EE 320 L ELECTRONICS I

LABORATORY 7: BIPOLAR TRANSISTOR CHARACTERIZATIONS

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
UNIVERSITY OF NEVADA, LAS VEGAS

1. OBJECTIVE

Get familiar with BJTs, and apply knowledge learned in lecture to practical applications. Understand how to set up DC bias for BJTs so that it works as designed.

2. COMPONENTS & EQUIPMENT

Power Supply	Breadboard & Jump wires
Function Generator	Resistors & Capacitors
Multimeter	BJT (2N2222A, 2N3904, 2N3906)
Oscilloscope	

3. BACKGROUND

A bipolar junction transistor (bipolar transistor or BJT) is a type of transistor that uses both electron and hole charge carriers. BJTs use two junctions between two semiconductor types, n-type and p-type, and they manufactured in two types, NPN and PNP.

A terminal is connected to each of the three semiconductor regions of the transistor, with the terminals labeled emitter (E), base (B), and collector (C). Each transistor consists of two *pn* junctions, the emitter-base junction (EBJ) and the collector-base junction (CBJ). Three BJT modes of operation: 1) Cutoff, 2) Active, 3) Saturation.

Key knowledges and formulas related to BJTs.

<table>
<tr>
<td>A simple structure of a npn transistor.</td>
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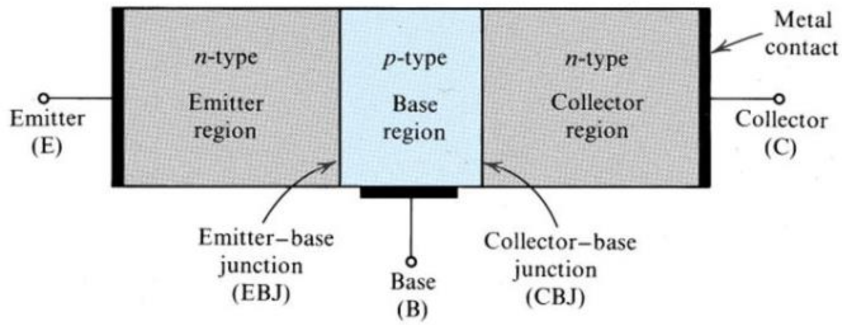

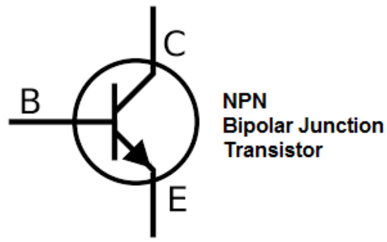

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<tr>
<td>A simple structure of a pnp transistor.</td>
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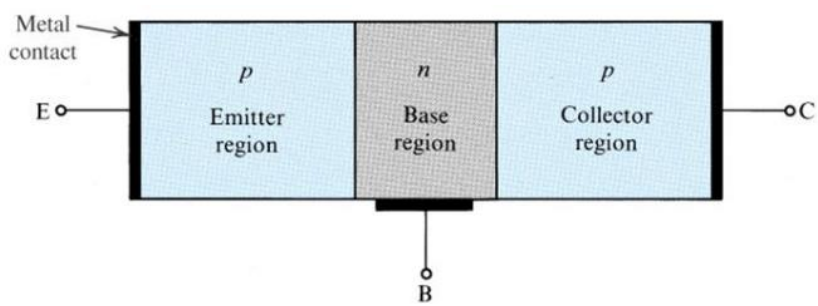

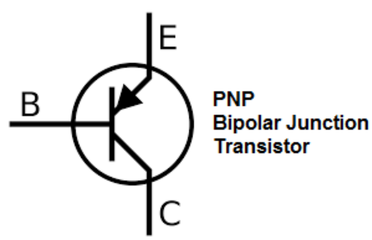

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<tr>
<td>BJT modes of operations.</td>
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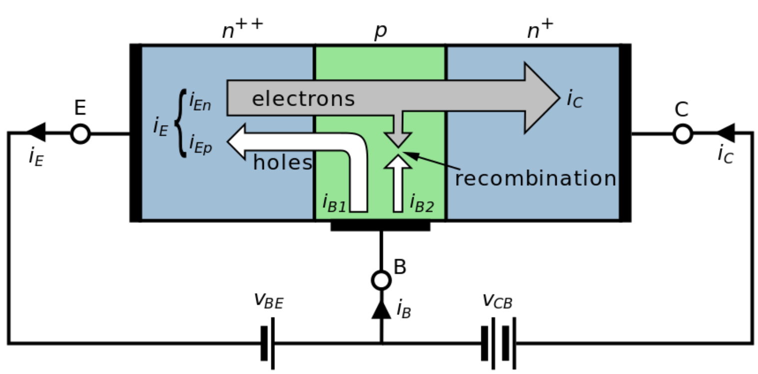

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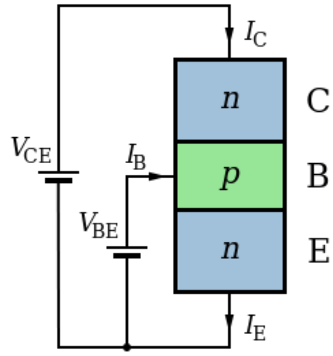

Applied voltages	B-E Junction Bias (NPN)	B-C Junction Bias (NPN)	Mode (NPN)
E < B < C	Forward	Reverse	Forward-active
E < B > C	Forward	Forward	Saturation
E > B < C	Reverse	Reverse	Cut-off
E > B > C	Reverse	Forward	Reverse-active
Applied voltages	**B-E Junction Bias (PNP)**	**B-C Junction Bias (PNP)**	**Mode (PNP)**
E < B < C	Reverse	Forward	Reverse-active
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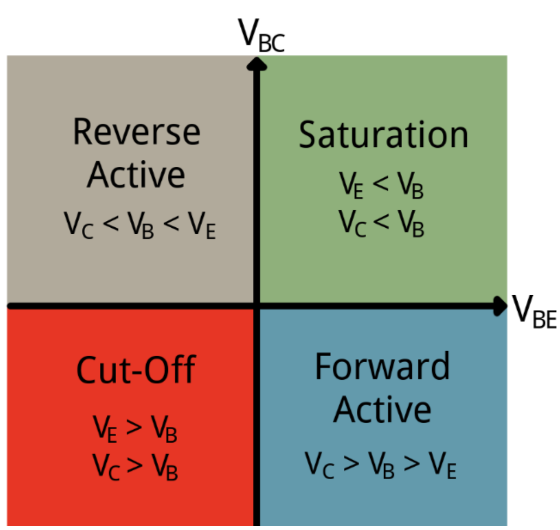
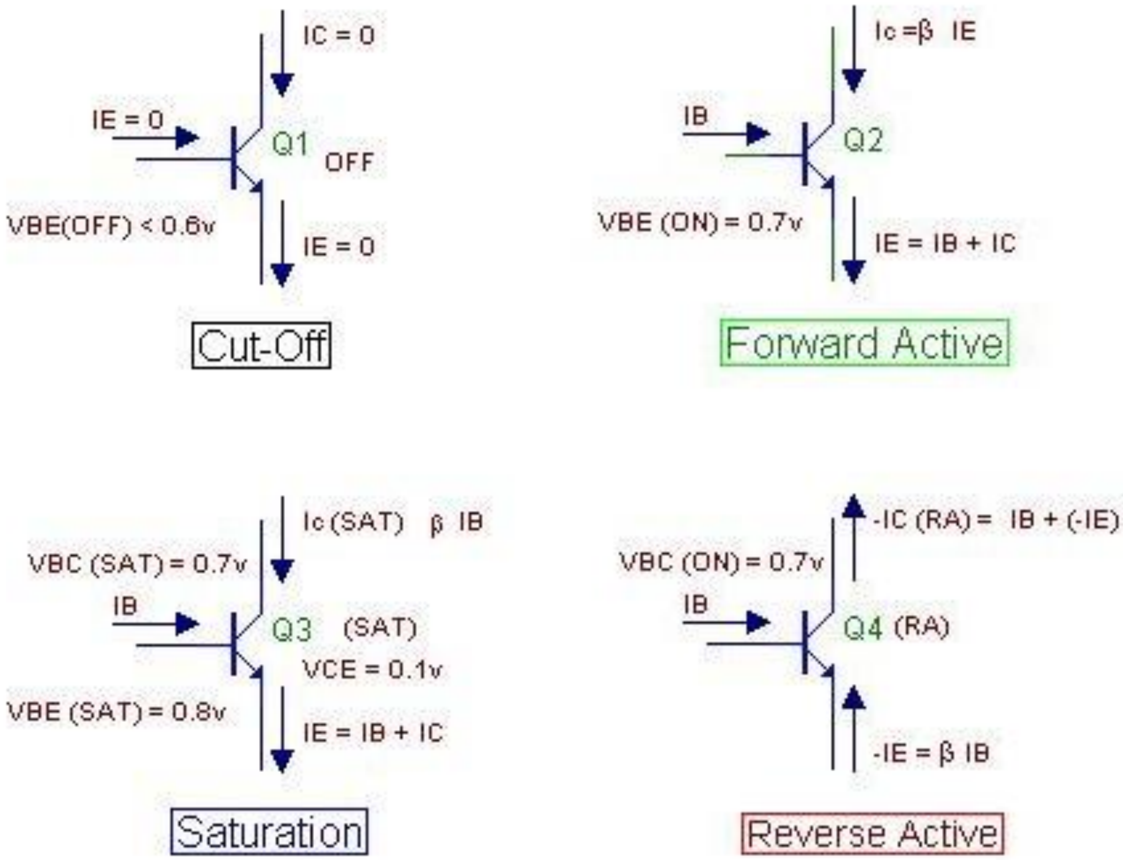
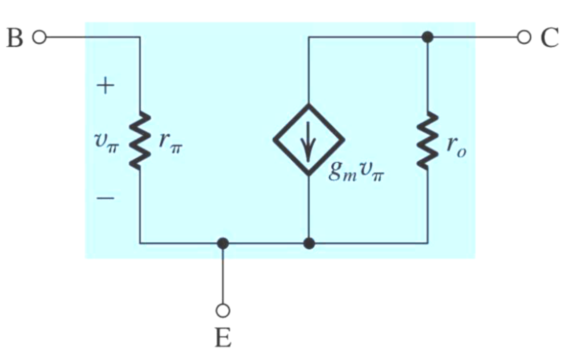
E > B < C	Forward	Forward	Saturation
E > B > C	Forward	Reverse	Forward-active



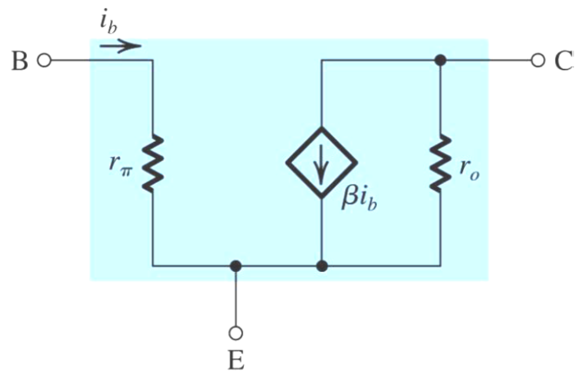


Hybrid-π Model

($g_m v_\pi$) Version

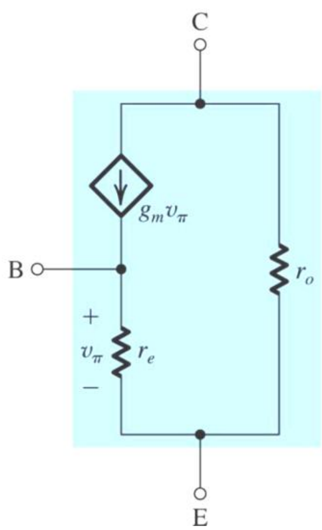


(βi_b) Version

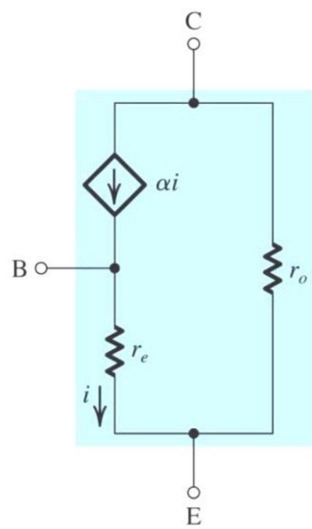


T Model

($g_m v_\pi$) Version



(αi) Version



4. LAB DELIVERIES

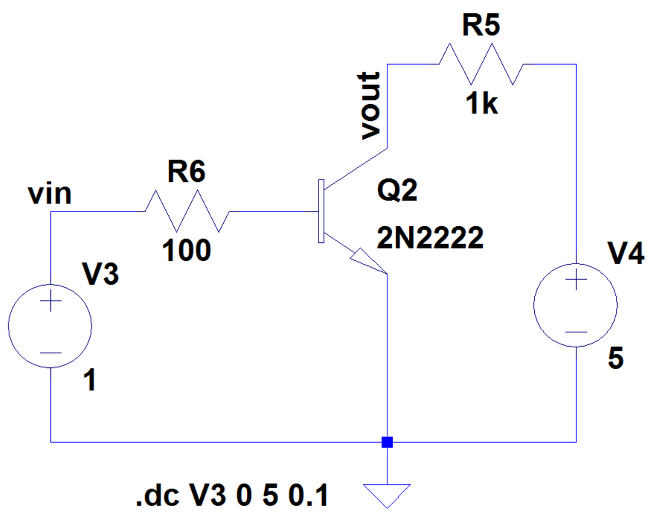
PRELAB:

1. **Learn the idea of BJT transistors, and understand the principles of various operation modes, i.e. how the current flows through PN junctions under different operation modes. Part of knowledge is covered in the previous section.**

2. **Overview the key character of BJT in the datasheet.**

2N2222A	https://www.onsemi.com/pub/Collateral/P2N2222A-D.PDF
2N3904	https://www.onsemi.com/pub/Collateral/2N3903-D.PDF

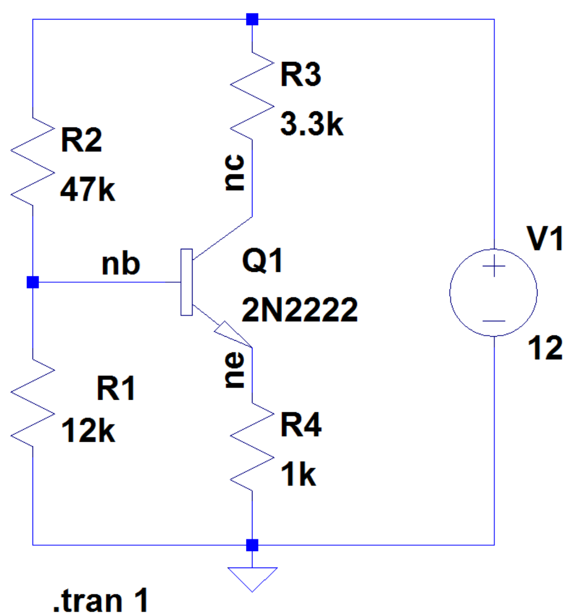
3. **Use hand-calculation and LTspice to obtain the voltages at "vout" in Circuit 1.**
   1) Assume the threshold voltage for V_{BE} to turn on Q2 (i.e. BJT 2N2222) is 0.7V.
   2) Calculate and simulate the circuit for voltage at "vout" when V3 = 0.1V, 0.5V, 0.7V, 1V, 2V, respectively.
   3) (LTspice) Run DC sweep analysis (i.e. command in the diagram) for V3 from 0V to 5V. Observe the voltage transfer characteristic (VTC) diagram.



Circuit 1

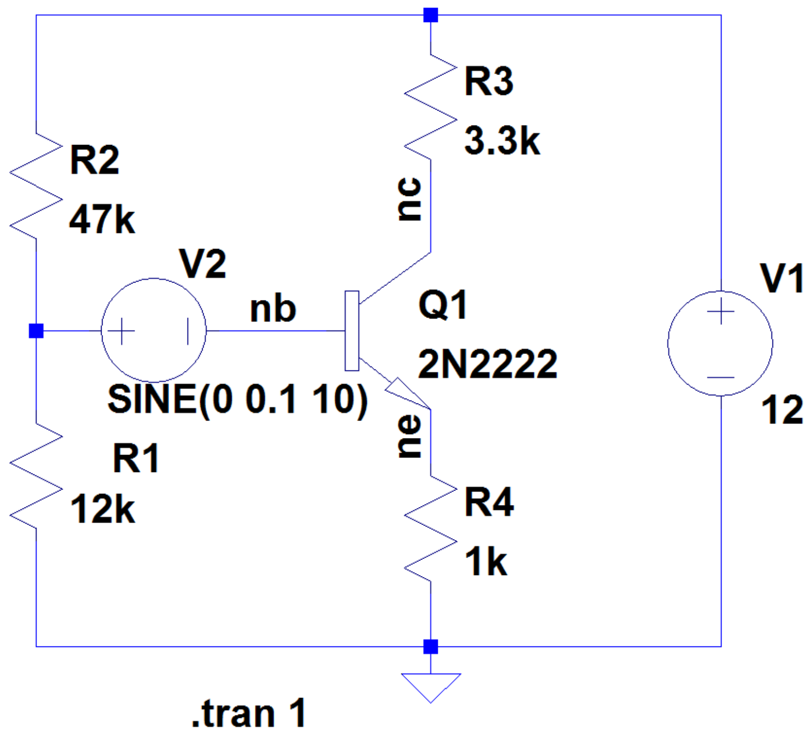
4. Use hand-calculation and LTspice to compute/simulate the voltages at *nb, nc, ne* in Circuit 2.

1) Write down the voltages at *nb*, *nc*, *ne*.
2) Compute and simulate the currents flowing through *nb* (i.e I(R1)-I(R2)), *nc* (i.e. I(R3)) and *ne* (i.e. I(R4)). What is the relationship among these current values?
3) Change R1 to 120Ω, and redo the computation and simulation for voltages and currents at *nb*, *nc*, *ne*. Compare the results with 1). Explain.



Circuit 2

5. **Use LTspice to simulate Circuit 3.**



Circuit 3

1) Add a sine waveform input between BJT's base node (i.e. *nb*) and intermediate node of R1 and R2. Set the sine waveform with an amplitude of 0.1V and a frequency of 10Hz.
2) Simulate the voltages and currents at/through *nc* and *ne.*
3) Set R1 = 120Ω, and repeat 2). Compare the results.
4) Reset R1 back to 12KΩ. Increase the sine waveform frequency to 1KHz. Repeat 2).
5) Run AC analysis for Circuit 2 for Bode plot from 1Hz to 100MHz.

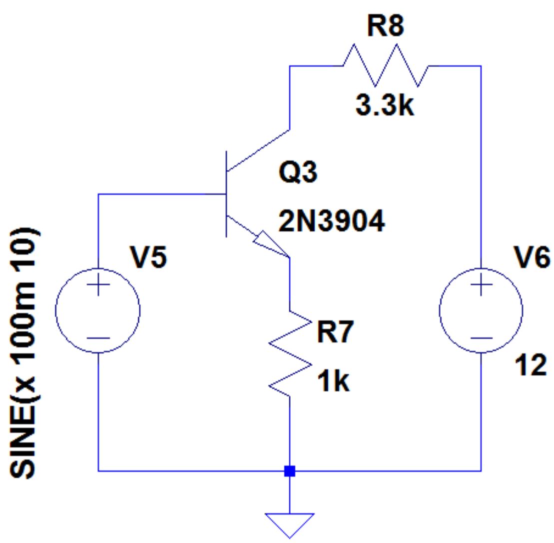
LAB EXPERIMENTS:

1. **Implement and measure Circuit 1 in Prelab Experiment 3 on breadboard, and compare with the hand-calculation and LTspice results.**
   - Sweep V3 input from DC 0V to 2V, with increment of 0.1V. Draw the VTC.

2. **Implement and measure Circuit 2 in Prelab Experiment 4 on breadboard, and compare with the hand-calculation and LTspice results.**

3. **Implement and measure Circuit 3 in Prelab Experiment 5 on breadboard, and compare with the hand-calculation and LTspice results.**

- Use R1 = 12KΩ and V2 frequencies of 10Hz, 100Hz, 1KHz and 10KHz, 100KHz, 1MHz, respectively, for measurement on board. Write down V_{pp} and draw the Bode plot.
- If Circuit 3 does not work, use the following Circuit 4 instead. Use the exact same value of V_{nb} measured in Circuit 2 for the offset "**x**" in function generator.



Circuit 4

POSTLAB REPORT:

Include the following elements in the report document:

<table>
<tr><th>Section</th><th colspan="2">Element</th></tr>
<tr><td>1</td><td colspan="2">Theory of operation
Include a brief description of every element and phenomenon that appear during the experiments.</td></tr>
<tr><td>2</td><td colspan="2">Prelab report
1. Is 2N2222A a PNP or NPN BJT?
2. Hand calculation and LTspice simulation results of Prelab Experiment 3.
3. LTspice simulation results of Prelab Experiment 4.</td></tr>
<tr><td rowspan="5">3</td><td colspan="2">Results of the experiments</td></tr>
<tr><th>Experiments</th><th>Experiment Results</th></tr>
<tr><td>1</td><td>Screenshots of LTspice simulations and multimeter readings for DC measurements.</td></tr>
<tr><td>2</td><td>Screenshots of LTspice simulations and oscilloscope waveforms.</td></tr>
<tr><td>3</td><td>Screenshots of LTspice simulations and oscilloscope waveforms.</td></tr>
<tr><td rowspan="5">4</td><td colspan="2">Answer the questions</td></tr>
<tr><th>Questions</th><th>Questions</th></tr>
<tr><td>1</td><td>In Lab Experiment 2 and 3 (i.e. Prelab Experiment 4 & 5), pls explain the voltage and current changes when switching R1 from 12KΩ to 120Ω.</td></tr>
<tr><td>2</td><td>What do you expect to see if change 2N2222A to a PNP BJT?</td></tr>
<tr><td>3</td><td>Compare the Bode plot drawn in LTspice (Prelab Experiment 5) and Lab Experiment 5. Explain why different if any.</td></tr>
</table>

5	**Conclusions** *Write down your conclusions, things learned, problems encountered during the lab and how they were solved, etc.*
6	**Images** *Paste images (e.g. scratches, drafts, screenshots, photos, etc.) in Postlab report document (only .docx, .doc or .pdf format is accepted). If the sizes of images are too large, convert them to jpg/jpeg format first, and then paste them in the document.* **Attachments (If needed)** *Zip your projects. Send through WebCampus as attachments, or provide link to the zip file on Google Drive / Dropbox, etc.*

5. REFERENCES & ACKNOWLEDGEMENT

1. Adel S. Sedra & Kenneth C. Smith, "Microelectronic Circuit", 6^{th} Ed.
2. Online sources: Google, Wikipedia, etc.
3. Previous lab instructions.
4. Related circuit component datasheets.

I appreciate the help from faculty members and TAs during the composing of this instruction manual. I would also thank students who provide valuable feedback so that we can offer better higher education to the students.