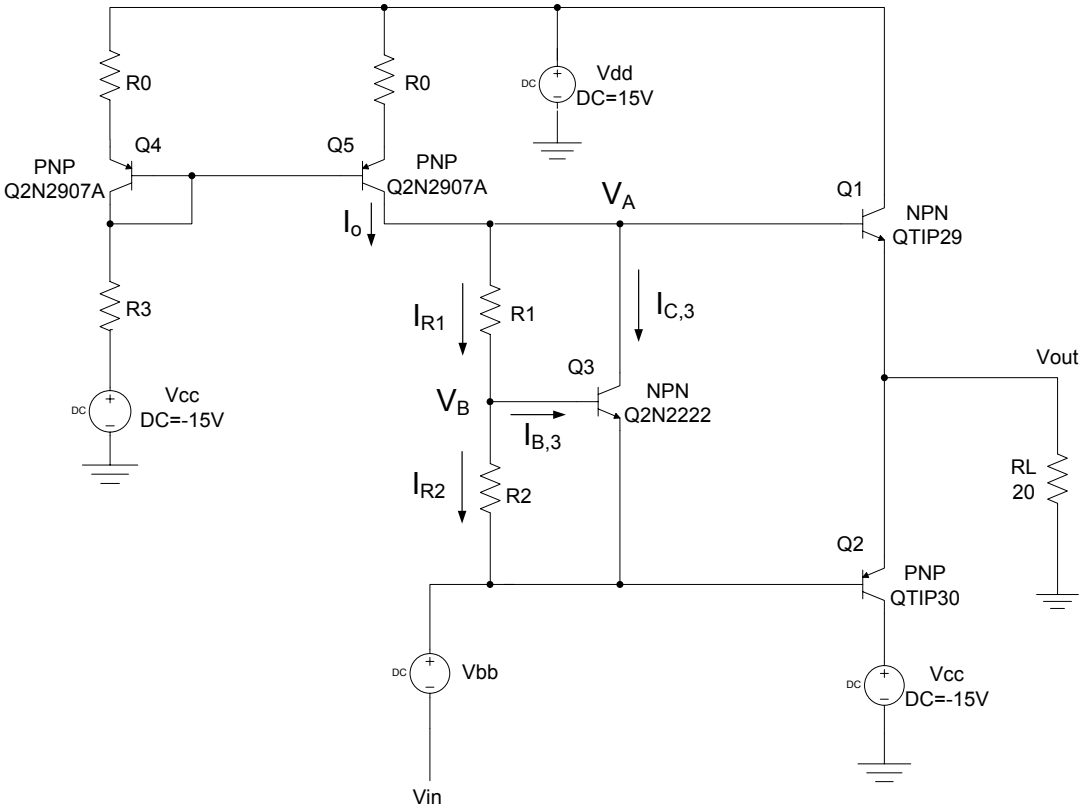
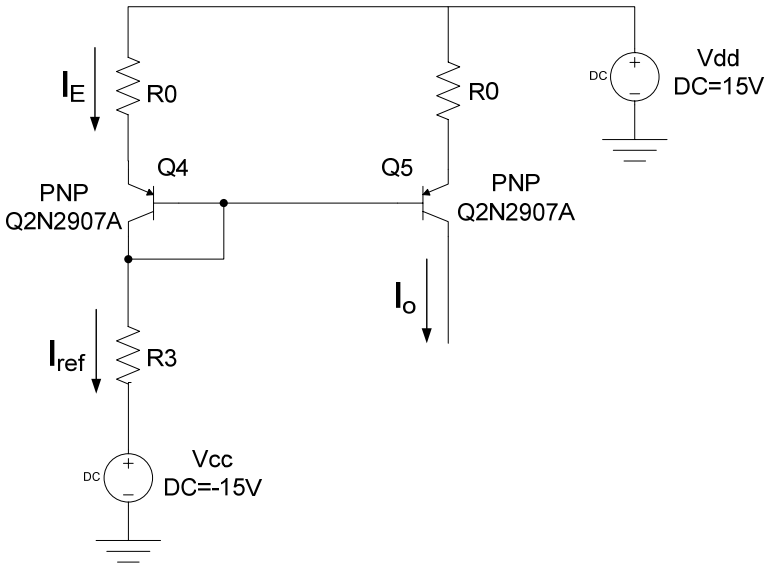
ECE304 Hands-on Lab 2 Pre-lab



Using hand calculations, design the output stage circuit. Assume BJT V_{BE} and β values are already known, and determine the resistor values manually. First build the current mirror (you can design the mirror in your own way for extra credit):



For large β value, we can simply assume that $I_{ref} = I_o = I_C = I_E$, therefore

$$V_{dd} - I_E R_0 - V_{EB,4} - I_{ref} R_3 = V_{cc}$$

$$I_o = I_{ref} = I_E \Rightarrow I_o(R_0 + R_3) = V_{dd} - V_{cc} + V_{BE,4}$$
$$\Rightarrow I_o = \frac{V_{dd} - V_{cc} + V_{BE,4}}{R_0 + R_3}$$

Note that for PNP transistor V_{BE} is negative. Make sure that $I_o \le 45mA$ (e.g. 30mA). You can choose any resistor values R_0 and R_3 you want, but make sure that the transistors are active, i.e., $V_C < V_E$ and $V_B < V_E$ (this is for PNP, there is a similar requirement for NPN). Also restrict your resistor choices to those available at the Stockroom.

We then connect the current mirror to the output stage circuit. To eliminate the DC offset voltage on Vout, the circuit should satisfy Vout=0 when DC input Vin=0. Choose appropriate resistor values R_1 and R_2 to meet the requirement. In real design, we use Q1 TIP29 and Q2 TIP30, two power transistors to replace the multiplier transistor in output stage circuit.

For Q1, $V_{BE,1} = V_A - V_{out} \Rightarrow V_A = V_{BE,1}$

For Q2, $V_{BE,2} = V_{bb} - V_{out} \Rightarrow V_{bb} = V_{BE,2}$ (For PNP transistor, V_{BE} is negative.)

For Q3, $V_{BE,3} = V_B - V_{bb} \Rightarrow V_B = V_{bb} + V_{BE,3} = V_{BE,2} + V_{BE,3}$

$$I_{R1} = \frac{V_A - V_B}{R_1} = \frac{V_{BE,1} - (V_{BE,2} + V_{BE,3})}{R_1}$$
$$I_{R2} = \frac{V_B - V_{bb}}{R_2} = \frac{V_{BE,3}}{R_2}$$
$$I_{B,3} = I_{R1} - I_{R2} = \frac{V_{BE,1} - V_{BE,2} - V_{BE,3}}{R_1} - \frac{V_{BE,3}}{R_2}$$
$$I_{C,3} = \beta \cdot I_{B,3} = \beta \cdot (I_{R1} - I_{R2})$$
$$I_{C,3} + I_{R1} = I_o \Rightarrow \beta \cdot (I_{R1} - I_{R2}) + I_{R1} = I_o$$

Assume that V_{BE} and β values are given, you can determine the resistor values R1 and R2. Again, choose appropriate resistance values available at the Stockroom, and make sure that all transistors are active.

After this first round calculation, we build the circuit with initial resistor values. Measure V_{BE} and β values on real circuit, and substitute these real values into hand-calculation equations and obtain new resistance values. This procedure is repeated until all requirements are satisfied.