ECE 65: Components & Circuits Lab

Lecture 11

BJT circuits

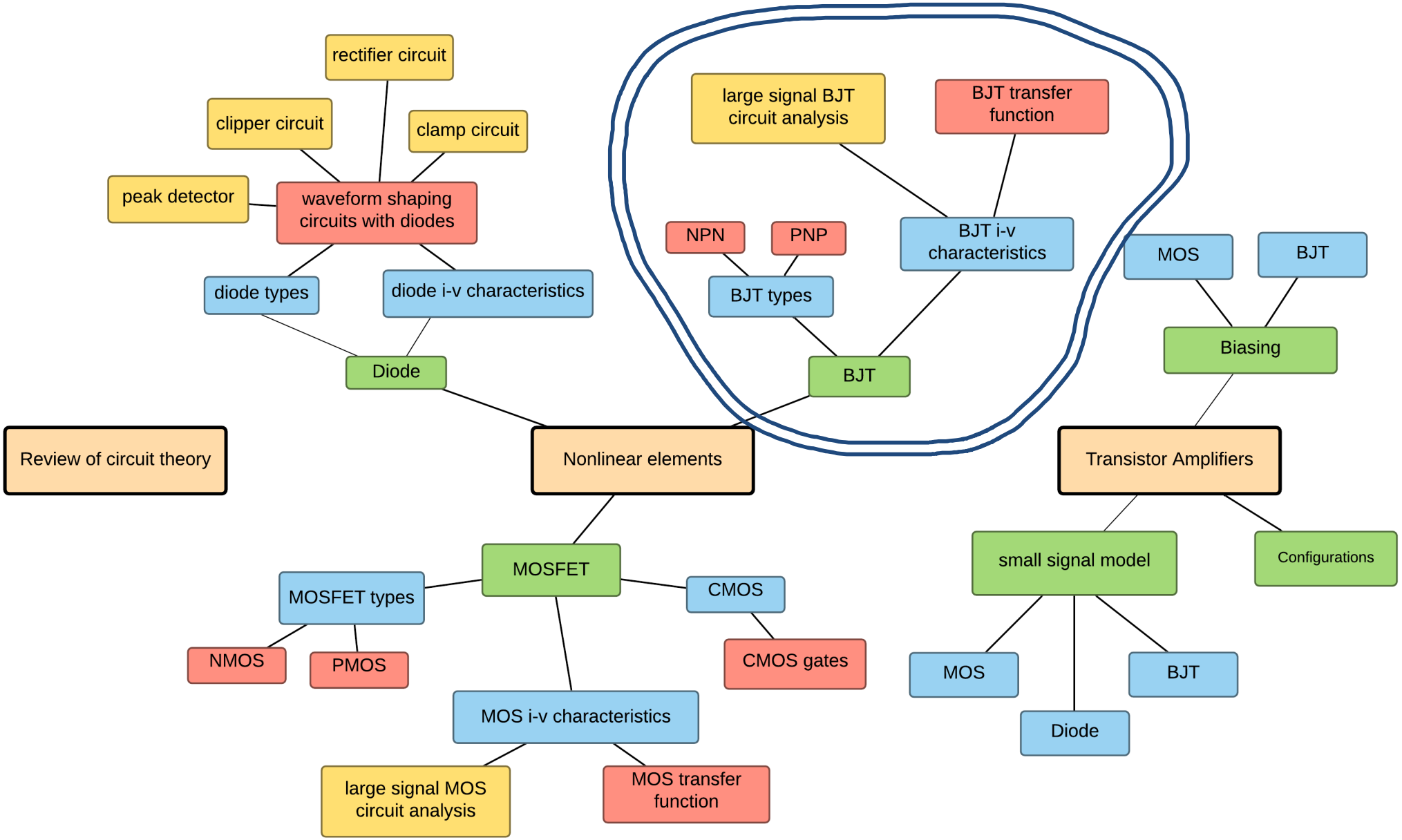
Reference notes: sections 3.2

Sedra & Smith (7th Ed): sections 6.1-6.3

Saharnaz Baghdadchi

Course map

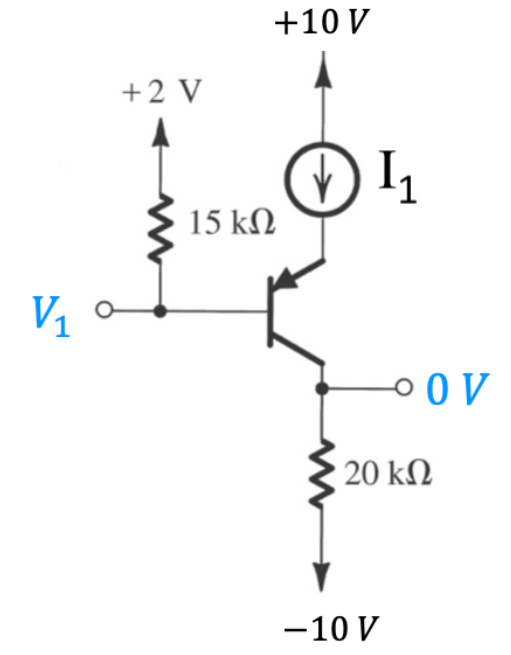
3. Bipolar Junction Transistor (BJT)

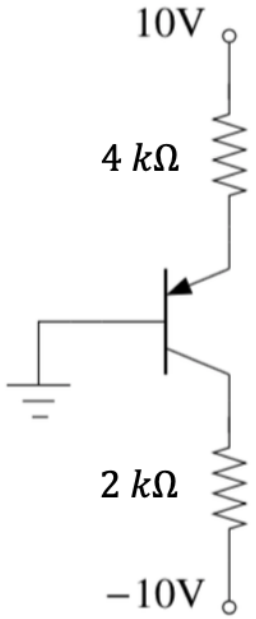


Note:

In the BJT and MOSFET circuits, to differentiate the applied node voltages from the measured node voltages:

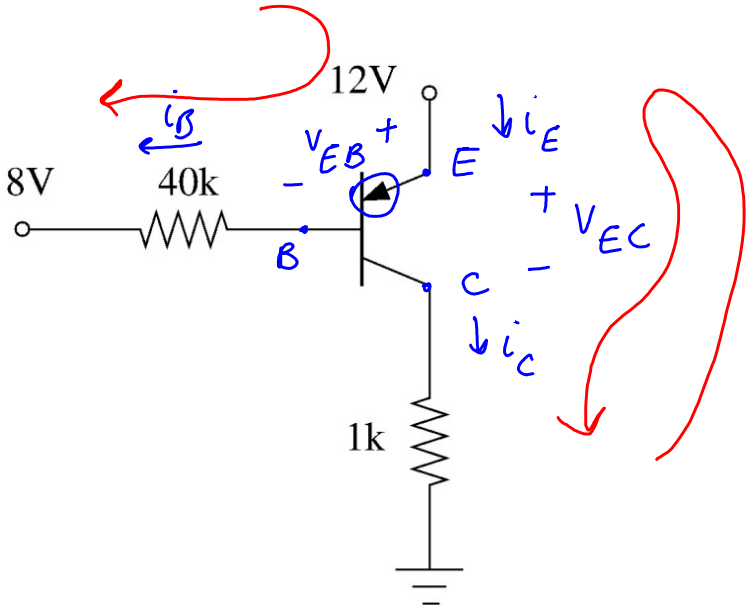
We will show the measured node voltages in **blue color** and the DC or AC voltage sources connected to different nodes in **black color**.





PNP Transistor Example:

In this circuit, find the transistor parameters (Si BJT with $\beta = 100$).



EB KVL:

$12 = V_{EB} + 40k \times i_B + 8$

$4 = V_{EB} + 40k \times i_B$

EC KVL:

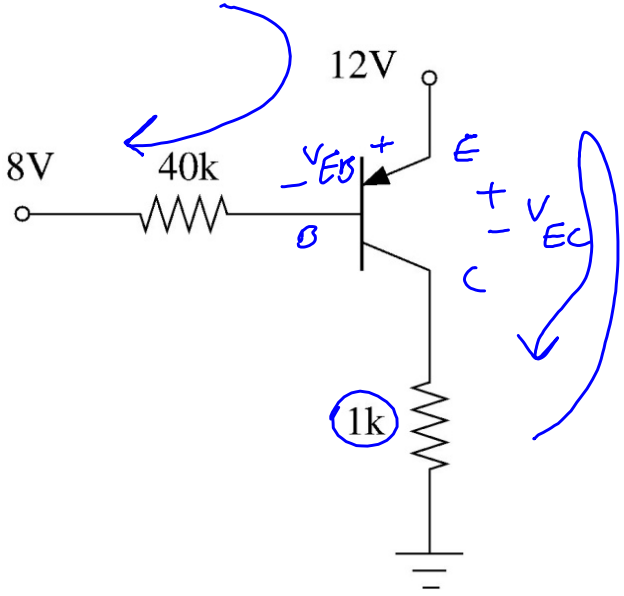
$12 = V_{EC} + 1k \times i_C$

Assume the BJT is in cut-off, $i_B = 0$, $V_{EB} < V_{D_0} = 0.7V$

EB KVL: $4 = V_{EB} + 40k \times 0 \longrightarrow V_{EB} = 4V > 0.7 \longrightarrow$ BJT is not in cut-off

BJT is ON, $i_B \geq 0$, $V_{EB} = V_{D_0} = 0.7\ V$

EB KVL, $4 = 40K \times i_B + 0.7 \longrightarrow i_B = 82.5\ \mu A > 0$



Assuming active mode:

$i_C = \beta i_B$, $V_{EC} \geq V_{D_0} = 0.7\ V$

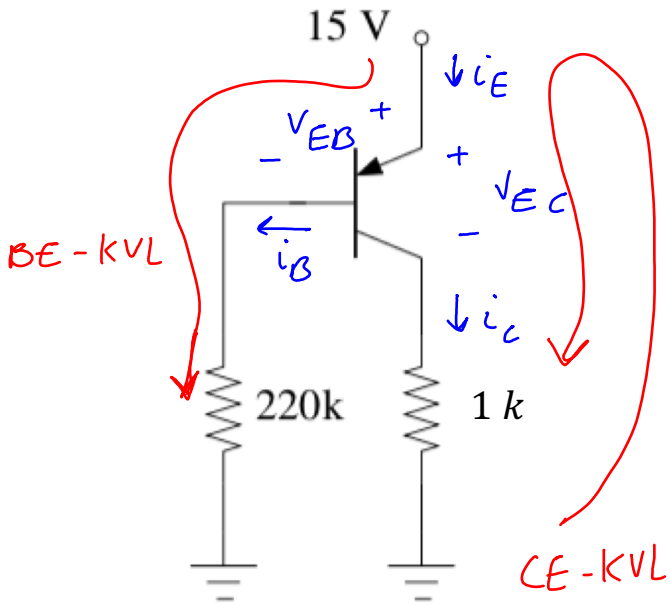
$i_C = 100 \times 82.8\ \mu A = 8.25\ mA$

EC KVL: $12 = V_{EC} + 10^3 \times 8.25 \times 10^{-3} \longrightarrow V_{EC} = 3.75\ V > 0.7$

Assumption was correct, BJT is in active mode.

Lecture 11 reading quiz

Find the transistor parameters in this BJT circuit. ($\beta = 100$, $V_{D0} = 0.7V$).



Assume Cut-off: $i_B = 0$, $V_{EB} < V_{D_0}$

BE-KVL: $15V = V_{EB} + 220k \times i_B$

with $i_B = 0 \longrightarrow V_{EB} = 15V > 0.7V \longrightarrow$ BJT is ON

$V_{EB} = 0.7V$, $i_B \geq 0$

BE-KVL: $i_B = \frac{15 - 0.7}{220k\Omega} = 65\,\mu A$

Assume active mode of operation: $i_C = \beta i_B$, $V_{EC} \geq V_{D_0}$

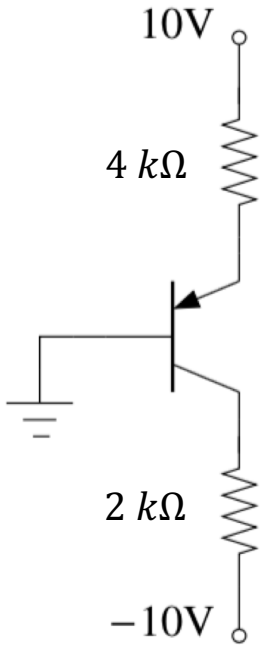
$i_C = 100 \times i_B = 6.5mA$

CE KVL: $15V = V_{EC} + 1k \times i_C \longrightarrow V_{EC} = 15V - 1k \times 6.5mA = 8.5V > V_{D_0}$

Assumption was correct, $i_C = 6.5mA$, $i_B = 65\,\mu A$, $V_{EC} = 8.5V$, $V_{EB} = 0.7V$

Clicker question 1:

The transistor in the following circuit has $\beta = 100$. Find the value for V_{EC}. (assume $V_{D0} = 0.7V$, $V_{sat} = 0.2\,V$).



A. $V_{EC} \approx 10.5\,V$

B. $V_{EC} = 0\,V$

C. $V_{EC} \approx 6.1\,V$

D. $V_{EC} = 0.2\,V$

Cut-off :	**Active:**	**Saturation:**
$i_B = 0, \quad i_C = 0$	$v_{EB} = V_{D0}, \quad i_B \geq 0$	$v_{EB} = V_{D0}, \quad i_B \geq 0$
$v_{EB} < V_{D0}$	$i_C = \beta\, i_B, \quad v_{EC} \geq V_{D0}$	$v_{EC} = V_{sat}, \quad i_C < \beta\, i_B$

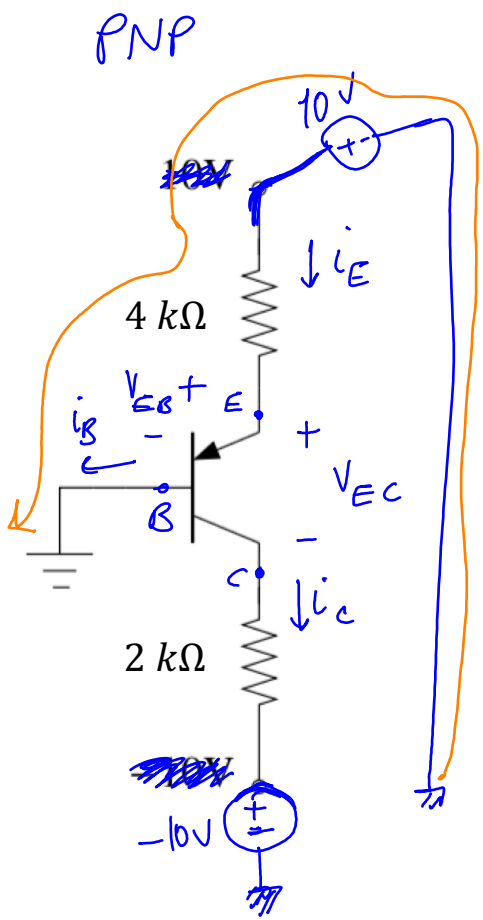
Assume BJT is in cut-off

$i_B = 0,\ i_C = 0,\ i_E = 0,\ V_{EB} < 0.7V$

$i_E = i_C + i_B$

EB KVL: $10\,V = 4k\Omega \times i_E + V_{EB}$

$V_{EB} = 10\,V > 0.7V \longrightarrow$ Assumption was wrong



BJT is ON, $V_{EB} = 0.7\,V,\ i_B \geq 0$

Assume BJT is in active region:

$i_C = \beta i_B,\ V_{EC} \geq V_D$.

EB KVL: $10\,V = 4k\Omega \times i_E + 0.7V \longrightarrow i_E = \frac{9.3V}{4k\Omega} = 2.325mA$

EC KVL: $10V = 4k\Omega \times i_E + V_{EC} + 2k\Omega \times i_C - 10V$

$20V = 4k\Omega \times i_E + 2k\Omega \times i_C + V_{EC}$

$20V = 4k \times 2.325mA + 2k\Omega \times 2.3mA + V_{EC} \longrightarrow V_{EC} \simeq 6.1V > 0.7$

$i_C = \beta i_B \longrightarrow i_B = \frac{1}{\beta} i_C$

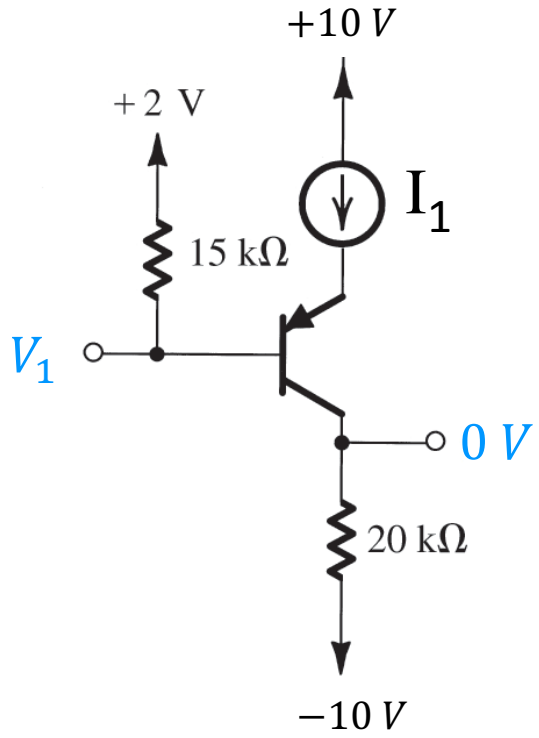
$i_C + i_B = i_E \longrightarrow i_C + \frac{1}{\beta} i_C = i_E \longrightarrow i_E = \frac{\beta+1}{\beta} i_C \longrightarrow i_C \simeq 2.3mA$

$V_{EC} = 6.1\ V > 0.7\ V$

assumption was correct.

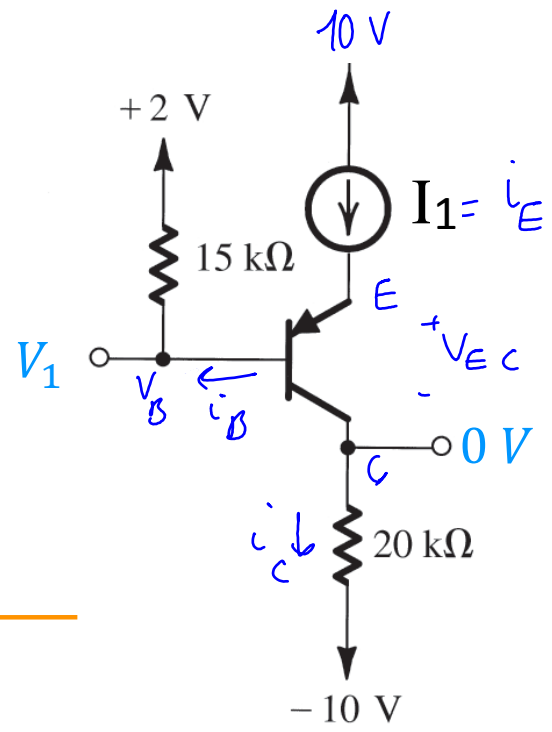
Discussion question 1:

In this BJT circuit find V_1 and I_1. Assume $\beta = 100$, $V_{D0} = 0.7V$, $V_{sat} = 0.2\,V$.



Cut-off :	Active:	Saturation:
$i_B = 0, \quad i_C = 0$	$v_{EB} = V_{D0}, \quad i_B \geq 0$	$v_{EB} = V_{D0}, \quad i_B \geq 0$
$v_{EB} < V_{D0}$	$i_C = \beta\, i_B, \quad v_{EC} \geq V_{D0}$	$v_{EC} = V_{sat}, \quad i_C < \beta\, i_B$

$$i_C = \frac{0-(-10V)}{20k\Omega} = 0.5mA \longrightarrow \text{BJT is ON}$$



Assume active mode:

$$i_B = \frac{i_C}{\beta} = 5\ \mu A$$

$$i_E = I_1 = 0.505\ mA$$

$$V_B = V_1 = 2V + 15k \times i_B = 2.075\ V$$

$$\text{BJT is ON} \longrightarrow V_{EB} = 0.7 = V_E - V_B = V_E - 2.075 = 0.7\ V$$

$$\longrightarrow V_E = 2.775V$$

$$V_{EC} = V_E - V_C = 2.775 - 0 = 2.775V > V_{D_0} \quad \checkmark$$

Assumption was correct.