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. LTspice plots and schematic (25 points).

**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.

\[ \beta = \frac{I_{c_{\text{flat}}}}{I_b} \]

\[ \beta = \text{__________} \quad \text{at } I_c = \text{__________}, \quad I_b = \text{__________} \]

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 $I_c$. $V_{BE} = 0.7\text{V}$, $V_E = V_B - 0.7\text{V}$, and thus $I_E = I_B + I_C = V_E/R_E = (V_B - 0.7\text{V})/R_E$. Since, $I_C = (I_E)\beta/(\beta+1)$ $I_C$ 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 $I_B = I_C/\beta$. Set the current through R1 is 10 times $I_B$.

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

$0.3\times R_{L\text{max}} < R_L < 0.7\times R_{L\text{max}}$

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 (DC .OP pnt) 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 (.OP) 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 $V_{EC}$ 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% ($\pm 5\%$) of the design current change in $R_L$ ($I_C$). Print and turn in your schematic showing voltages and currents of the nodes (DC .OP pnt) 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 ($V_{CC}$) range: _______________V to _______________V from _______________mA to _______________mA of your load current $I_C$.

PNP Diode Current Source

<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>RE</td>
<td></td>
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<tr>
<td>RL</td>
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</tbody>
</table>

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

1. On LTspice build an NPN Diode Current Source with the 2N3904 transistor and 1N4001 diodes from part 2 of the prelab with $V_{cc}=10V_{dc}$, $I_{c}=5mA$ and choose $R_L$ between $0.3*R_{L_{max}}< R_L<0.5*R_{L_{max}}$. The procedure for calculating the resistor values is the same as the prelab.

$V_{diode}=0.448V_{dc}$ such that $V_{B}$ = 4*V$_{diode}$. Design $R_E$ for 5ma current through $R_L$ which is equal to $I_c$. $V_{BE}=0.7V$, $V_{E}=V_{B}-0.7V$, and thus $I_c=I_B+I_C=V_{E}/R_E=(V_B-0.7V)/R_E$. Since, $I_C=(I_E)/\beta/(\beta+1)$ $I_C$ is almost independent of $V_{CE}$ as long as the transistor is not saturated ($V_{CE}>0.2V$) and $V_{BE}=0.6V$ to 0.7V. Use $R_E$ to set $I_c$ then $I_B=I_C/\beta$. Set the current through $R_1$ is 10 times $I_B$.

Find maximum value for $R_{L_{max}}$ with supply $V_{cc}=10V_{dc}$. $V_{CE}=0.2V$ and $V_{E}=V_{B}-V_{BE}$ for this calculation of $R_{L_{max}}$ maximum. Choose a value for $R_L$ that is less than 0.5*$R_{L_{max}}$ and larger than 0.3*$R_{L_{max}}$.

$0.3*R_{L_{max}}< R_L<0.5*R_{L_{max}}$

Show all work and run a .op simulation to fill out the table.

2. Run a DC Sweep on the NPN Diode Current designed above from 1V to 15V and answer the question 2 and 3 on the data sheet. (Define your supply voltage ($V_{cc}$) range for 10% ($\pm$5%) current range ($\pm$5% of the IRL you found from .op simulation). 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?)

3. On LTspice build an PNP Diode Current Source with the 2N3906 transistor and 1N4902 diodes from part 3 of the prelab with $V_{cc}=10V_{dc}$, $I_{c}=5mA$ and choose $R_L$ between $0.3*R_{L_{max}}< R_L<0.5*R_{L_{max}}$. The procedure is the same as 1. Show all work and run a .op simulation to fill out the table.

4. Run a DC Sweep on the PNP Diode Current designed above from 1V to 15V and answer question 5. (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$5%) variation of the target current IRL. How much did the load current ($I_{RL}$) change as the Vcc changed after it began to stabilize (flatten)? Is this an ideal current source?)

Required Attachments: Lab experiment
1. Schematic of NPN current source with node voltages and currents shown
2. DC Sweep of NPN current source showing current $I_c$
3. Schematic of PNP current source with node voltages and currents shown
4. DC Sweep of PNP current source showing current $I_c$
1. **NPN 2N3904 Diode Current Source Vcc = 10Vdc**

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<th>Value</th>
<th>Measured</th>
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<tbody>
<tr>
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<td>IRL</td>
<td></td>
</tr>
<tr>
<td>RL</td>
<td>IRE</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>VC</td>
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<tr>
<td>Vcc</td>
<td>VE</td>
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<tr>
<td></td>
<td>VB</td>
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2. What Ic and Vcc did Ic it begin to stabilize Vcc=__________ Ic=__________
Include plot.

3. Around the target current: Supply voltage range Vcc __________ to __________ and
IRL __________ to __________
How much did IR change after it stabilized? IRL change __________
Is this current source ideal?
Why or why not?

4. **PNP 2N3906 Diode Current Source Vcc = 10Vdc**

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

5. 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 IR change after it stabilized? IR change __________
Is this current source ideal?
Why or why not?

Required Attachments: Lab experiment
1. Schematic of NPN current source with node voltages and currents shown
2. DC Sweep of NPN current source showing current Ic
3. Schematic of PNP current source with node voltages and currents shown
4. DC Sweep of PNP current source showing current Ic