EE 2274
BJT Biasing

PreLab:

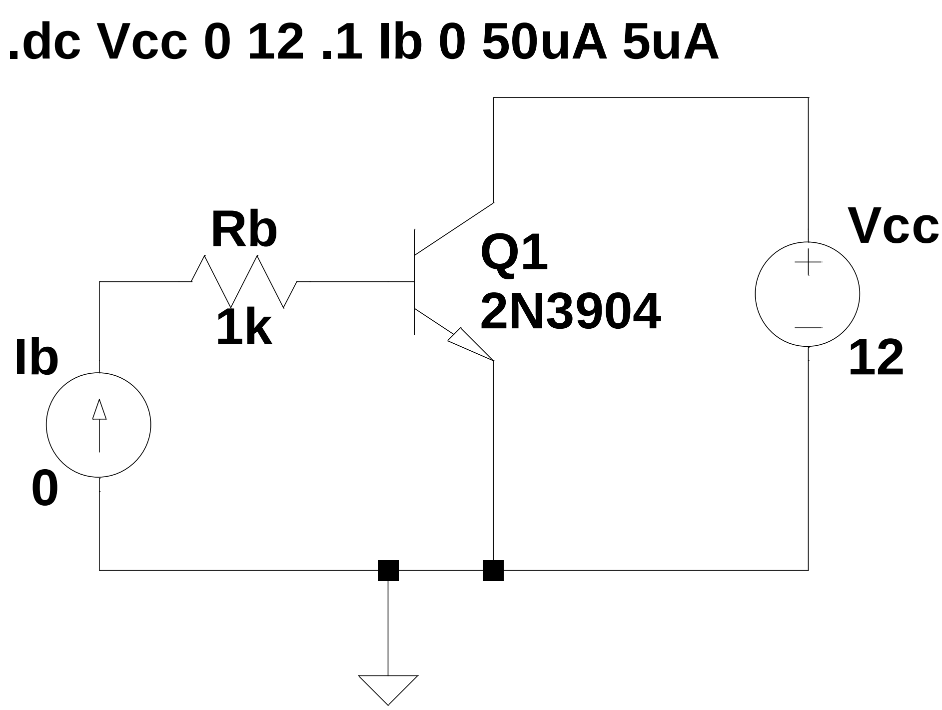
1. Common Emitter (CE) Transistor Characteristics curve

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. 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.

Rb = 1kΩ $\beta = \frac{I_{C\,flat}}{I_B}$

β=______________ at I_C = ____________, I_B = _____________ Show your work:



Common Emitter (CE)

2. Diode Current Source (NPN)

Shown below is a current source made from an NPN transistor design for **I_C = 1.6mA** assume β =100. The purpose of the diodes is to create a constant voltage drop Vdiode. Vdiode = 0.448Vdc such that V_B = 4*Vdiode. Design R_E for 1.6ma current through R_L which is equal to Ic. V_{BE} = 0.7V, $V_E = V_B - 0.7V$, and thus $I_E = I_B + I_C = V_E/R_E = (V_B - 0.7V)/R_E$. 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 R1 is 10 times I_B.

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

$$0.3*R_{Lmax} < R_L < 0.7*R_{Lmax}$$

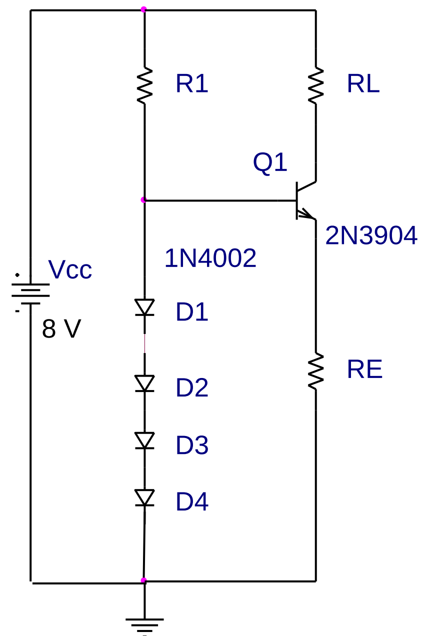
Note that the load (R_L) is above the collector of the transistor and is said to sink the current in the load by the NPN transistor. Calculate the voltage V_{CE} with the load resistor at Vcc = 8Vdc.

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% (±5%) of the design current change in R_L (Ic). 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% (±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.



NPN Diode Current Source

NPN Diode Current Source Table

Component	Calculate value	Standard 10% value used
R1		
R_E		
R_L		

3. Diode Current Source (PNP)

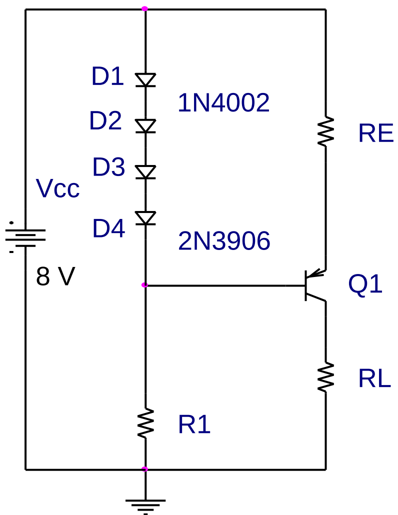
Design a PNP current source for $\mathbf{I_C = 1.6mA}$, similar to the NPN current source shown, using a PNP (2N3906) transistor, assume β = 100. Use the same procedure as 2 above. Remember that while the NPN will sink the current through the load, the PNP should source the current into the load (R_L). Determine the R_{Lmax} 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_{Lmax} with supply V_{CC}=8Vdc. V_{EC} = 0.2V and $V_E = V_B + V_{EB}$ for this calculation of R_{Lmax} maximum. Choose a value for R_L that is less than $0.7R_{Lmax}$ and larger than $0.3R_{Lmax}$.

Calculate the voltage V_{EC} with the load resistor at V_{CC}= 8Vdc
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% (±5%) of the design current change in R_L (Ic). 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% (±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

PNP Diode Current Source Table

Component	Calculate value	Standard 10% value used
R1		
R_E		
R_L		

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 **Vcc= 10Vdc, Ic = 5mA and choose RL between 0.3*RLmax< RL<0.5*RLmax.** The procedure for calculating the resistor values is the same as the prelab.

Vdiode = 0.448Vdc such that V_B = 4*Vdiode. Design R_E for 5ma current through R_L which is equal to Ic. V_{BE} = 0.7V, $V_E = V_B - 0.7V$, and thus $I_E = I_B + I_C = V_E/R_E = (V_B - 0.7V)/R_E$. 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 R1 is 10 times I_B.

Find maximum value for R_{Lmax} with supply Vcc=10Vdc. V_{CE} = 0.2V and $V_E = V_B - V_{BE}$ for this calculation of R_{Lmax} maximum. Choose a value for R_L that is less than 0.5*R_{Lmax} and larger than 0.3*R_{Lmax}.

$$0.3*R_{Lmax} < R_L < 0.5*R_{Lmax}$$

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 (Vcc) range for 10% (±5%) current range (±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 1N4002 diodes from part 3 of the prelab with **Vcc= 10Vdc, Ic = 5mA and choose RL between 0.3*RLmax< RL<0.5*RLmax**. 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% (±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 Ic
3. Schematic of PNP current source with node voltages and currents shown
4. DC Sweep of PNP current source showing current Ic

DATA SHEET
EXPERIMENT BJT Biasing

1. NPN 2N3904 Diode Current Source Vcc = 10Vdc

	Value		**Measured**
RE		I_{RL}	
RL		I_{RE}	
R1		V_C	
Vcc		V_E	
		V_B	

2. What Ic and Vcc did I_C it begin to stabilize Vcc=___________ Ic=_____________
Include plot.

3. Around the target current: Supply voltage range **Vcc** __________ to _________ and IR_L ________ to _________
How much did I_{RL} change after it stabilized? IR_L change ______________

Is this current source ideal?
Why or why not?

4. PNP 2N3906 Diode Current Source V_{CC} = 10Vdc

	Value		**Measured**
RE		I_{RL}	
RL		I_{RE}	
R1		V_C	
Vcc		V_E	
		V_B	

5. What Ic and V_{CC} did it begin to stabilize V_{CC}=___________ Ic=_____________
Around the target current: Supply voltage range $\mathbf{V_{CC}}$ __________ to _________ and IR_L _________to _________
How much did I_{RL} change after it stabilized? IR_L 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