ECEN325: Electronics
Spring 2024

Bipolar Junction Transistor (BJT)

Sam Palermo

Analog & Mixed-Signal Center

Texas A&M University

Announcements & Reading

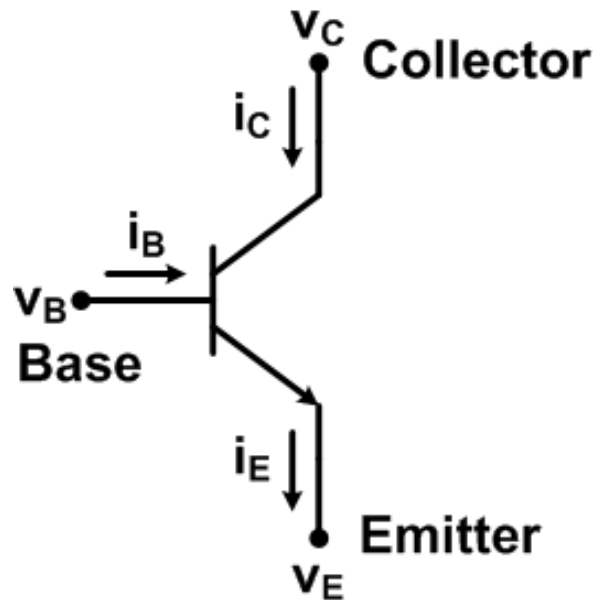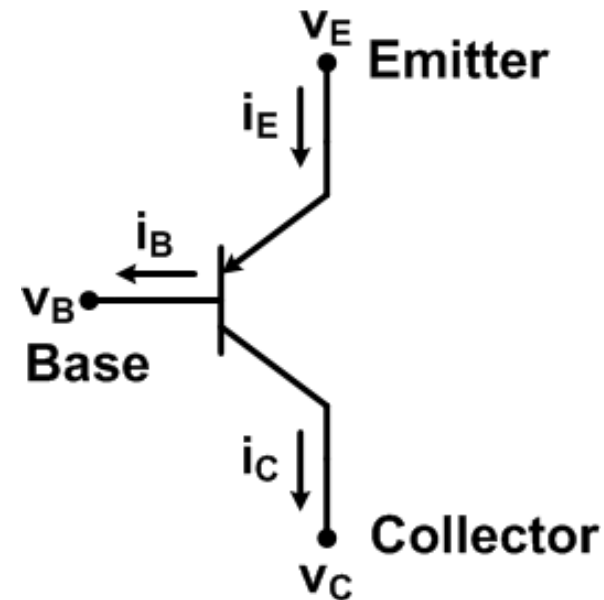- HW4 due Mar 19

- Razavi Ch4
  - 4.1-4.4, 4.6, 4.7
- Razavi Ch5

BJT Circuit Symbols

NPN
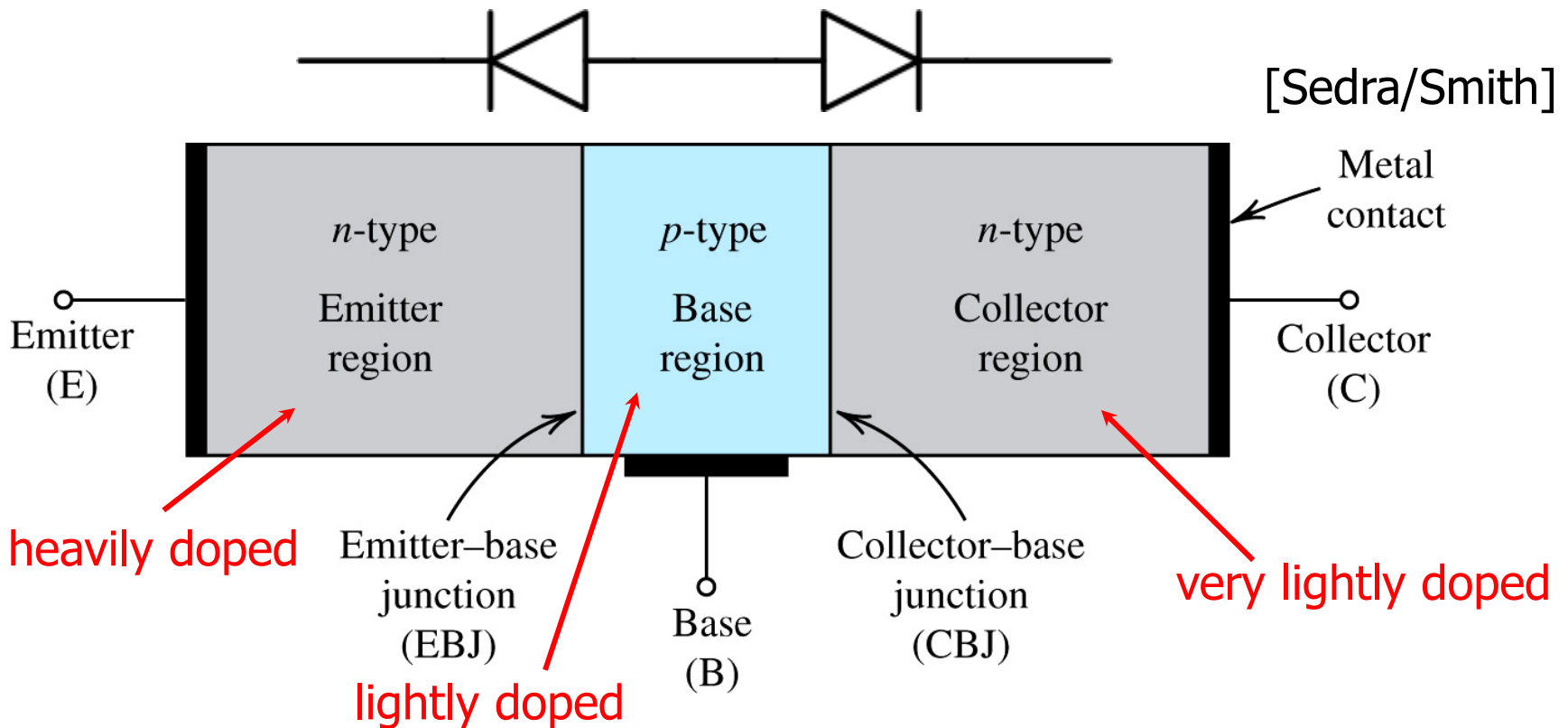
v_C Collector

i_C

i_B

v_B

Base

i_E

Emitter

v_E

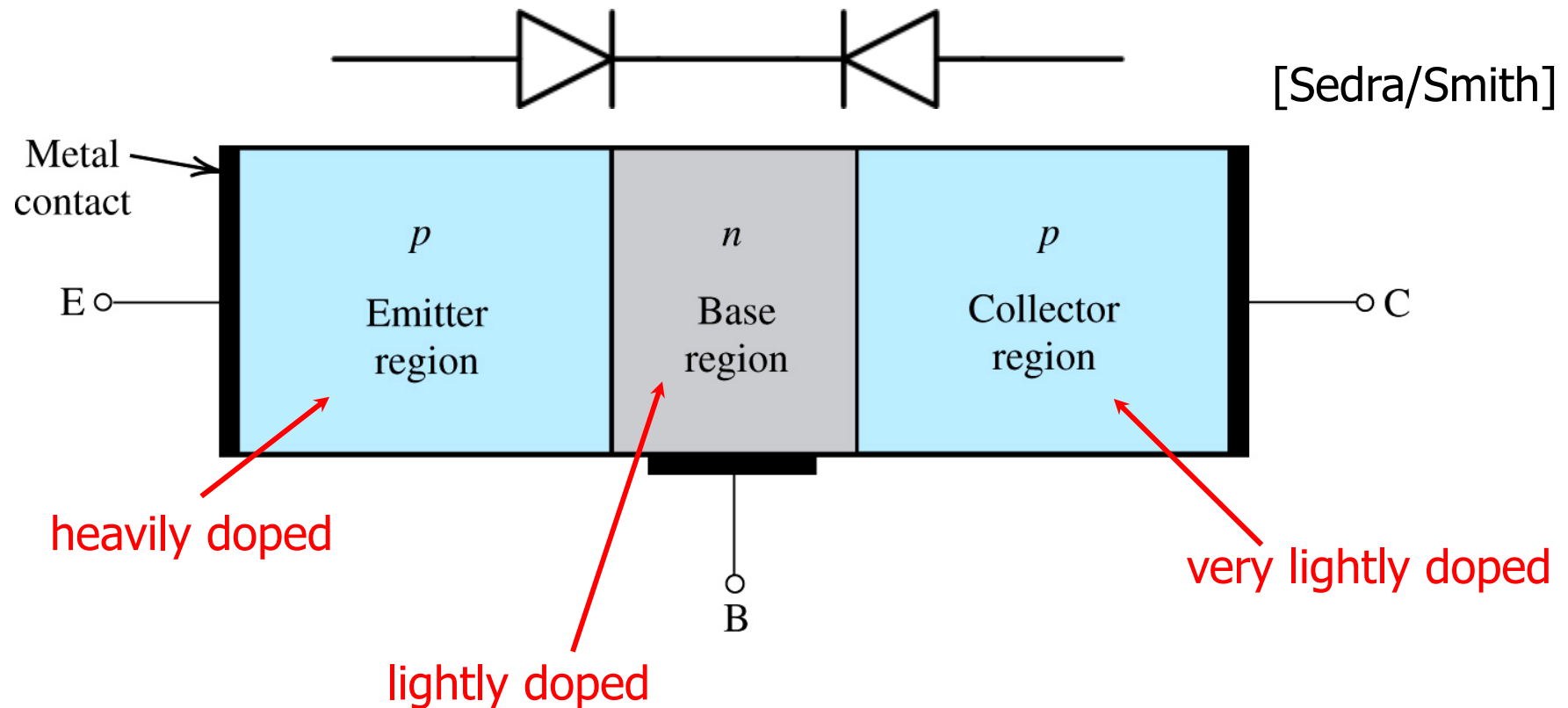**PNP**

v_E Emitter

i_E

i_B

v_B

Base

i_C

Collector

v_C

- BJTs are 3 terminal devices
  - Collector, Base, & Emitter
- 2 complementary BJT devices: NPN & PNP

NPN BJT Device Structure

[Sedra/Smith]

- BJTs consist of 2 back-to-back junctions (diodes) with a shared middle region
  - np & pn for the NPN transistor
- Doping level varies dramatically with region

PNP BJT Device Structure

[Sedra/Smith]

Metal contact

p — Emitter region — *heavily doped*

n — Base region — *lightly doped*

p — Collector region — *very lightly doped*

E

C

B

- BJTs consist of 2 back-to-back junctions (diodes) with a shared middle region
  - pn & np for the PNP transistor
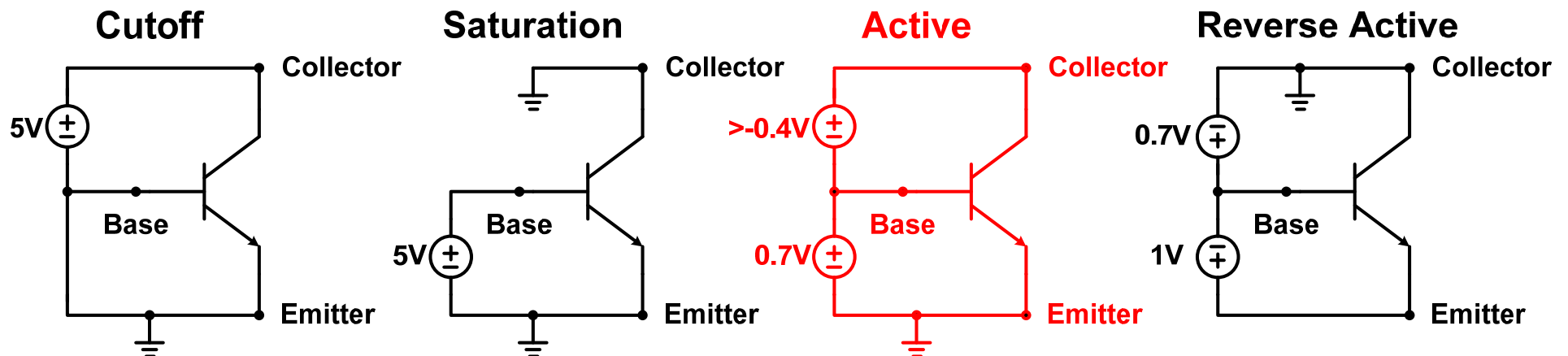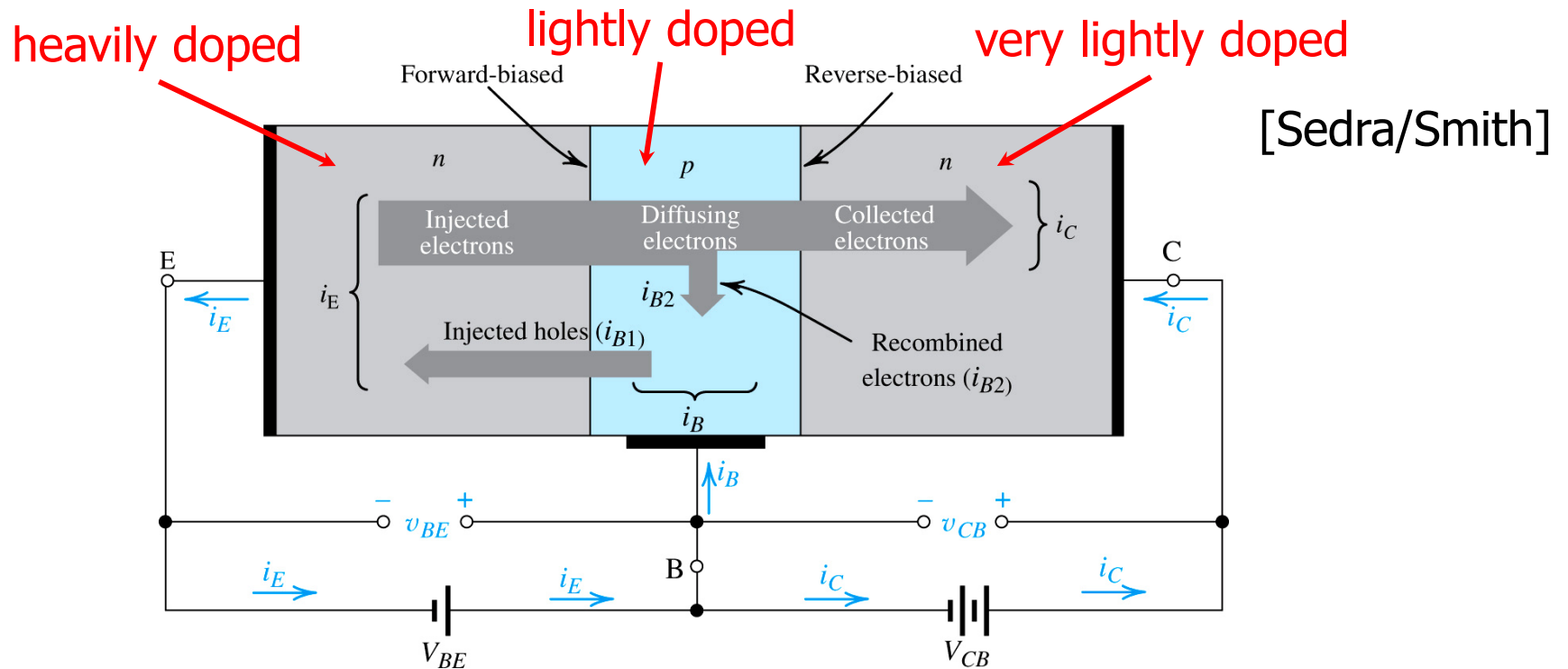- Doping level varies dramatically with region

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BJT Modes of Operation

Mode	Base-Emitter Junction	Base-Collector Junction	Application
Cutoff	Reverse	Reverse	Digital Logic "Switch Off"
Saturation	Forward	(Strong) Forward (>0.4V)	Digital Logic "Switch On"
Active	**Forward**	**Reverse (Weak Forward <0.4V)**	**Analog Amplifier**
Reverse Active	Reverse	Forward	??

Cutoff   **Saturation**   **Active**   **Reverse Active**

NPN Active Mode Operation

heavily doped

lightly doped

very lightly doped

[Sedra/Smith]

Forward-biased

Reverse-biased

n

p

n

Injected electrons

Diffusing electrons

Collected electrons

i_C

E

C

i_E

i_E

i_{B2}

i_C

Injected holes (i_{B1})

Recombined electrons (i_{B2})

i_B

$-$ v_{BE} $+$

i_B

$-$ v_{CB} $+$

i_E

i_E

B

i_C

i_C

V_{BE}

V_{CB}

- Emitter current i_E consists of injected electrons into the base and injected holes from the base
  - Due to the doping disparity, the electron current is much greater than the hole current
- The electrons injected into the base diffuse across the narrow base region and are swept or "collected" into the collector due to the V_{CB} bias
- The net result is a collector current which is almost equal to the emitter current, and whose values are determined by the V_{BE} bias

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