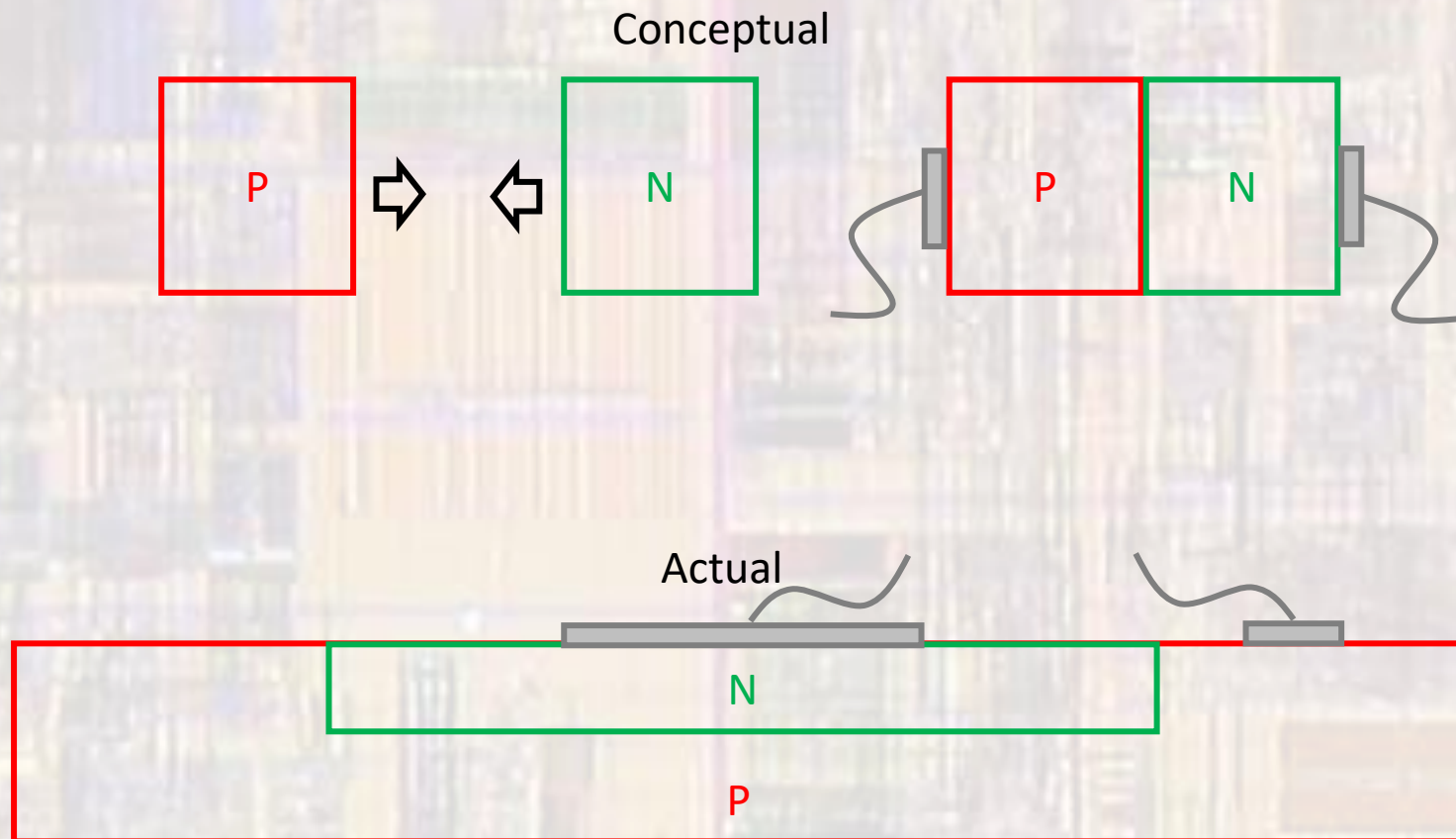


# Bipolar Junction Transistor Physics

Last updated 2/17/22

# PN Junction Physics

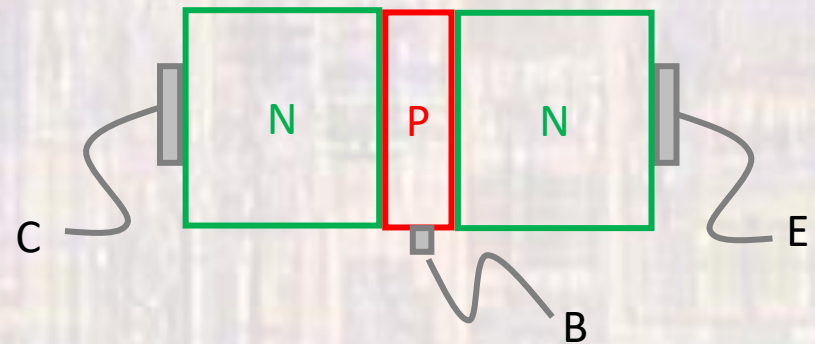
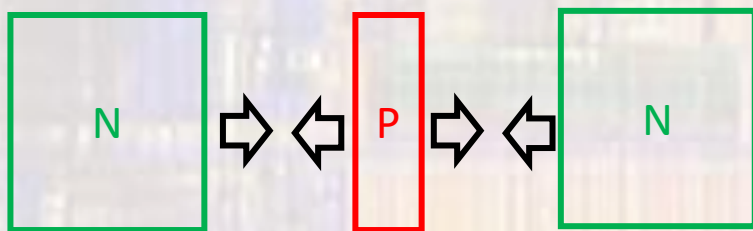
- Review



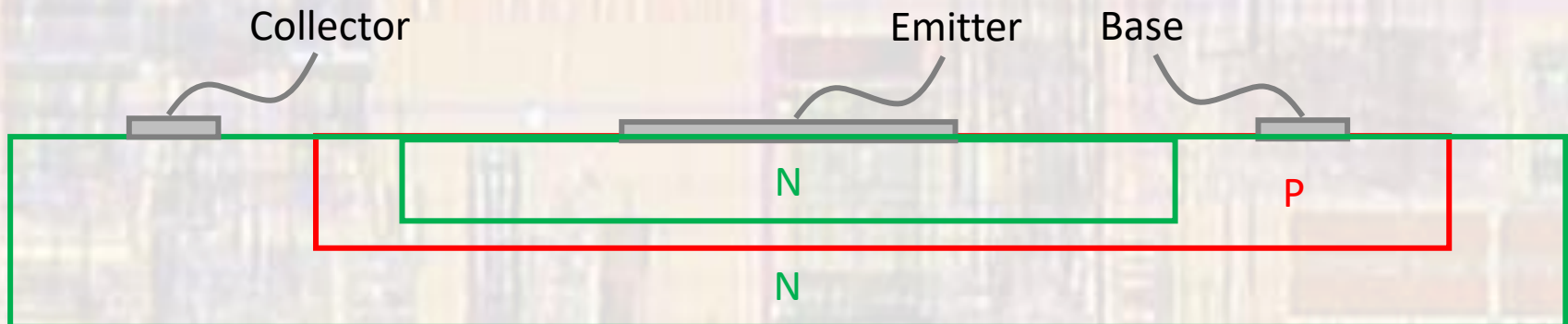
# BJT Physics

- NPN Construction

Conceptual



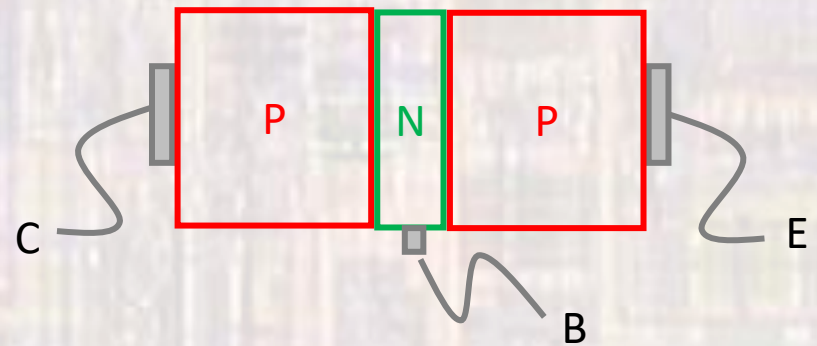
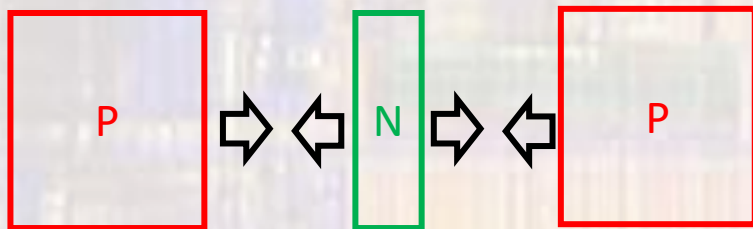
Actual



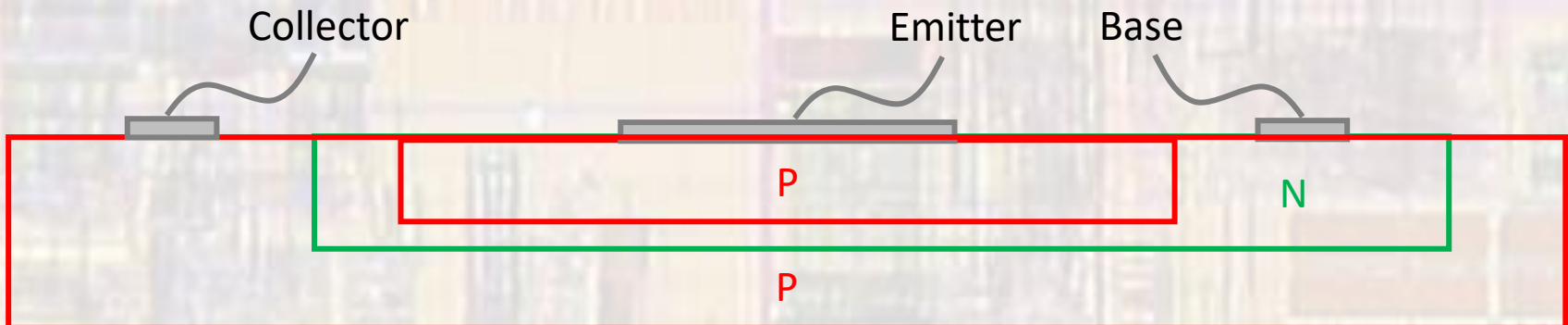
# BJT Physics

- PNP Construction

Conceptual

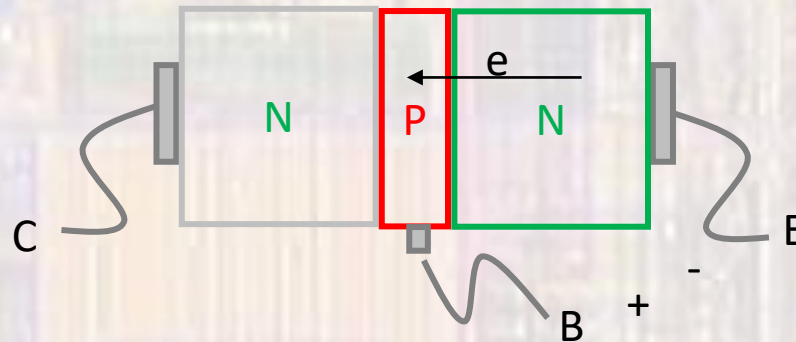


Actual



# BJT Physics

- Forward Active Mode - NPN
  - B-E junction forward biased, C-B junction reverse biased
  - B-E junction forward biased



$$J_{p\text{-diff}} \uparrow > J_{p\text{-drift}}$$

$$J_{n\text{-diff}} \uparrow > J_{n\text{-drift}}$$

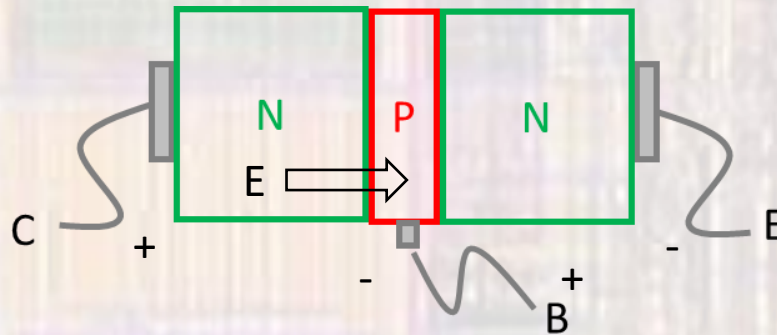
$$J_{P\text{-diff}} = -qD_P \nabla_P$$

$$J_{N\text{-diff}} = qD_N \nabla_N$$

- With the emitter more highly doped than the Base
  - $\nabla_N \gg \nabla_P$
  - The majority of the current is electrons diffusing (being emitted) from the Emitter into the base

# BJT Physics

- Forward Active Mode - NPN
  - B-E junction forward biased, C-B junction reverse biased
  - C-B junction reverse biased



$$J_{p\text{-diff}} \downarrow < J_{p\text{-drift}}$$

$$J_{p\text{-drift}} = qp\mu_p E$$

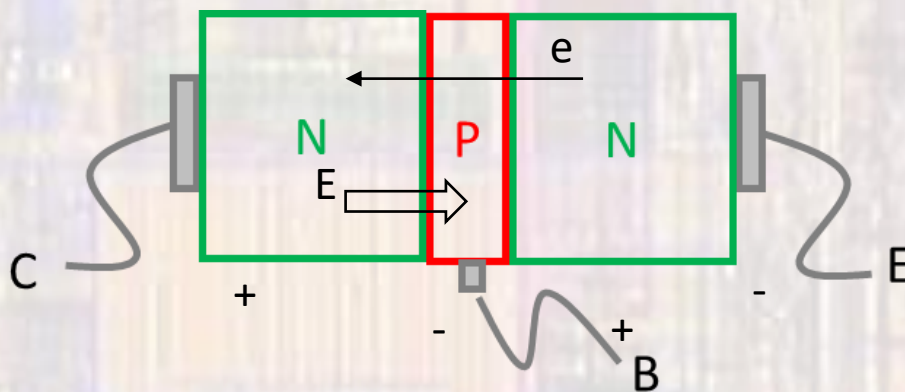
$$J_{n\text{-diff}} \downarrow < J_{n\text{-drift}}$$

$$J_{n\text{-drift}} = qn\mu_n E$$

- Small negative current
- E – electric field from C to B

# BJT Physics

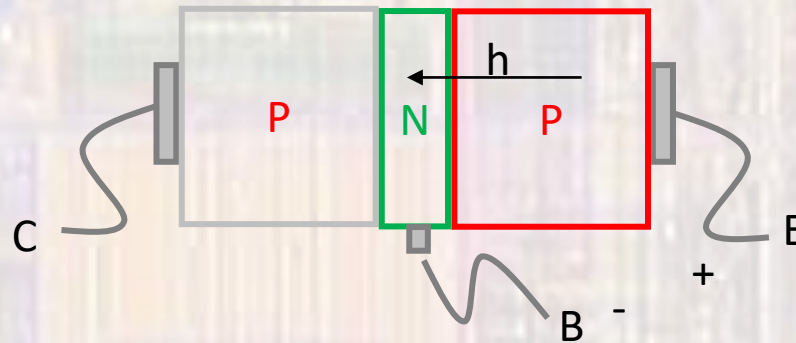
- Forward Active Mode - NPN
  - B-E junction forward biased, C-B junction reverse biased



- With a short base – the electrons injected into the base get swept into the collector by the electric field
- In the ideal case all of the electrons would be swept into the collector, leaving only a small hole current in the base
- In the real case – additional factors lead to a small (relative to emitter) base current

# BJT Physics

- Forward Active Mode - PNP
  - B-E junction forward biased, C-B junction reverse biased
  - B-E junction forward biased



$$J_{p\text{-diff}} \uparrow > J_{p\text{-drift}}$$

$$J_{n\text{-diff}} \uparrow > J_{n\text{-drift}}$$

$$J_{P\text{-diff}} = -qD_P \nabla_P$$

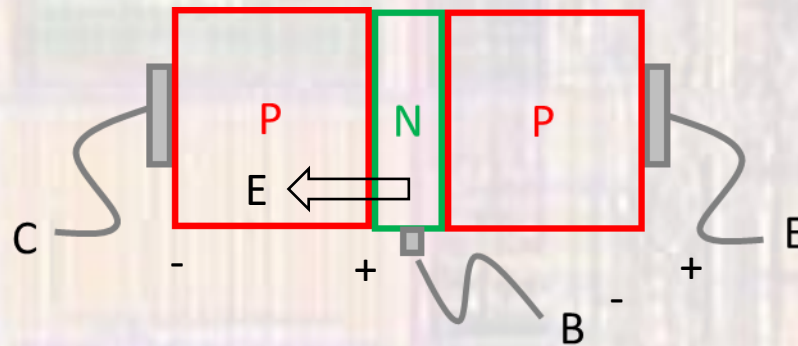
$$J_{N\text{-diff}} = qD_N \nabla_N$$

- With the emitter more highly doped than the Base
  - $\nabla_P \gg \nabla_N$
  - The majority of the current is holes diffusing (being emitted) from the Emitter into the base



# BJT Physics

- Forward Active Mode - PNP
  - B-E junction forward biased, C-B junction reverse biased
  - C-B junction reverse biased



$$J_{p\text{-diff}} \downarrow < J_{p\text{-drift}}$$

$$J_{p\text{-drift}} = qp\mu_p E$$

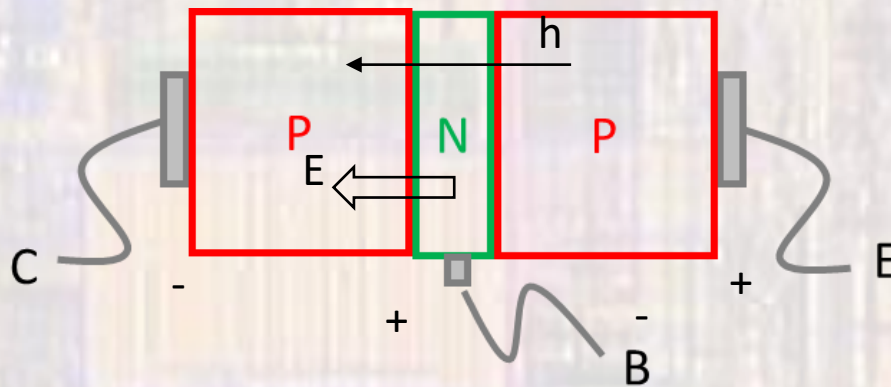
$$J_{n\text{-diff}} \downarrow < J_{n\text{-drift}}$$

$$J_{n\text{-drift}} = qn\mu_n E$$

- Small negative current
- E – electric field from C to B

# BJT Physics

- Forward Active Mode - PNP
  - B-E junction forward biased, C-B junction reverse biased



- With a short base – the holes injected into the base get swept into the collector by the electric field
- In the ideal case all of the holes would be swept into the collector, leaving only a small electron current in the base
- In the real case – additional factors lead to a small (relative to emitter) base current