EE 2274
BJT Biasing

PreLab:
1. **Common Emitter (CE) Transistor Characteristics curve**

Generate the characteristics curves for a 2N3904 in LTspice by plotting Ic by sweeping Vce over a set of Ib steps. Label your graph and determine the DC beta of the transistor from your graph. The dc beta of the transistor can be found by dividing the collector current by the base current when the collector current just begins to flatten out. Print the schematic and plot of the transistor characteristics curve generated in LTspice turn in with prelab. Use the circuit below for your model Rb = 1kΩ. Show all work.

**Hints:** A couple of LTspice hints use the **DC Sweeps** to generate your graph of collector current Ic for a set of base currents Ib over a range of Vce (Vcc). Set the DC Sweep source 1 voltage source (Vcc) to sweep from 0 to 12Vdc in 0.1v increments. Set the DC Sweep source 2 current source (Ib) to sweep from 0 to 50ua in 5ua increments. From the curves at Vce = 4V, Ib = 15uA find Ic, and β. Include schematic and plot.

\[
R_b = 1k\Omega \quad \beta = \frac{I_C^{\text{flat}}}{I_B}
\]

\[
\beta = \text{______________} \quad \text{at } I_C = \text{______________, } I_B = \text{______________} \quad \text{Show your work:}
\]

```
.dc Vcc 0 12 .1 Ib 0 50uA 5uA
```

![Common Emitter (CE) Circuit](image-url)
2. Diode Current Source (NPN)

Shown below is a current source made from an NPN transistor design for $I_C = 1.6 \text{mA}$ assume $\beta = 100$. The purpose of the diodes is to create a constant voltage drop $V_{\text{diode}}$. $V_{\text{diode}} = 0.448 \text{Vdc}$ such that $V_B = 4 \times V_{\text{diode}}$. Design $R_E$ for 1.6mA current through $R_L$ which is equal to $I_C$. $V_{\text{BE}} = 0.7 \text{V}$, $V_E = V_B - 0.7 \text{V}$, and thus $I_E = I_B + I_C = V_E/R_E = (V_B - 0.7 \text{V})/R_E$. Since, $I_C = (I_E/\beta + 1) \ I_C$ is almost independent of $V_{CE}$, as long as the transistor is not saturated ($V_{CE} > 0.2 \text{V}$) and $V_{BE} = 0.6 \text{V to } 0.7 \text{V}$. Use $R_E$ to set $I_C$ then $I_B = I_C/\beta$.

Find maximum value for $R_{\text{Lmax}}$ with supply $V_{cc}=8\text{Vdc}$. $V_{CE} = 0.2 \text{V}$ and $V_E = V_B - V_{BE}$ for this calculation of $R_{\text{Lmax}}$ maximum. Choose a value for $R_L$ that is less than $0.7 \times R_{\text{Lmax}}$ and larger than $0.3 \times R_{\text{Lmax}}$.

$0.3 \times R_{\text{Lmax}} < R_L < 0.7 \times R_{\text{Lmax}}$

Note that the load ($R_L$) is above the collector of the transistor and is said to sink the current in the load by the NPN transistor. Calculate the voltage $V_{CE}$ with the load resistor at $V_{cc} = 8\text{Vdc}$.

Verify your design in LTspice showing voltages and currents. To verify that your circuit is a current source independent of $Vcc$. Run a DC Sweep in LTspice of $Vcc$ from 1 to 12 volts. Determine the range of the supply voltage ($Vcc$) for a 10% ($\pm 5\%$) of the design current change in $R_L$ ($I_C$). Print and turn in your schematic showing voltages and currents of the nodes in addition to the I-V curve with your pre-lab.

Define your supply voltage ($Vcc$) range based on current range 10% ($\pm 5\%$) of the design current.

Supply voltage ($Vcc$) range: _______________V to _______________V from ___________mA to ___________mA of your load current ($I_C$) of design current.
3. Diode Current Source (PNP)

Design a PNP current source for $I_C = 1.6\text{mA}$, similar to the NPN current source shown, using a PNP (2N3906) transistor, assume $\beta = 100$. Use the same procedure as 2 above. Remember that while the NPN will sink the current through the load, the PNP should source the current into the load ($R_L$). Determine the $R_{L\text{max}}$ and choose an $R_L$ as you did in 2. Print and turn in your schematic showing voltages and currents of the nodes in addition to I-V curve with your pre-lab. $V_{CC}$ (range from v to v).

Find maximum value for $R_{L\text{max}}$ with supply $V_{CC}=8\text{Vdc}$. $V_{EC} = 0.2\text{V}$ and $V_E = V_B + V_{EB}$ for this calculation of $R_{L\text{max}}$ maximum. Choose a value for $R_L$ that is less than $0.7R_{L\text{max}}$ and larger than $0.3R_{L\text{max}}$.

Calculate the voltage $V_{ce}$ with the load resistor at $V_{CC}=8\text{Vdc}$
Verify your design in LTspice showing voltages and currents. To verify that your circuit is a current source independent of $V_{CC}$. Run a DC Sweep in LTspice of Vcc from 1 to 12 volts. Determine the range of the supply voltage ($V_{CC}$) for a 10% ($\pm5\%$) of the design current change in $R_L$ ($I_C$). Print and turn in your schematic showing voltages and currents of the nodes in addition to the I-V curve with your pre-lab
Define your supply voltage ($Vcc$) range based on current range 10% ($\pm5\%$) of the design current.
Supply voltage ($V_{cc}$) range: _____________V to _____________V from
___________mA to _____________mA of your load current $I_c$.

![Diagram of PNP Diode Current Source]

PNP Diode Current Source Table

<table>
<thead>
<tr>
<th>Component</th>
<th>Calculate value</th>
<th>Standard 10% value used</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_E$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_L$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Required Attachments: PreLab
1. I-V characteristics of BJT and schematic
2. LTspice schematic of NPN with associated node voltages and component currents
3. DC Sweep of NPN current source showing load current
4. LTspice schematic of PNP with associated node voltages and device currents
5. DC Sweep of PNP current source showing load current
Lab Procedure:

1. Use the **curve tracer** to generate a transistor characteristic curve of the 2N3904 NPN transistor, and print the curve to include in with your lab. What is the DC $\beta$ from the curve at a Q-Point close to the one you use in LTspice? Mark on the curve.

2. Build a NPN Diode Current Source with the 2N3904 transistor and 1N4001 diodes, $V_{cc} = 8Vdc$ Compare with design voltages and currents, LTspice voltages and currents, and measured voltages and currents.

3. Perform an appropriate DC sweep of $V_{cc}$ from 1 to 12Vdc step size 200mv on the NPN current source. Add a formula step to convert the voltage across the $R_L$ to mA current. Capture the plot on the computer to be turned in with the lab. At what voltage ($V_{cc}$) and current ($I_{RL}$) did the current begin to stabilize?

**Convert to a current:**

Sweep the circuit using the Basic DC sweep $Vin$ from 1 to 12V. Plot the $I_{load}$ current in **mA** not amps. Add formula data to output section of the Sweep step

Load BaicDCSweep > open Step Setup Tab > Open Add Step Tab > Add Step >

Processing > Analog Signal > Formula.

Divide voltage across $R_L$ by $R_L$ (Current in Amp) and scale to mA.

Drag this new step into the sweep loop just below the DMM step.

Open the sweep step > Sweep Output Tab > Add > Processed Data vs. Voltage X-Axis.

4. Define your supply voltage ($V_{cc}$) range for any 10% ($\pm 5\%$) current ranges that includes 100% rated current. In the active regulation range, how much did the current change through the DC sweep? Is this amount of change in current reasonably small, such that the design can be used as a nearly ideal current source? Why?

5. Build your PNP current source with the 2N3906 transistor and 1N4001 diodes $V_{cc}= 8Vdc$ Compare the PNP Current Source with your design values, LTspice values, and measured values. Perform an appropriate DC sweep of $V_{cc}$ from 1 to 12Vdc step size 200mv and include plot. Add a formula step to convert the voltage across $R_L$ to a mA current plot

6. At what voltage ($V_{cc}$) and current ($I_{RL}$) did the current begin to stabilize (flatten)? Define your supply voltage ($V_{cc}$) range for the target current range of 10% ($\pm 5\%$) variation of the target current. How much did the load current ($I_{RL}$) change as the $V_{cc}$ changed after it began to stabilize (flatten)?

Required Attachments: Lab experiment

1. I-V Characteristic of BJT
2. DC Sweep of NPN plot of current thru $R_L$: Convert voltage to mA current
3. DC Sweep of PNP plot of current thru $R_L$: Convert voltage to mA current
DATA SHEET
EXPERIMENT BJT Biasing

1. Turn in copy of 2N3904 output characteristics curves generated by the Tektronix curve tracer. Mark on the curve the Q-Point used Vce=__________ Ic=__________ Ib=__________

$\beta = $ 

2. **NPN 2N3904 Diode Current Source Vcc = 8Vdc**

<table>
<thead>
<tr>
<th>Value</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE</td>
<td>IRL</td>
</tr>
<tr>
<td>RL</td>
<td>IRE</td>
</tr>
<tr>
<td>R1</td>
<td>VC</td>
</tr>
<tr>
<td>Vcc</td>
<td>VE</td>
</tr>
<tr>
<td></td>
<td>VB</td>
</tr>
</tbody>
</table>

3. What Ic and Vcc did Ic begin to stabilize Vcc=__________ Ic=__________
Include plot.

4. Around the target current: Supply voltage range Vcc __________ to __________ and IRl __________ to __________
How much did IRL change after it stabilized? IRl change ______________

Is this current source ideal?
Why or why not?

5. **PNP 2N3906 Diode Current Source Vcc = 8Vdc**

<table>
<thead>
<tr>
<th>Value</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE</td>
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<td>VE</td>
</tr>
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<td></td>
<td>VB</td>
</tr>
</tbody>
</table>

6. What Ic and Vcc did it begin to stabilize Vcc=__________ Ic=__________
Around the target current: Supply voltage range Vcc __________ to __________ and IRl __________ to __________
How much did IRL change after it stabilized? IRl change ______________

Is this current source ideal?
Why or why not?
Include plot.
Required Attachments:
1. I-V Characteristic of BJT
2. DC Sweep of NPN current scale mA add formula step in loop
3. DC Sweep of PNP current scale mA add formula step in loop