Announcements

Exam 1: Thursday, Feb. 7, 6:30 PM, LILY 1105. (Weeks -1- 4 topics, semiconductors, diodes, BJT. i.e. HW1-HW4)

Two practice exams are posted on BlackBoard

Professor Janes will conduct a help session for Exam 1 on Thursday, 2/7 at 1:30 PM in ME 1061.

Spice 1 project postponed until Monday, Feb. 11

Note that there was an error in Lecture 11 Slide 8. Now corrected (and L11 has been split into two parts)
Announcements

We will have class on Friday, Feb. 8.

The topic will be MOSFETs. Sedra and Smith 5.1 and 5.2
NPN Common emitter (active region)

\[ I_C = \beta I_B = \alpha I_E \]

\[ I_C = I_Se^{V_{BE}/V_T} \]
\[ I_B = \frac{I_S}{\beta} e^{V_{BE}/V_T} \]

\[ I_C = \beta I_B \quad I_C = \alpha I_E \]

\[ \beta = \frac{\alpha}{1-\alpha} \gg 1 \quad \alpha = \frac{\beta}{\beta+1} < 1 \]

BE: FB \quad V_{BE} > 0

BC: RB \quad V_{CB} = V_{CE} - V_{BE} > 0

Lundstrom: 2019
NPN DC circuit analysis

Find $I_C$ and $R_C$

$+5 \text{ V}$

$2 \text{ V} \quad \beta = 75$

$-5 \text{ V}$

$R_E = 4 \text{ k}\Omega$

$R_C = ? \text{ k}\Omega$
1) Assume active region
2) Find $I_E$
3) Find $I_C$
4) Find $V_C$
5) Find $R_C$
6) Check: Active region?
DC circuit analysis

\[ I_C \]

+5 V

\[ R_C = ? \text{kΩ} \]

2 V \quad \beta = 75

\[ R_E = 4 \text{kΩ} \]

−5 V

Lundstrom: 2019
DC circuit analysis

Circuit: $V_B = 0V$
Forward Active: $V_{BE} = 0.7V$
=> $V_E = -0.7V$

$I_E = 4.3V/4k\Omega = 1.08 \text{ mA}$

$I_C = \alpha I_E = 1.07 \text{ mA}$

Specified: $V_{CE} = 2V$
$V_E = -0.7V \Rightarrow V_C = 1.3 \text{ V}$

Voltage across $R_C = 3.7V$
$R_C = 3.5 \text{ k}\Omega$
DC circuit analysis: Result

\[ I_C = 1.07 \text{ mA} \]
\[ R_C = 3.5 \text{ k}\Omega \]
\[ V_C = 1.3 \text{ V} \]

\[ R_E = 4 \text{ k}\Omega \]
Now change the problem

\[ V_{CE} = 75 + 5 \]

\[ R_E = 4 \, k\Omega \]

\[ R_C = 10 \, k\Omega \]

\[ I_C = ? \, mA \]

\[ \beta = 75 \]

Find \( I_C \) and \( V_{CE} \)
Now change the problem

$I_C = \text{? mA}$

$R_C = 10 \text{ k}\Omega$

$\beta = 75$

$V_{CE} = \text{? V}$

$R_E = 4 \text{ k}\Omega$

$-5 \text{ V}$

$5 \text{ V}$

1) Assume active region
2) Find $I_E$
3) Find $I_C$
4) Find $V_C$
5) Find $R_C$
6) Check: Active region?
Now change the problem

\[ I_C = \text{? mA} \]

\[ V_{CE} = \text{? V} \]

\[ \beta = 75 \]

\[ R_C = 10 \text{ k}\Omega \]

\[ R_E = 4 \text{ k}\Omega \]

\[ +5 \text{ V} \]

\[ -5 \text{ V} \]
Now change the problem

\[ I_C = ? \text{ mA} \]

\[ R_C = 10 \text{ k}\Omega \]

\[ \beta = 75 \]

\[ V_{CE} = ? \text{ V} \]

\[ R_E = 4 \text{ k}\Omega \]

\[ +5 \text{ V} \]

\[ -5 \text{ V} \]

\[ I_E = \frac{-0.7 - (-5.0)}{4 \text{ k}\Omega} = 1.08 \text{ mA} \]

\[ I_C = \frac{\beta}{\beta + 1} I_E = 1.07 \text{ mA} \]

\[ V_C = 5 - 1.07 \times 10 < 0! \]
The transistor is saturated!

\[ V_{CE} < 0.7 \]

saturation \( V_{CE} \approx 0.2 \)

active
Saturation analysis

\[ I_C = ? \text{ mA} \]

\[ R_C = 10 \text{ K}\Omega \]

\[ \beta = 75 \]

\[ V_{ce_{sat}} \approx 0.2 \text{ V} \]

\[ R_E = 4 \text{ K}\Omega \]

\[ +5 \text{ V} \]

\[ -5 \text{ V} \]
Saturation analysis: result

\[ I_C = \text{? mA} \]

\[ R_C = 10 \text{ K}\Omega \]

\[ \beta = 75 \]

\[ V_{CESat} \approx 0.2 \text{ V} \]

\[ R_E = 4 \text{ K}\Omega \]

\[ +5 \text{ V} \]

\[ -5 \text{ V} \]

\[ I_E = \frac{-0.7 - (-5.0)}{4 \text{ k}\Omega} = 1.08 \text{ mA} \]

\[ V_C = -0.7 + 0.2 = -0.5 < 0 \]

\[ I_C = \frac{5 - (-0.5)}{10 \text{ k}\Omega} = 0.55 \text{ mA} \]
DC circuit design

Specify $R_C$ and $R_E$ so that:

\[
\begin{align*}
I_C &\approx 0.5 \text{ mA} \\
V_{CE} &\approx 2.0 \text{ V}
\end{align*}
\]

$\beta = 75$
NPN DC circuit design

$I_C = 0.5 \text{ mA}$

$R_C = ? \text{ k}\Omega$

$V_{CE} = 2.0 \text{ V}$

$R_E = ? \text{ k}\Omega$

+$5 \text{ V}$

$-5 \text{ V}$

Lundstrom: 2019
PNP Circuit Analysis

Find $I_C$ and $V_{EC}$

$V_E = +10 \text{ V}$

$R_E = 8.6 \text{ k}\Omega$

$V_{EC} \quad \beta = 50$

$I_C$

$R_C = 5 \text{ k}\Omega$

$-10 \text{ V}$

Lundstrom: 2019
NPN and PNP Circuit Analysis
Ignore base currents and compute $V_{out}$

(Example 6.11 Sedra and Smith)
In analysis, assume an operating region, do the analysis, then check that the proper operating region was assumed.

Generally, design is “easier” than analysis (but more open).
BJT Circuit Analysis and Design

1) NPN BJT Circuit Analysis and Design
2) PNP Circuits
3) NPN and PNP Circuits