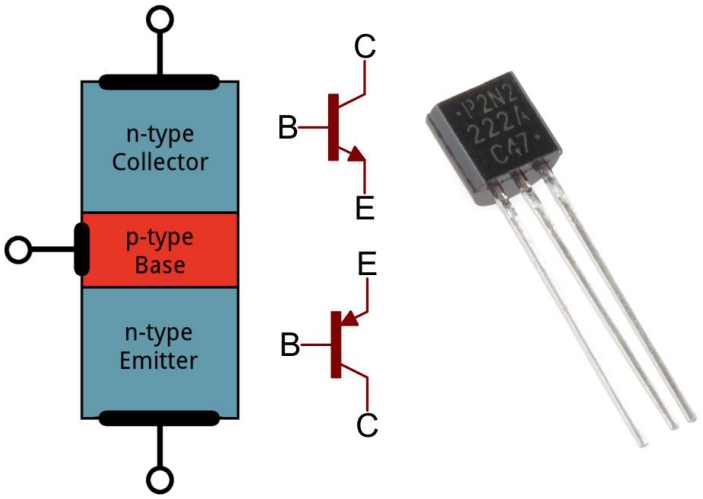
CO2015

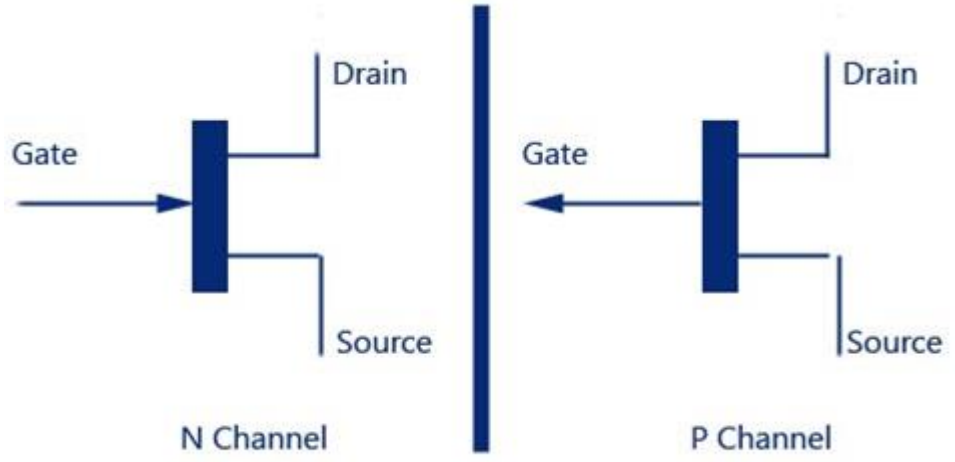
Introduction to Transistors and Appliactions

DCE
Dept. of Computer Engineering

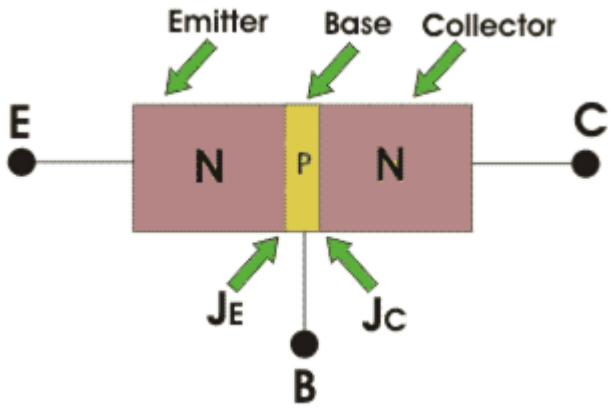
What is Transistor?

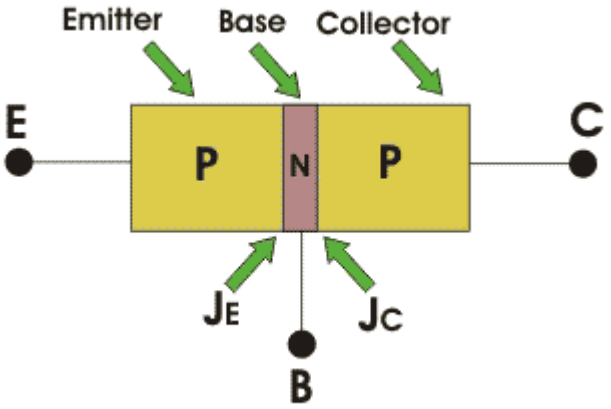
- Transistor is a semiconductor device used to:
  - Amplifier signal
  - Switch signal or electrical power
- There are two types of basic transistor out there: Bi-Polar Junction (BJT) and Metal-Oxide Field-Effect (MOSFET)

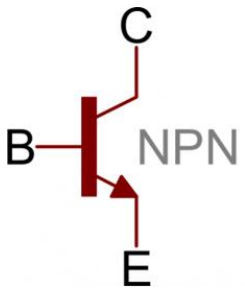


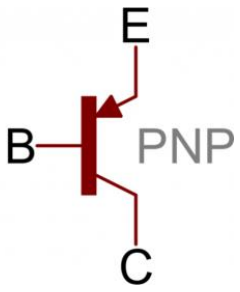


Transistor



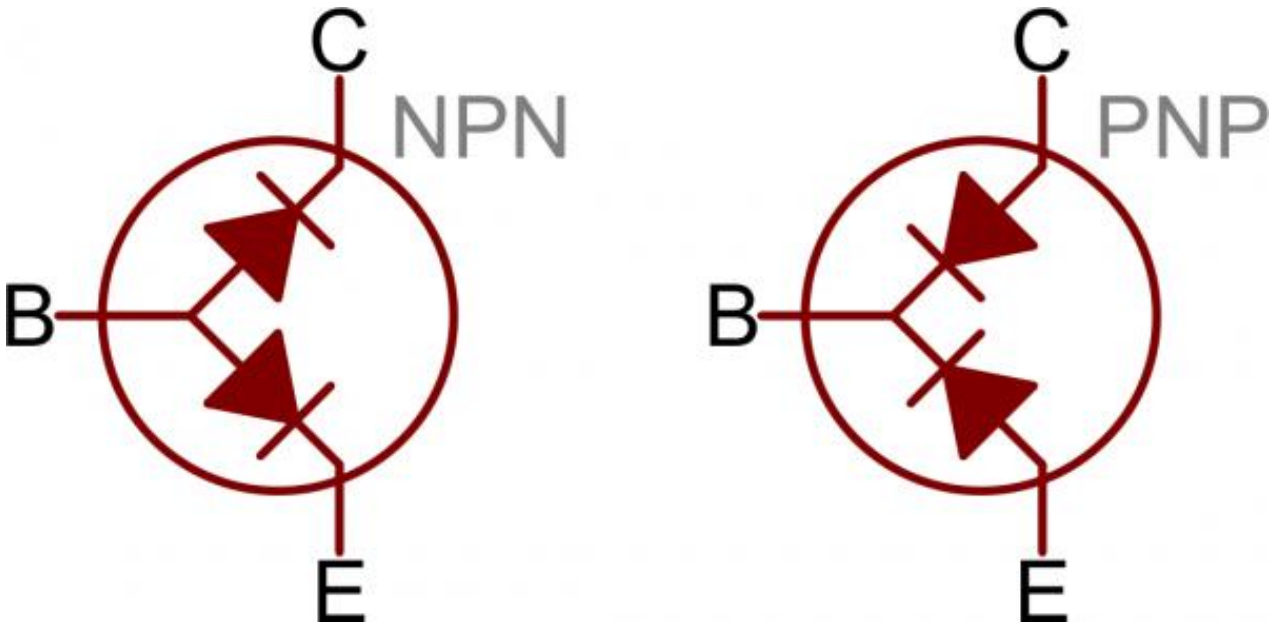


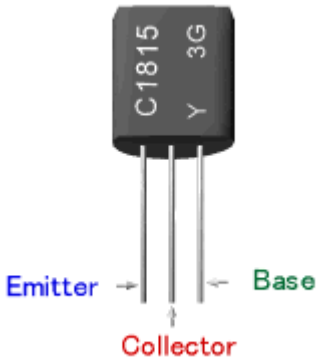




- Bi-polar Junction Transistor (BJT)
- **Collector** (C), **Base** (B), and **Emitter** (E)

Transistor = 2 Diodes

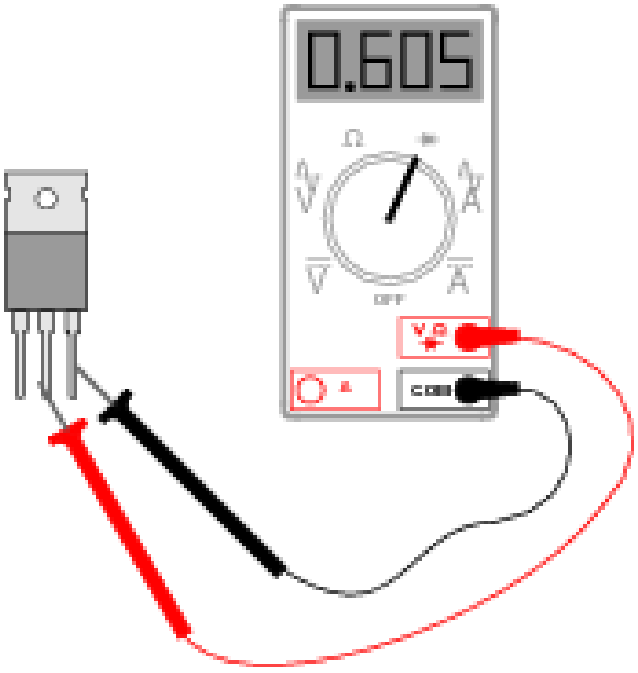


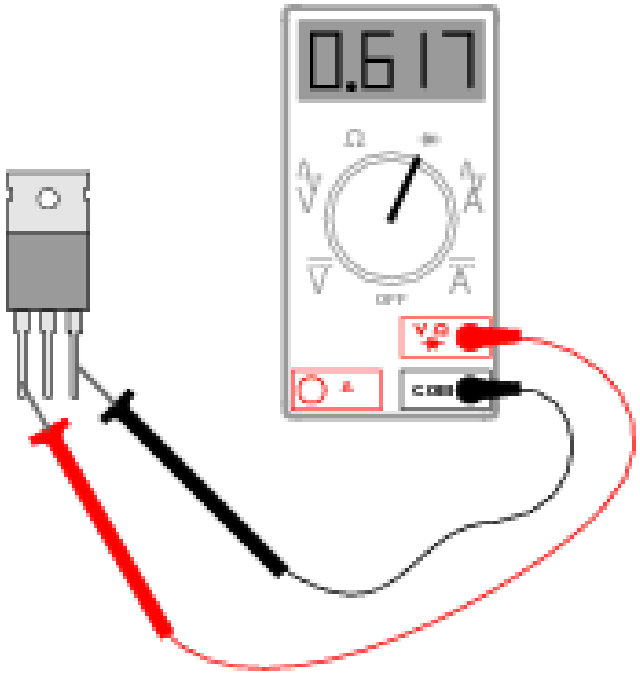


- Checking transistors is similar to diodes
- Pin order: ECB or BCE

Exercise

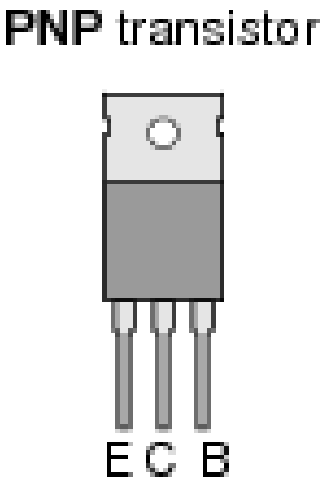
- From these measurements, determine what type of BJT this is (PNP or NPN)



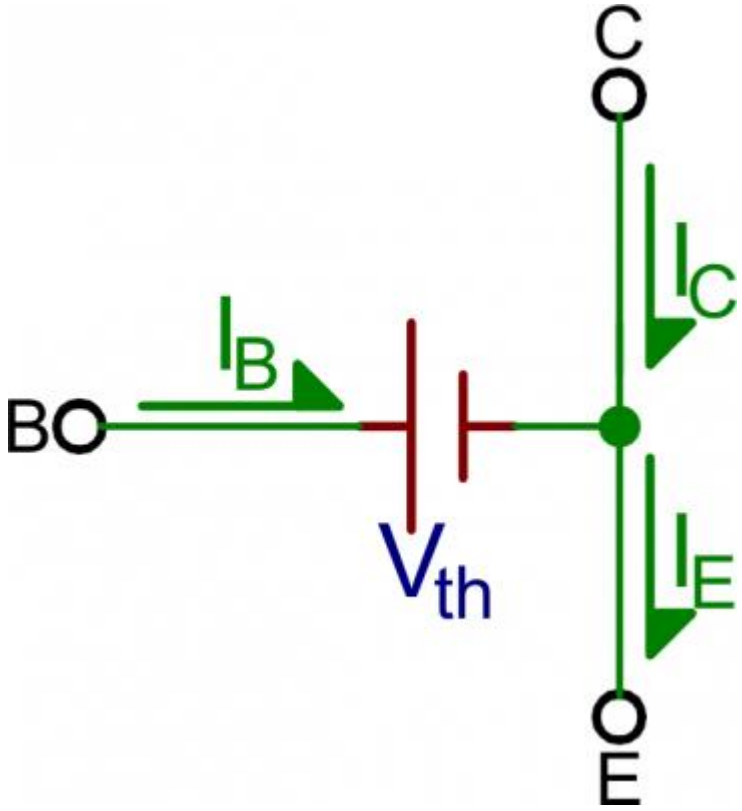


Answer

- PNP transistor

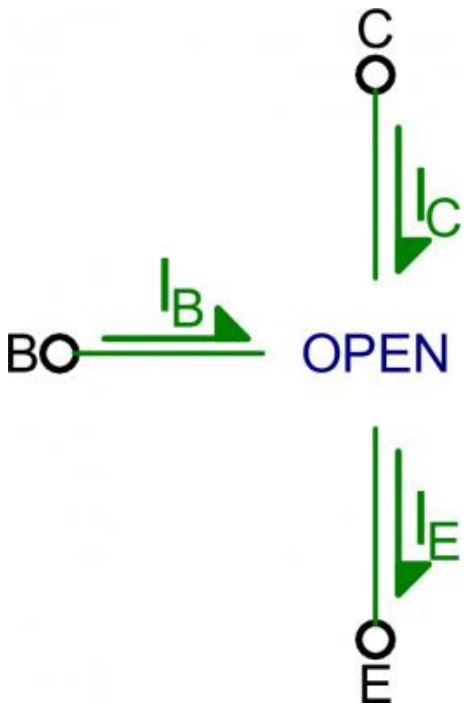


Saturation Mode



- Saturation is the **ON MODE** of a transistor
- A transistor in saturation mode acts like a short circuit between collector and emitter

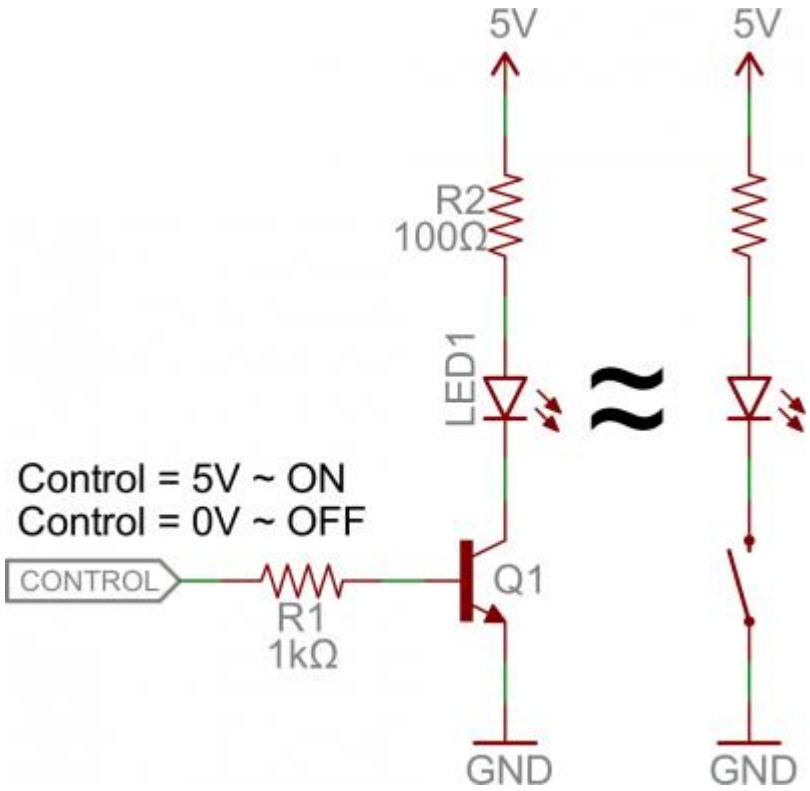
Cut-Off Mode



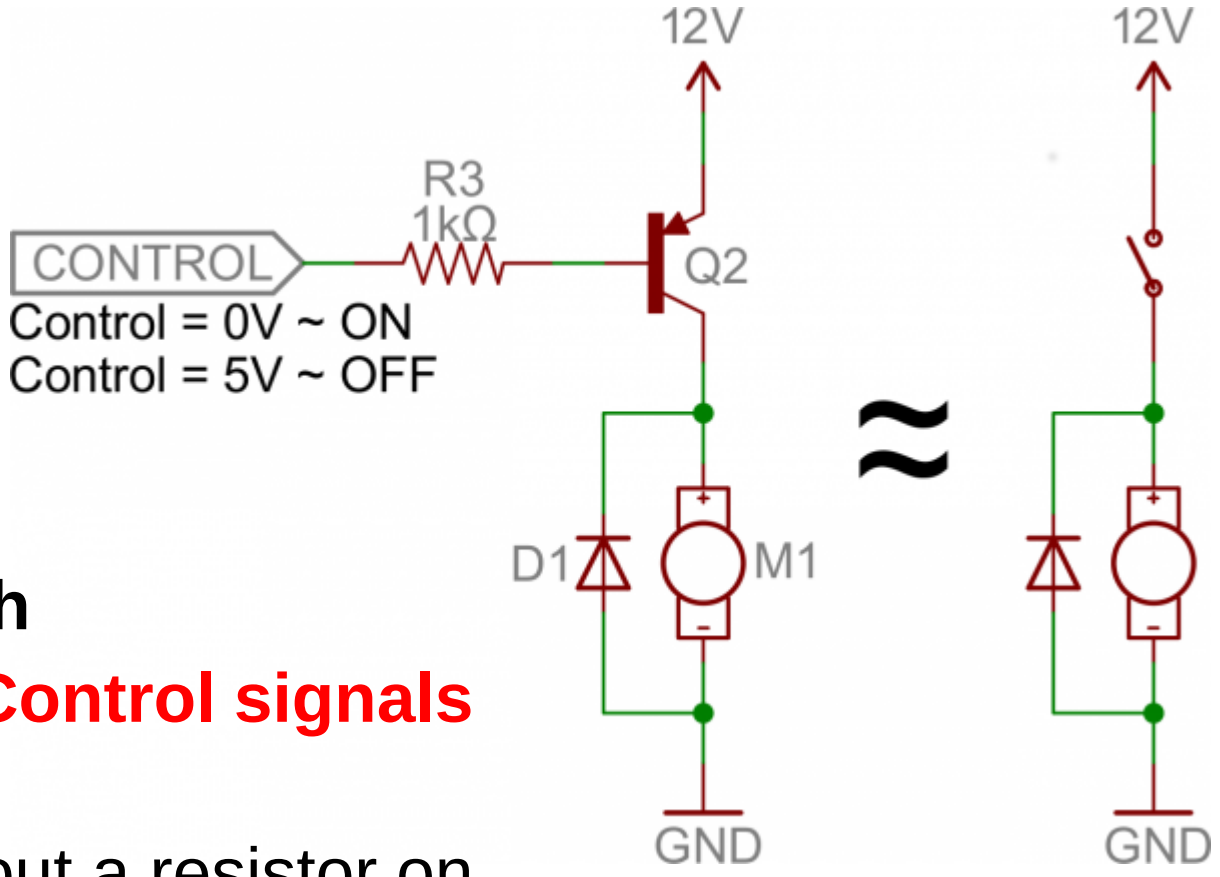
- Cutoff mode is the opposite of saturation
- There is no collector current, and therefore no emitter current
- It almost looks like an open circuit

Applications I: Switches

- When the voltage at the base is greater than 0.6V, the transistor starts saturating **short circuit**
- When the voltage at the base is less than 0.6V the transistor is in cutoff mode **open circuit**
- **Low-side switch**

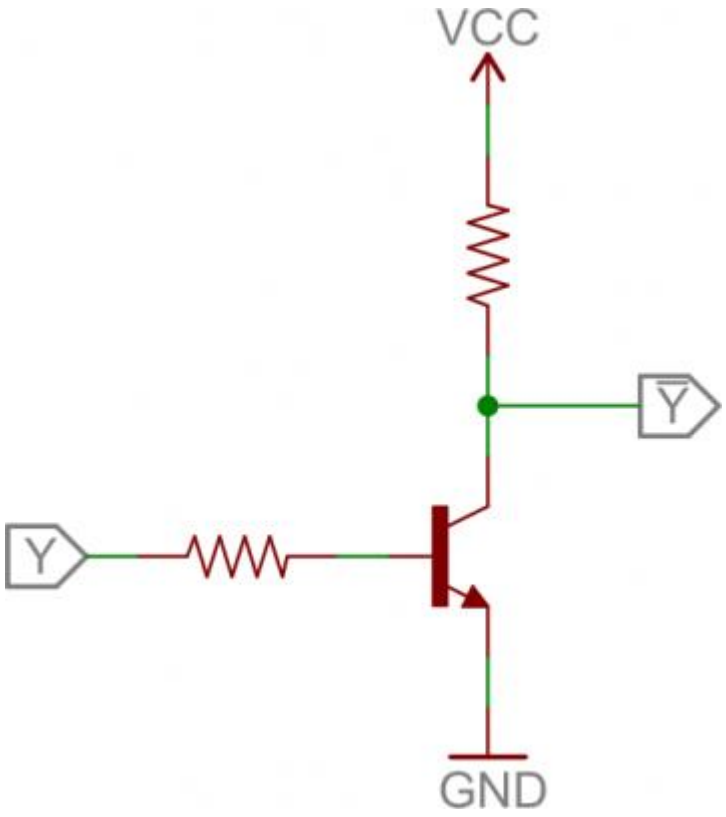


Applications I: Switches

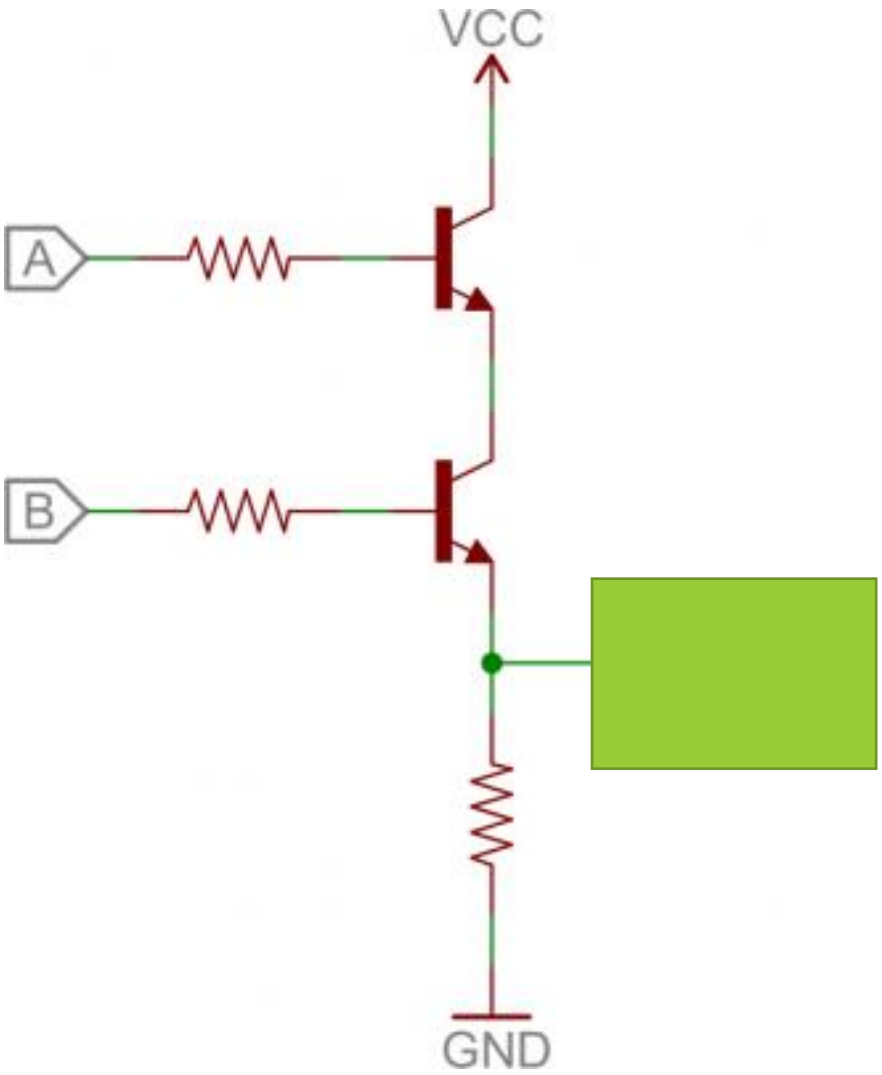


- **High side switch**
- PNP transistor: **Control signals are reversed**
- A transistor without a resistor on the base is like an LED with no current-limiting resistor

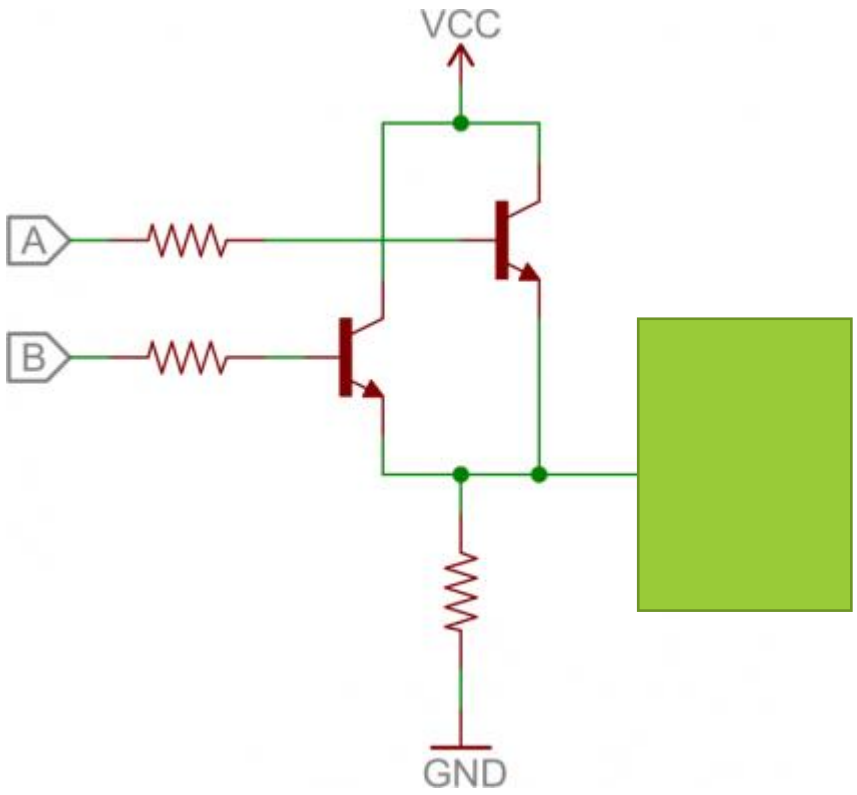
Logic Gate - NOT



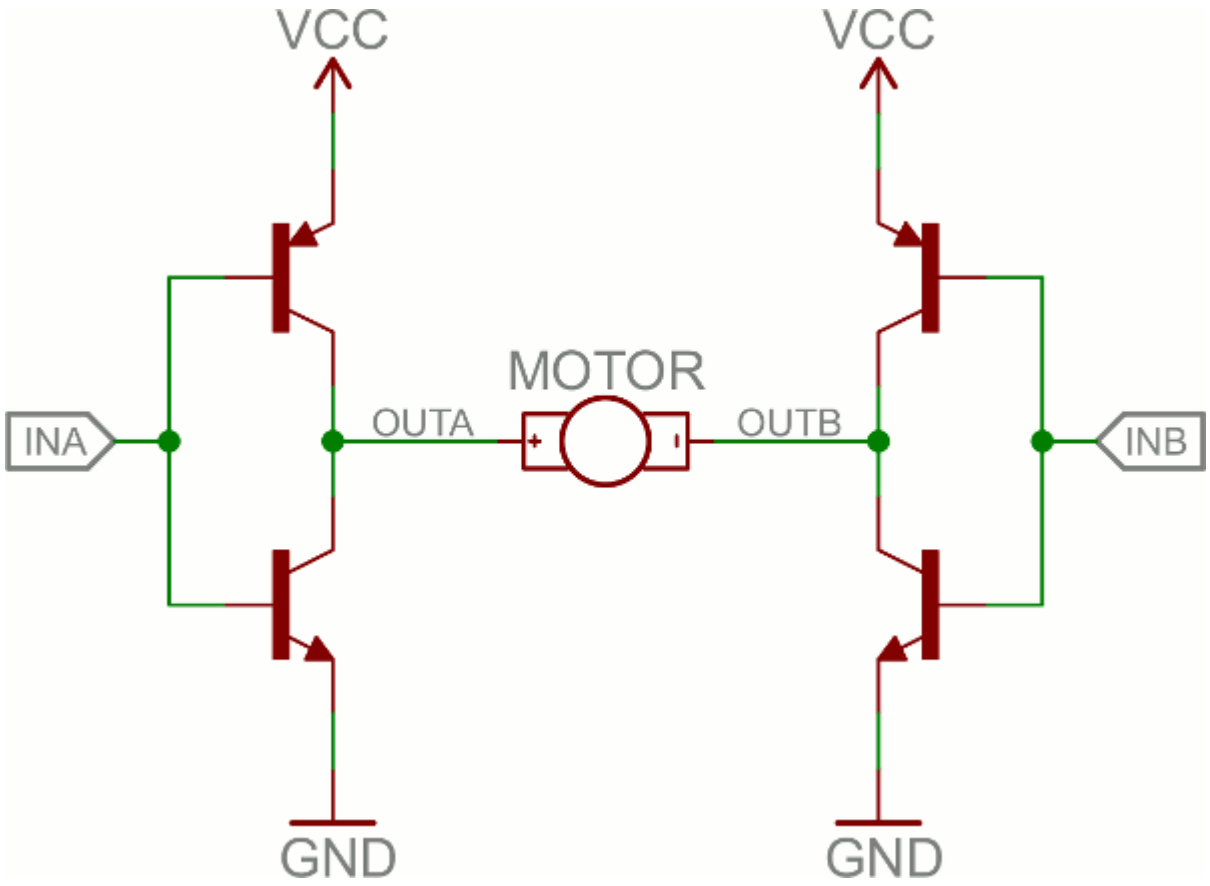
Logic Gates



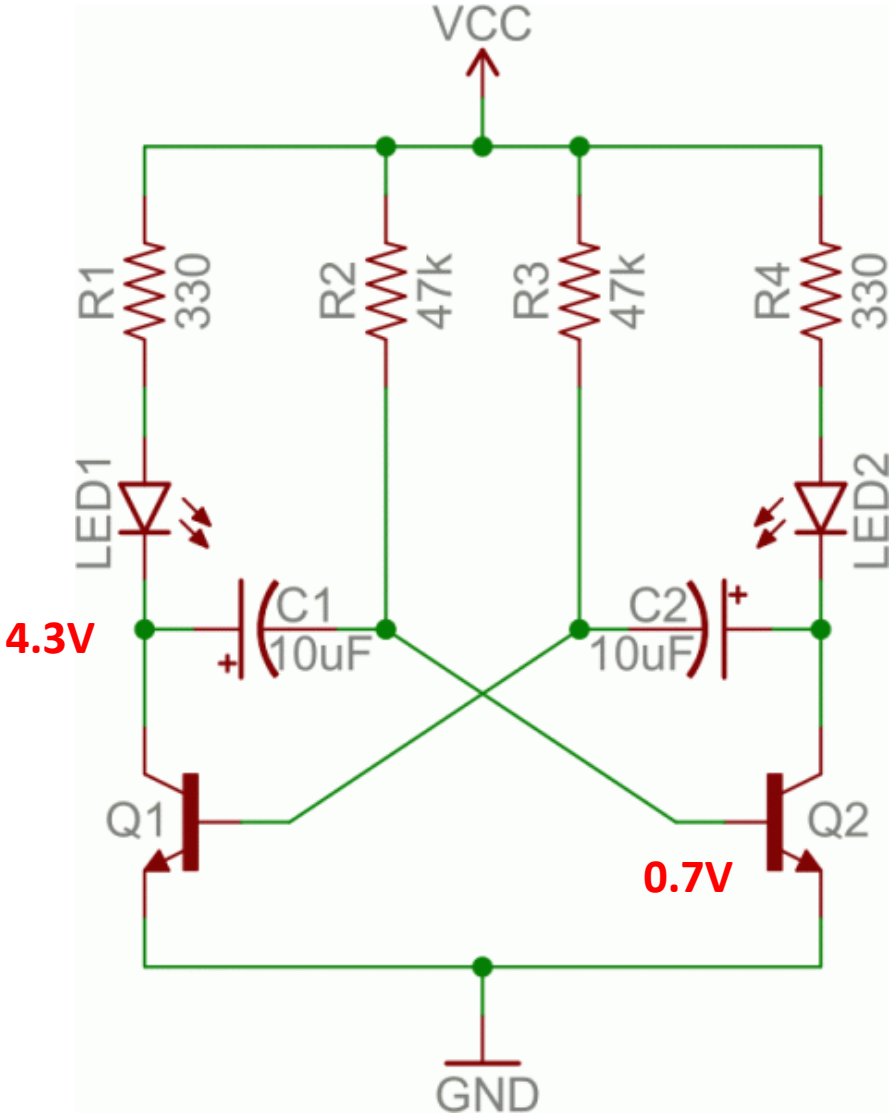
Logic Gate



H-Bridge

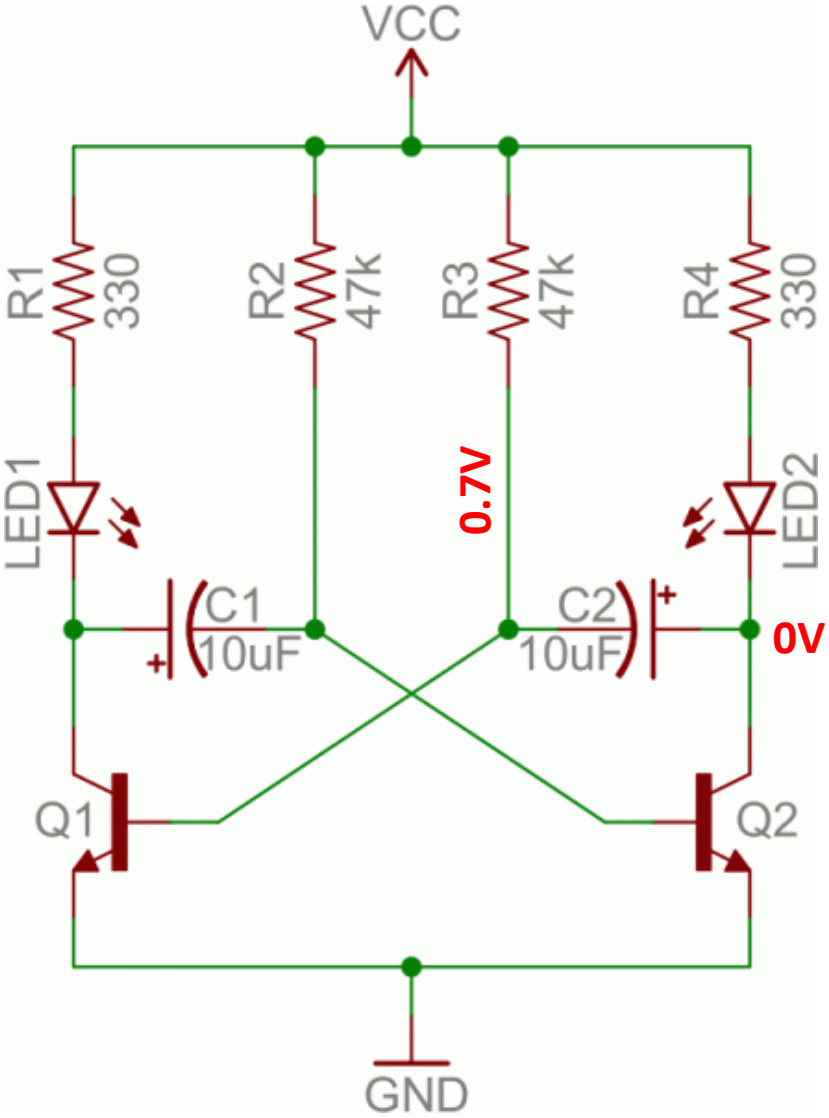


Oscillator



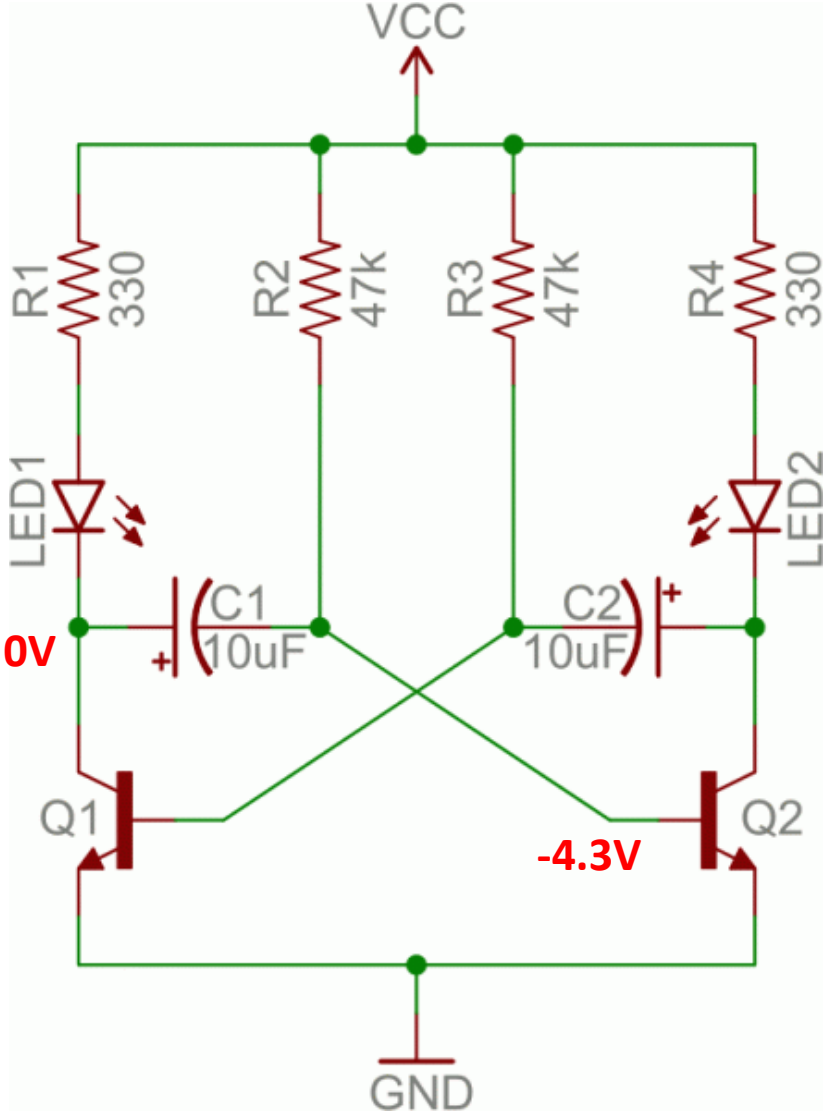
- Q2 ON – Q1 OFF
- V_{BE} (Q2) = 0.7V
- The voltage from V_{CC} charges C1 to 4.3V

Oscillator



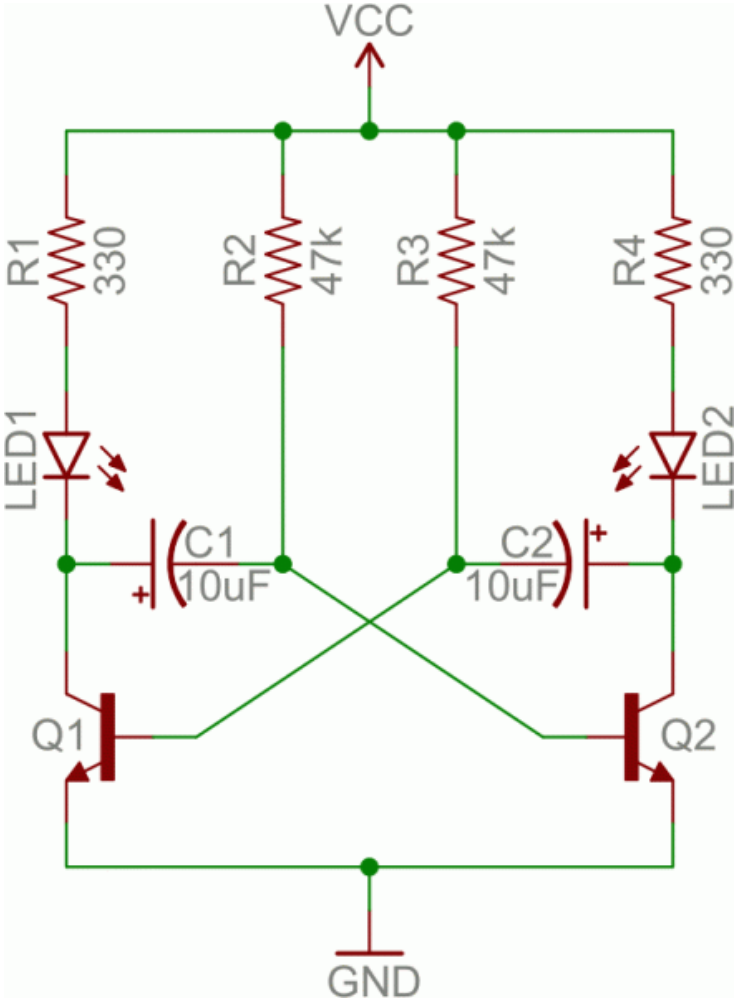
- Positive of C2 is connected to GND (due to Q2 is ON)
- VCC slowly charges C2 until 0.7V → Q1 ON

Oscillator



- VC1 is currently 4.3V
- Positive pin returns to 0V
- Negative pin goes to minus 4.3V ⍰ Q2 OFF

Oscillator



$$f = \frac{1}{\ln(2) \cdot (R_2 C_1 + R_3 C_2)}$$

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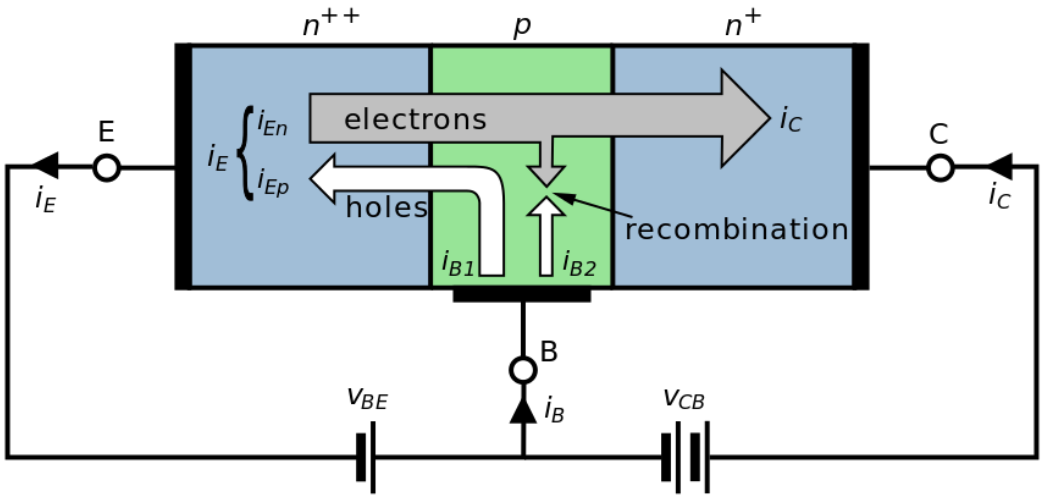
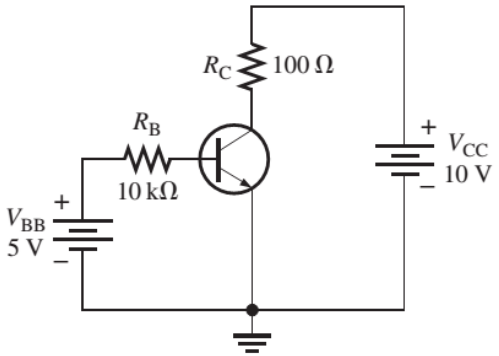
Amplifier using Bipolar Junction Transistor





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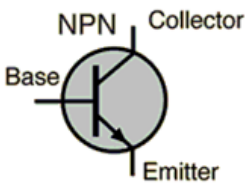
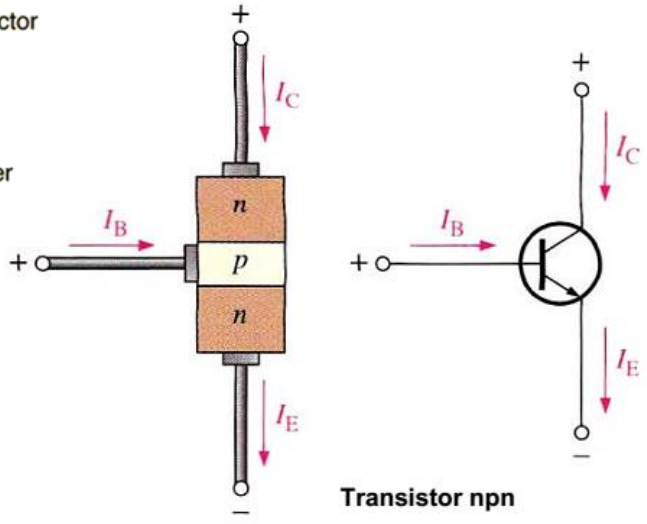
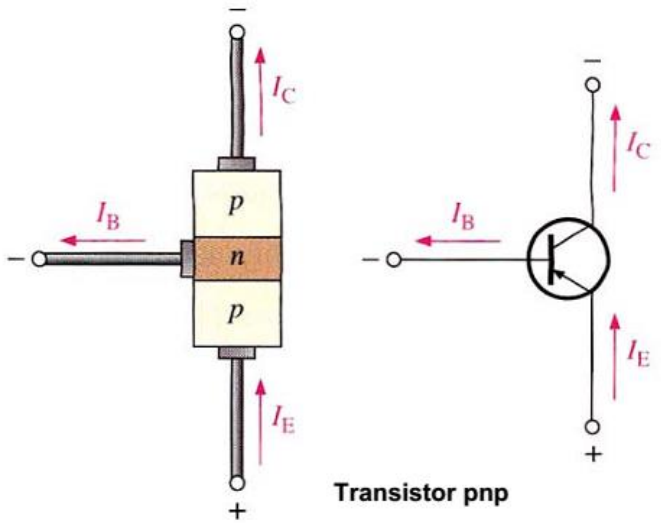
Bipolar Junction Transistor

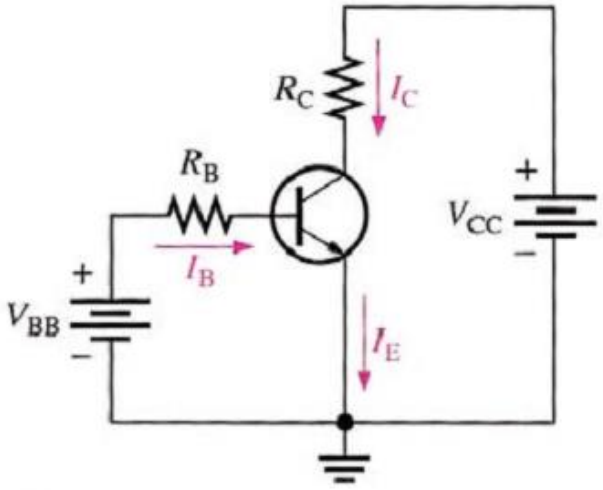




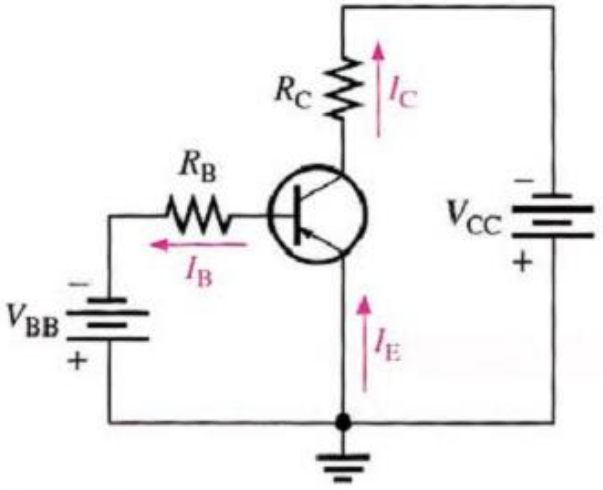
Transistor npn



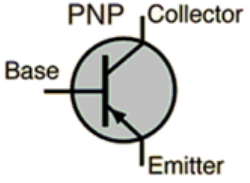
Transistor pnp



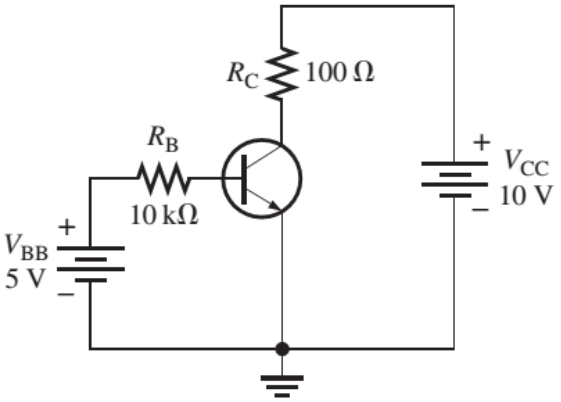
(a) *npn*

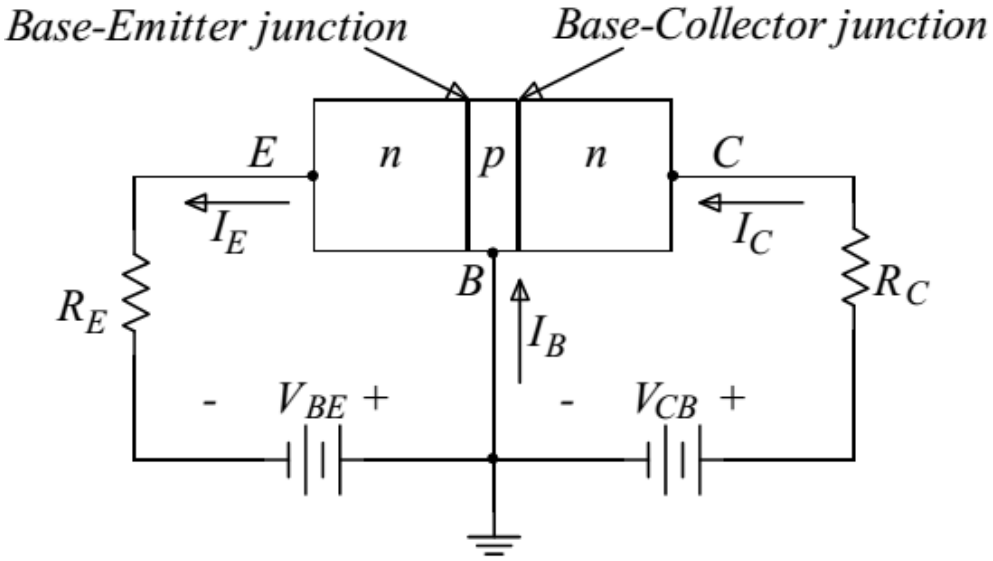


(b) *pnp*



BJT as Amplifier





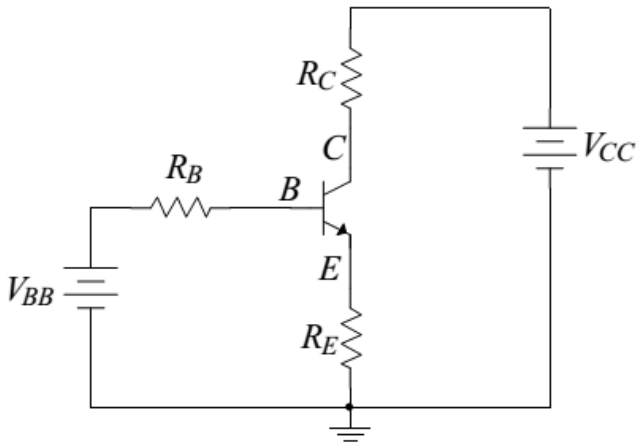
$$I_E = I_C + I_B$$

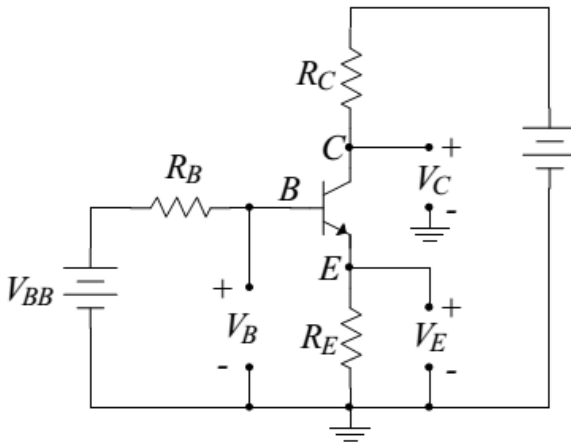
$$\beta_{DC} = \frac{I_C}{I_B}$$

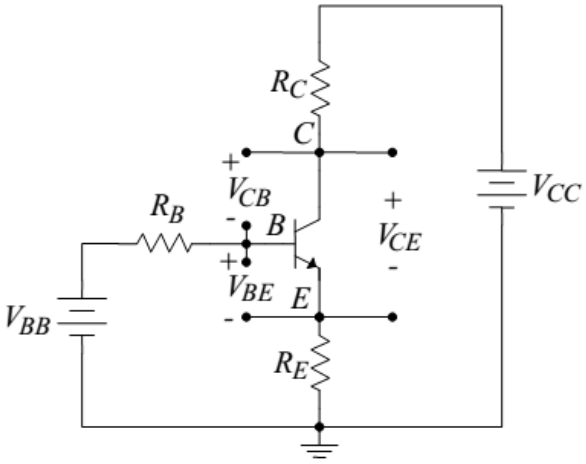
$$\alpha_{DC} = \frac{I_C}{I_E}$$

Voltages in a BJT

- v_{CC} , v_{BB}
- v_C , v_B , v_E
- v_{BE} , v_{CE} , v_{CB}

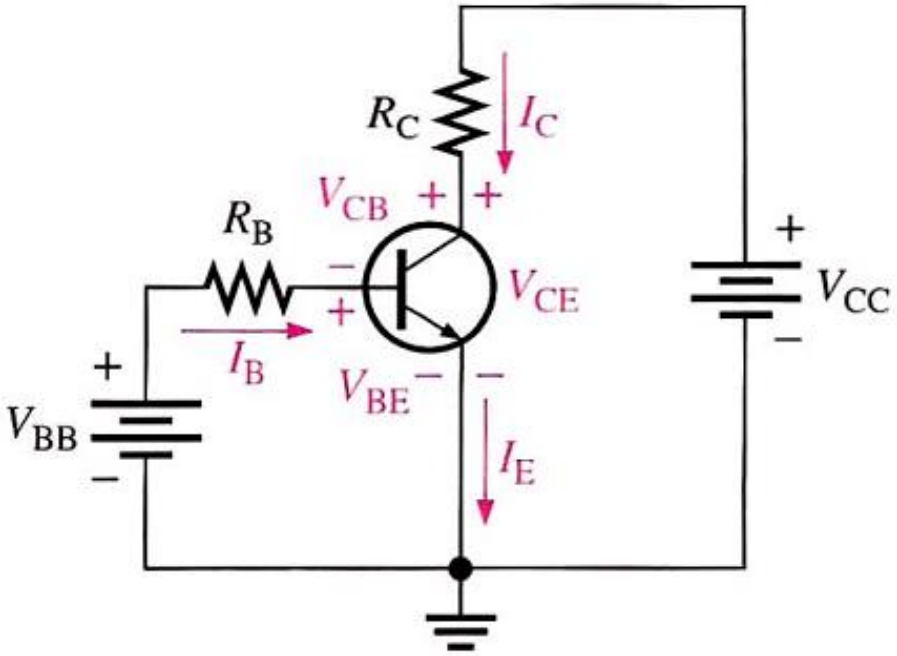






Current and Voltage Analysis

- E-B: Forward Bias (like diode)
  - $V_{BE} \approx 0.7V$
- Base Circuit



$$V_{BB} = R_B \bullet I_B + V_{BE}$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

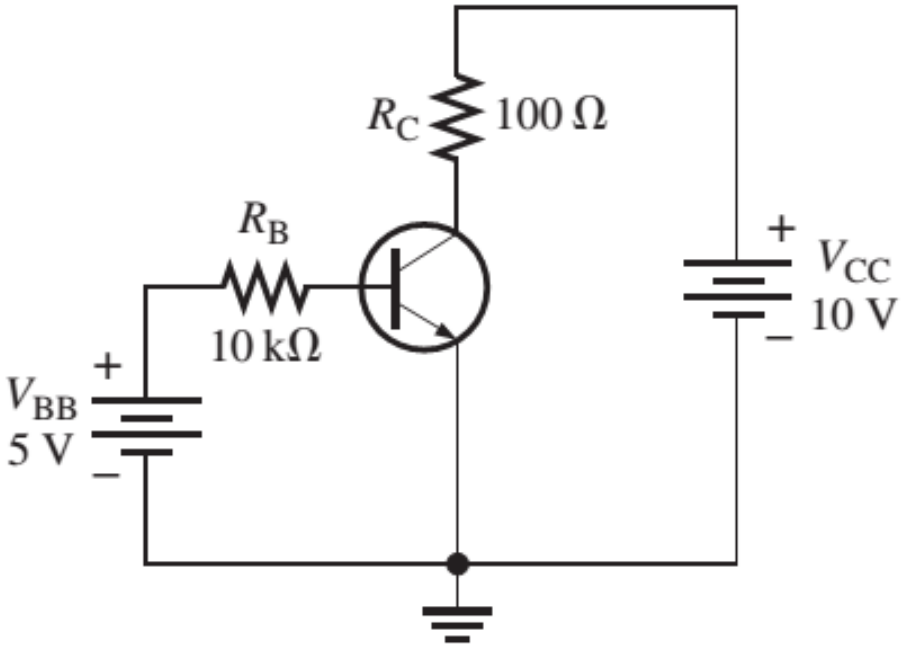
- Collector Circuit

$$V_{CC} = R_C \bullet I_C + V_{CE}$$

$$V_{CE} = V_{CC} - R_C \bullet I_C = V_{CC} - R_C \bullet (\beta_{DC} \cdot I_B)$$

Exercise 1

- Determine $I_B, I_C, I_E, V_{BE}, V_{CE}$ and V_{CB} for the given circuit when $\beta_{DC} = 150$

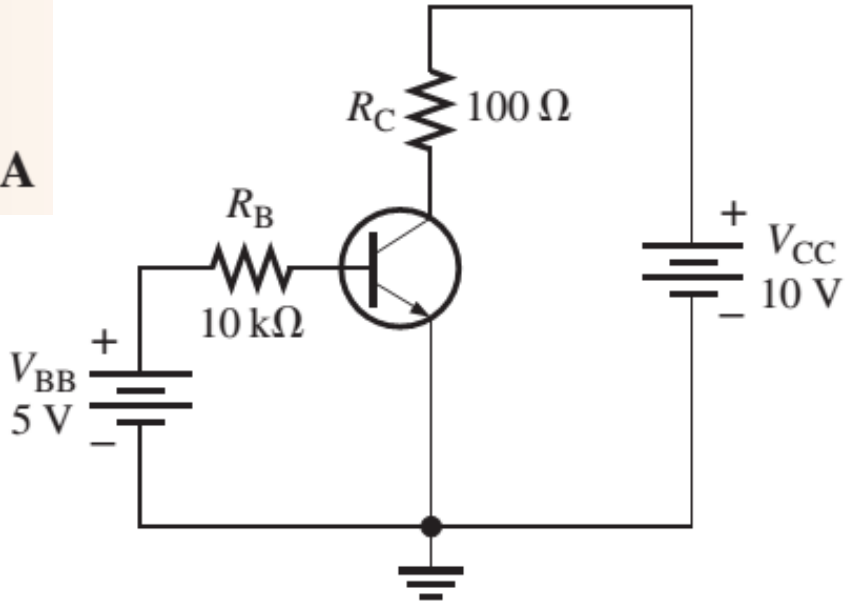


Solution 1

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5\,\text{V} - 0.7\,\text{V}}{10\,\text{k}\Omega} = \mathbf{430\ \mu A}$$

$$I_C = \beta_{DC} I_B = (150)(430\,\mu\text{A}) = \mathbf{64.5\ mA}$$

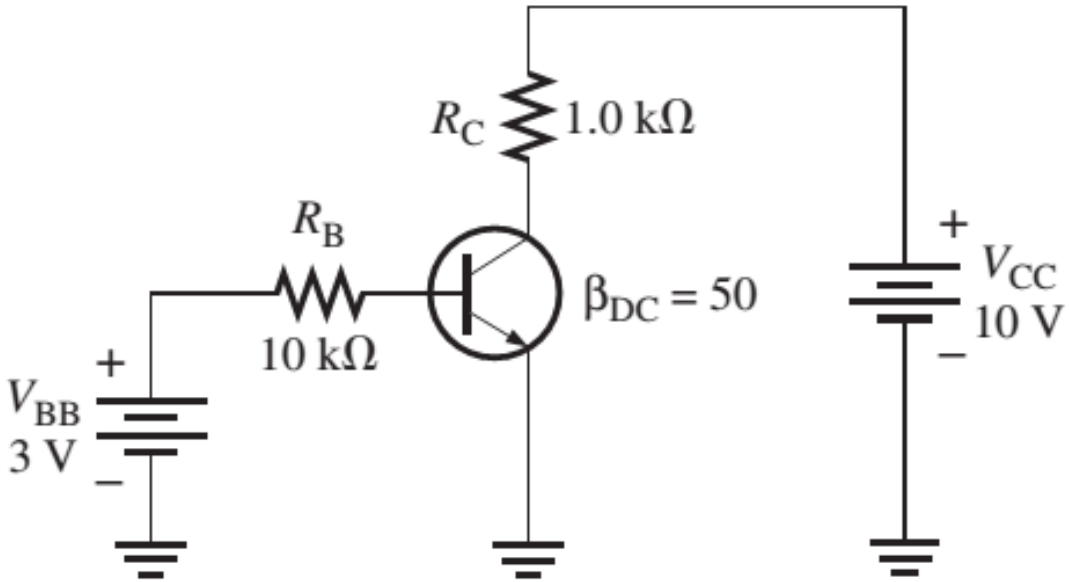
$$I_E = I_C + I_B = 64.5\,\text{mA} + 430\,\mu\text{A} = \mathbf{64.9\ mA}$$



$$V_{CE} = V_{CC} - I_C R_C = 10\,\text{V} - (64.5\,\text{mA})(100\,\Omega) = 10\,\text{V} - 6.45\,\text{V} = \mathbf{3.55\ V}$$

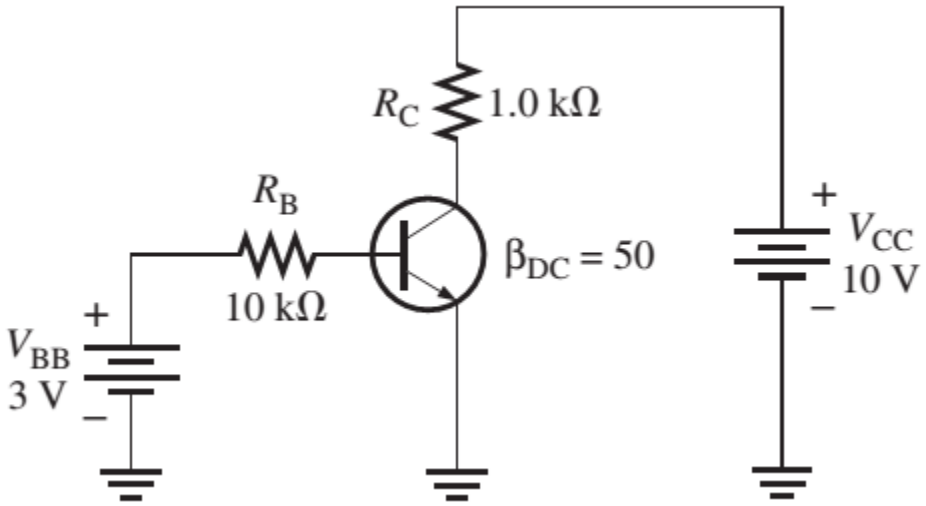
$$V_{CB} = V_{CE} - V_{BE} = 3.55\,\text{V} - 0.7\,\text{V} = \mathbf{2.85\ V}$$

Exercise 2



- Determine I_B ,I_C ,I_E ,V_{BE} ,V_{CE} and V_{CB}

Solution 2



- Assume that the circuit is working linearly

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3\,\text{V} - 0.7\,\text{V}}{10\,\text{k}\Omega} = \frac{2.3\,\text{V}}{10\,\text{k}\Omega} = 0.23\,\text{mA}$$

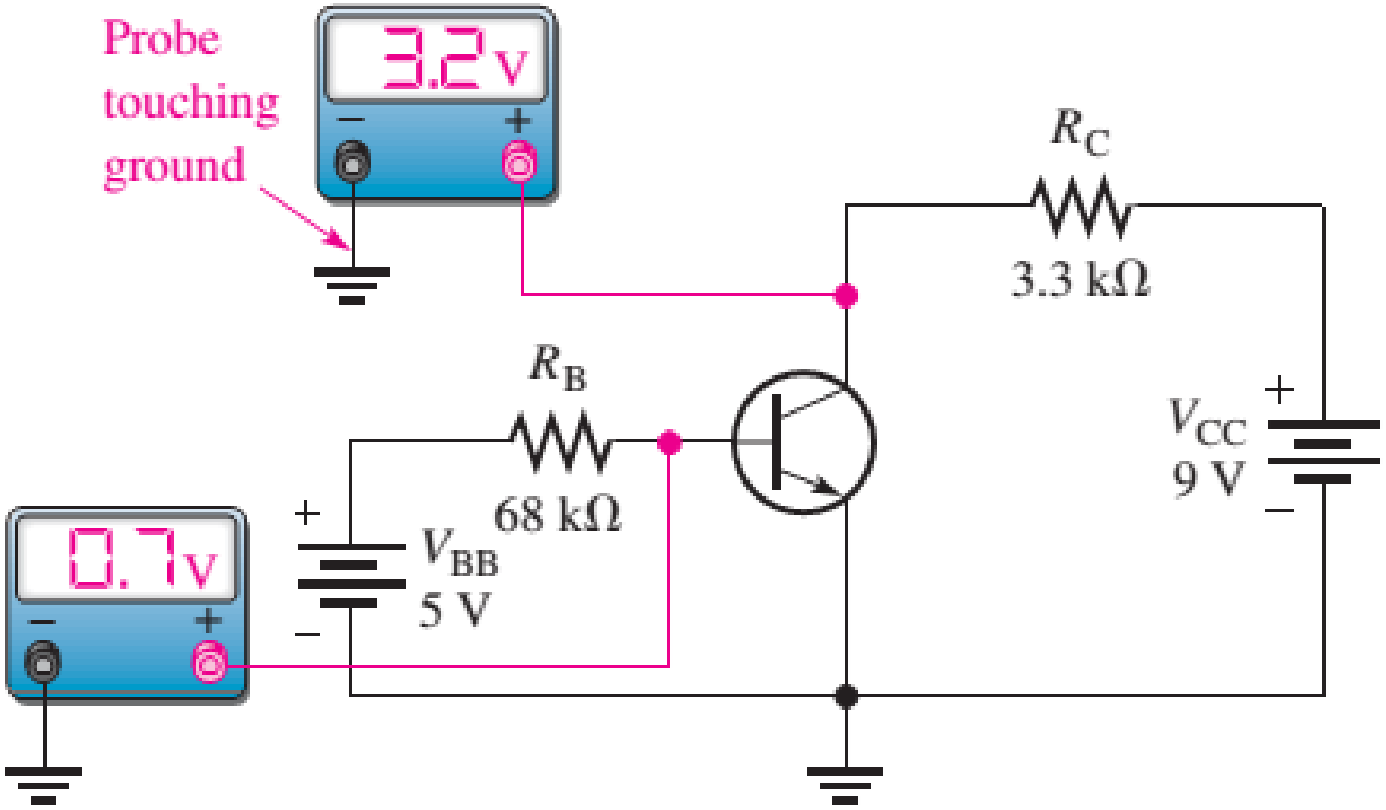
$$I_C = \beta_{DC} I_B = (50)(0.23\,\text{mA}) = 11.5\,\text{mA}$$

Solution 2

- $I_C = (V_{CC} - V_{CE}) \quad / R_C$
- Saturation Mode

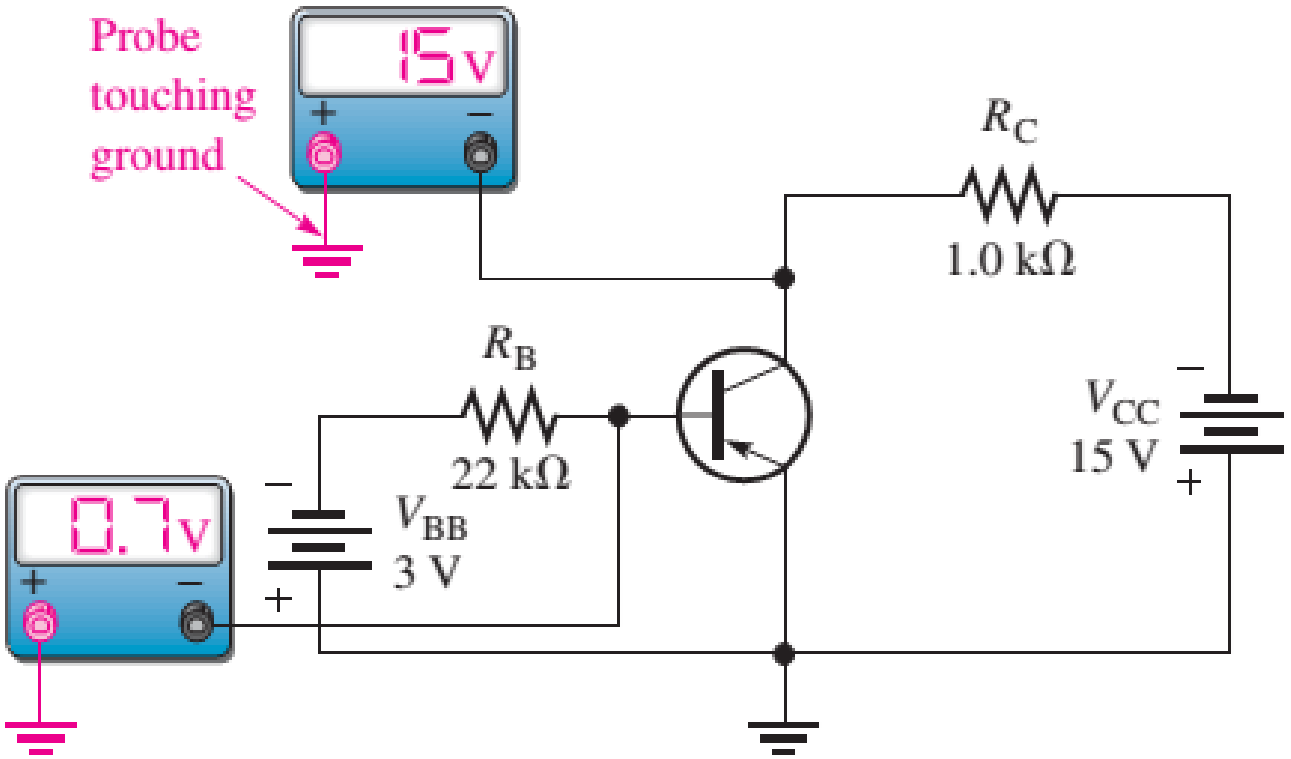
Exercise 3

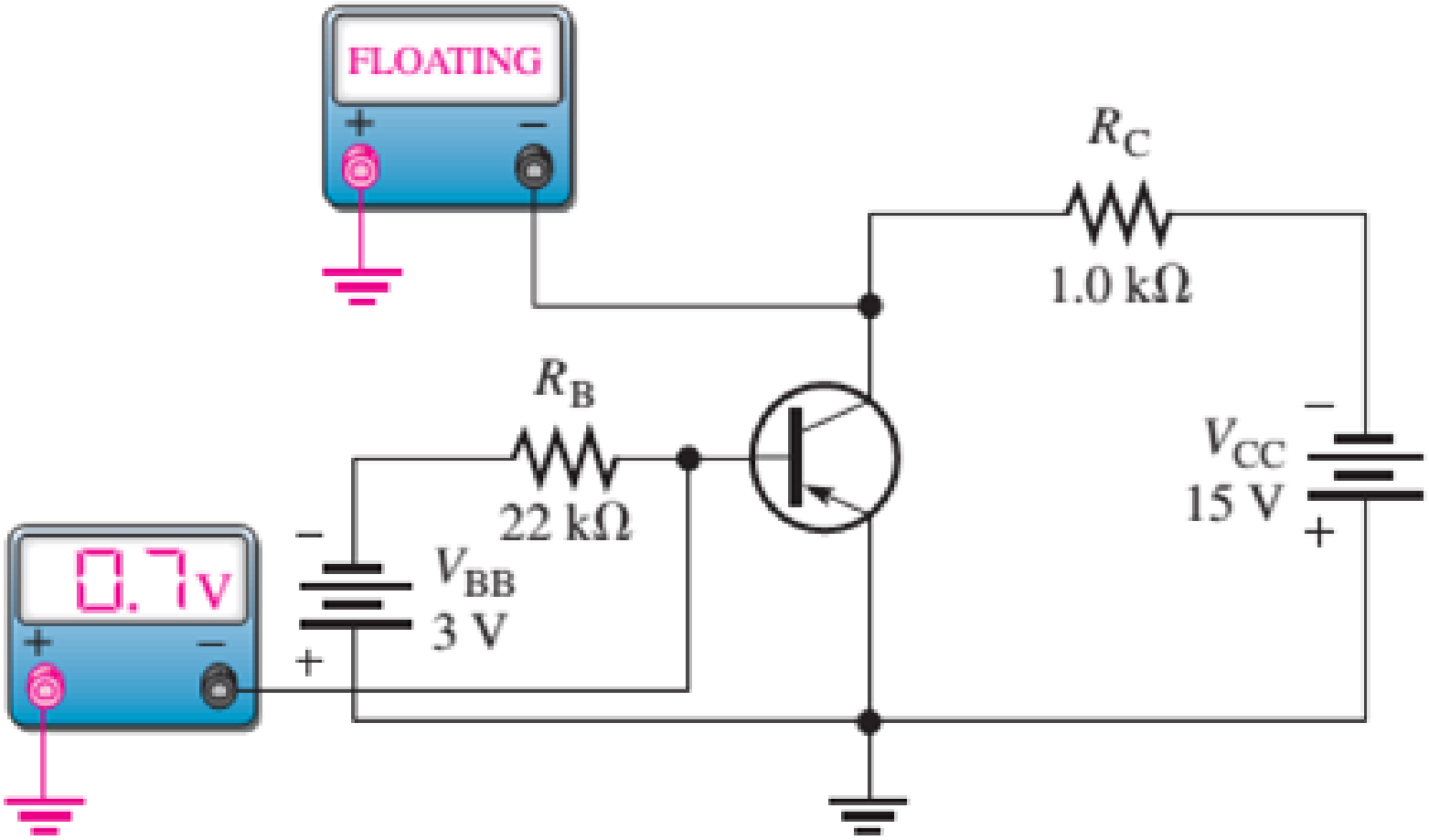
- Determine β_{DC}



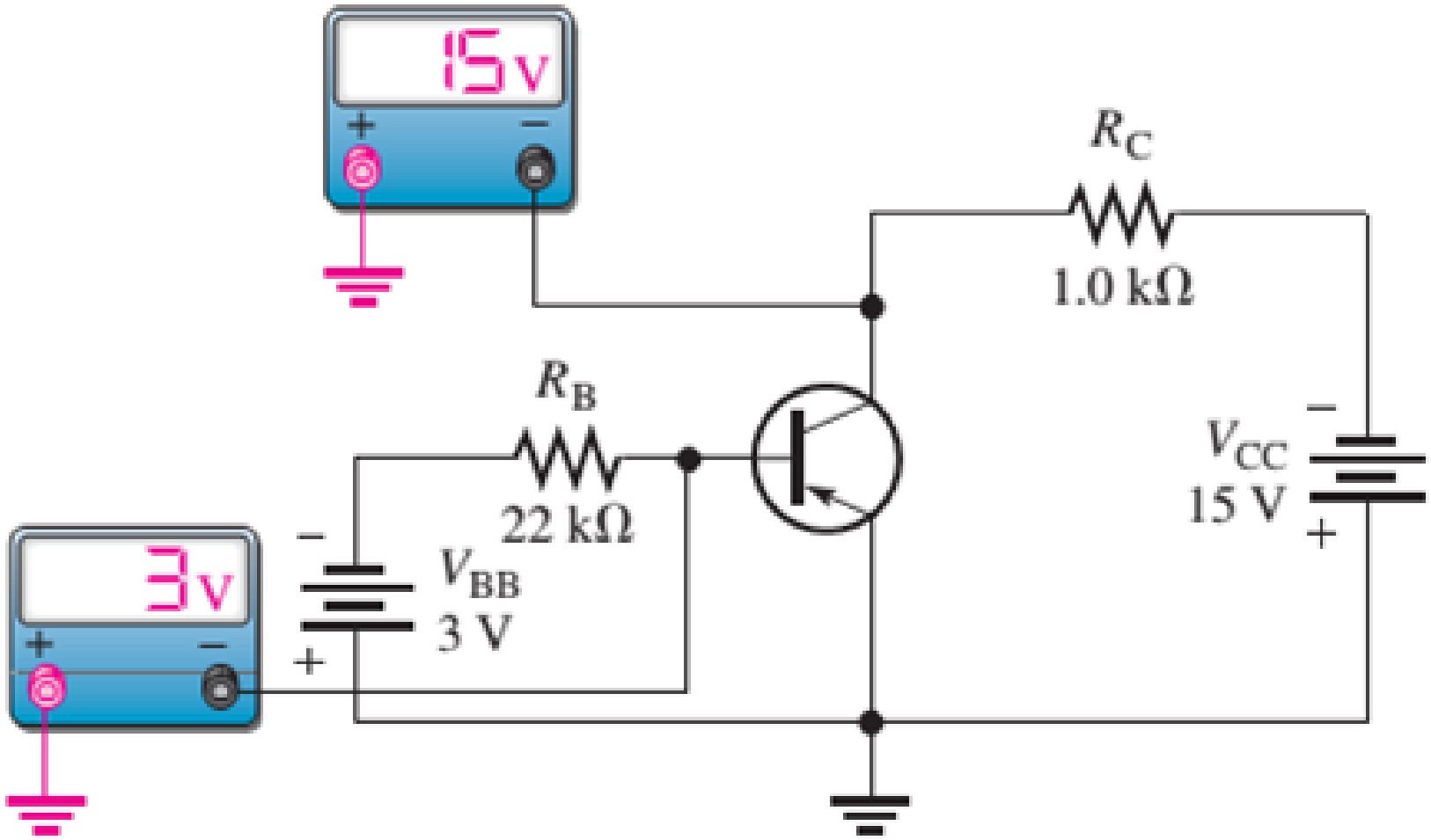
Exercise 4

- Explain why VC is 15V

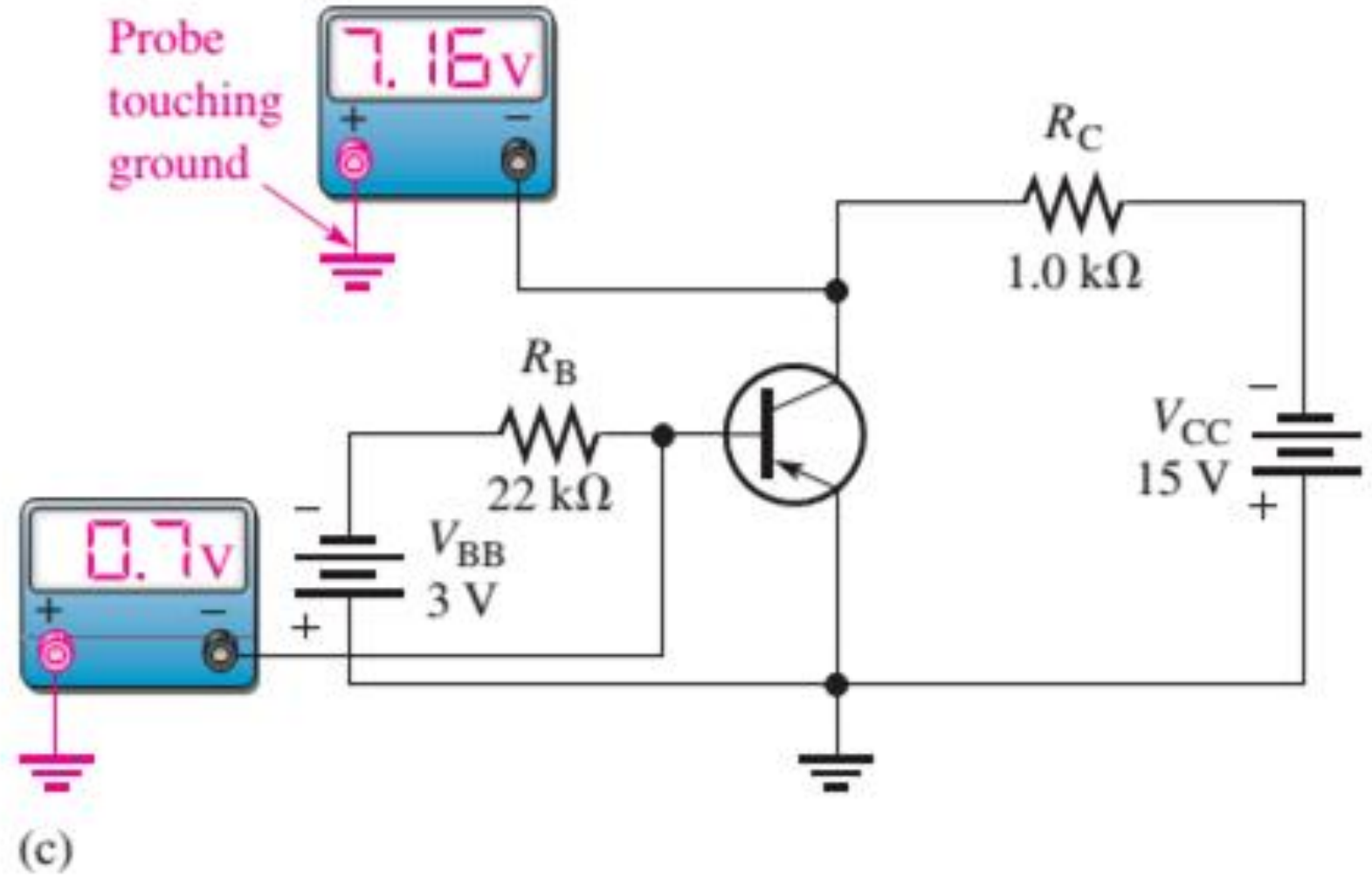



FLOATING
R_C
1.0 kΩ
R_B
22 kΩ
V_{BB}
3 V
V_{CC}
15 V
0.7v

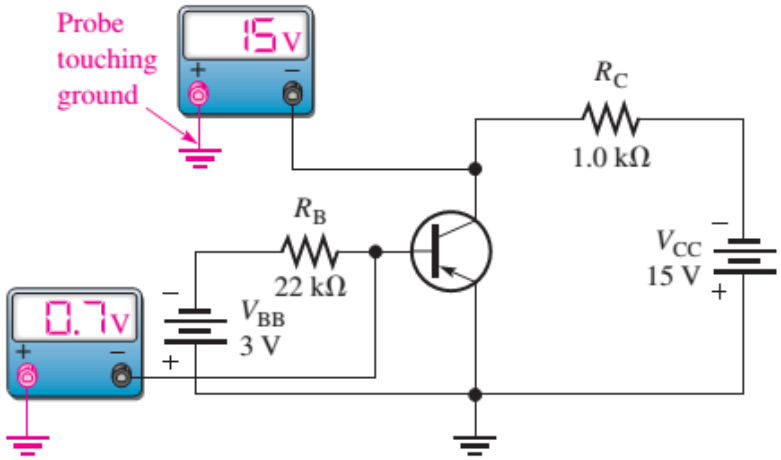
Exercise 4



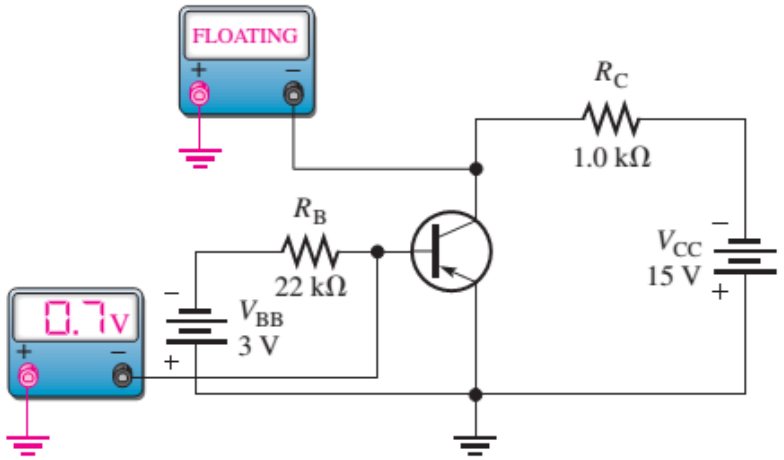
Exercise 4


Probe
touching
ground
7.16v
R_C
1.0 kΩ
R_B
22 kΩ
V_{CC}
15 V
0.7v
V_{BB}
3 V
(c)

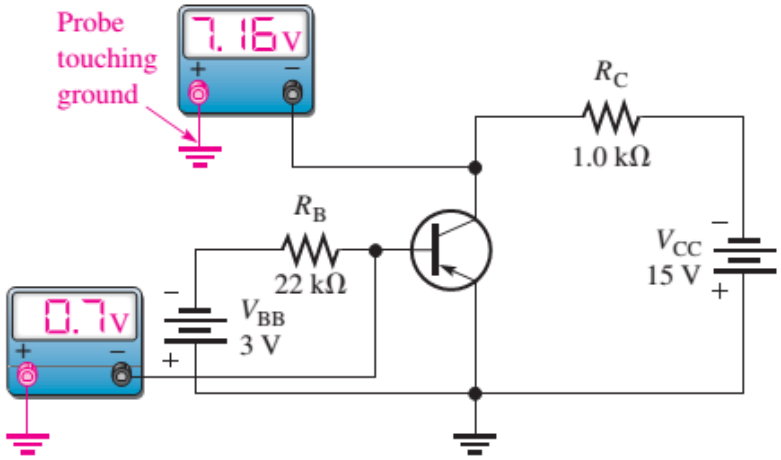
Exercise 4



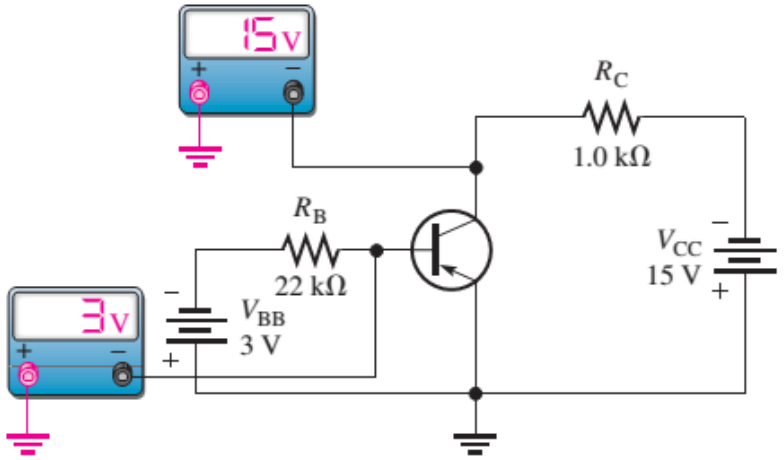
(a)



(b)

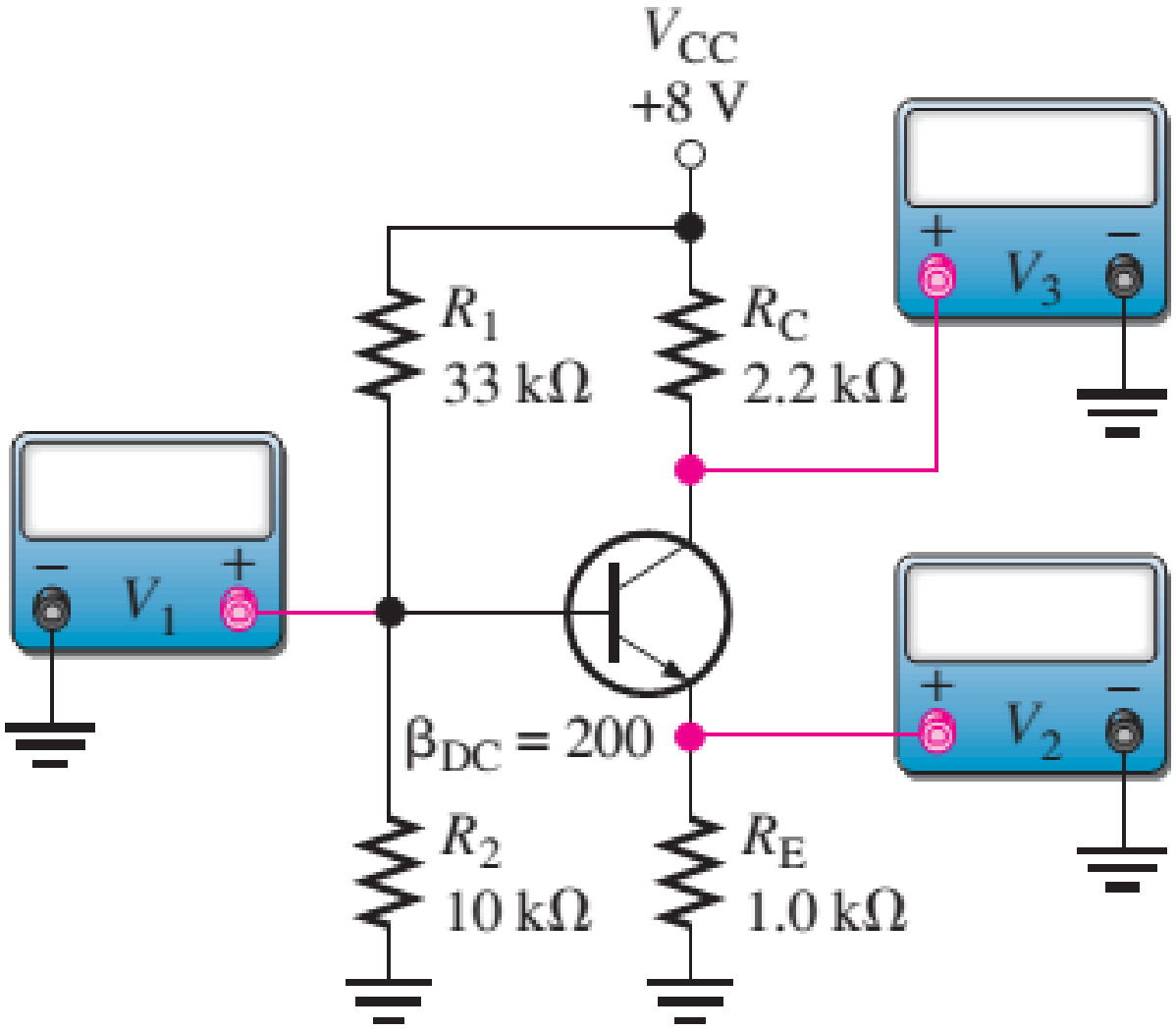


(c)



(d)

Exercise 5



Midterm (45 mins – Closed Book)

- Multichoice + Written

- Chapter 1: Basic Electronic Components
  - Deterimine the resistor values (4-band colors, 5-band colors)
  - LEDs connectors (Serial + Parallel)

- Chapter 2: Diode
  - Diode Principles and Models
  - Applications using Diodes

- Chapter 3: BJT (npn)
  - Amplifier Coefficient, Applications
  - Vbe = 0.7 (for default)