1. For each of the following op-amps: PMOS-input folded cascode, NMOS-input telescopic cascode w/ CM-tracking NMOS cascode bias, NMOS-input current-mirror cascode, assuming that L=1um, V_{DSAT}=200mV, and I_{D}=40uA for all devices in the signal path, and a 100fF load capacitance,
   a. Calculate R_o, A_v, and the unity gain frequency
   b. Draw the region of output swing vs. input common-mode range over which all devices remain in saturation, and annotate/label all of the lines with the corresponding values. Assume a 3V single-sided supply.
   c. Calculate the current consumption of the three different topologies, ignoring the bias circuitry
   d. Draw the bias circuits necessary for each amplifier, and discuss how the devices in the bias circuits should be sized (and why). Assume that you have a single reference current available from your reference generation block (which we’ll talk about next week).
   e. Given your answers above, is there a clear winner overall? What if all I care about is gain? Swing? Power? Complexity?

2. Get a copy of the TI/Burr-Brown OPA334 datasheet. Note that they call V_{DD} “V+”, and V_{SS} is “V-“.
   a. Based on the input common mode range, what can you guess about the topology of the input stage?
   b. What is the low frequency gain, in dB and Volts/Volt?
   c. What is the unity gain frequency and phase margin?
   d. What is the slew rate, and what is the corresponding highest frequency sine wave with 200mV peak-to-peak amplitude that the amplifier can drive at it’s output without slewing?

   a. What is the unity gain frequency and phase margin?
   b. What is the typical input offset voltage at 25C, and the worst-case over process, voltage, and temperature?
   c. Look at figure 24, and write an expression for the differential gain from V_{IN} to the input to the Class AB control circuitry. Write the gain in terms of gm and ro of the 8 transistors in that part of the circuit, M1a_P, M1a_N, M1b_P, M1b_N, and the N and P cascades. You can assume that the current sources have infinite output resistance.
PMOS-Input Folded Cascode

- $V_{B\text{tail}}$
  - $M_{\text{tail}}$
  - $V_{B\text{P}}$
  - $V_{B\text{N1}}$
  - $V_{B\text{N2}}$

- $V_{i+}$
  - $M_{1L}$
  - $M_{1R}$

- $V_{i-}$
  - $V_{B\text{N1}}$
  - $M_{2L}$
  - $M_{2R}$

- $V_{o}$
  - $M_{3L}$
  - $M_{3R}$
  - $M_{3L_{C}}$
  - $M_{3R_{C}}$
  - $M_{2L_{C}}$
  - $M_{2R_{C}}$
NMOS-Input Telescopic Cascode

\[ \text{Vo} \]

\[ \text{M1Csrcb} \]

\[ \text{M1Csrca} \]

\[ \text{M2LC} \]

\[ \text{M2LR} \]

\[ \text{M1LC} \]

\[ \text{M1RL} \]

\[ \text{M1RC} \]

\[ \text{M2RC} \]

\[ \text{VBP1a} \]

\[ \text{VBP1b} \]

\[ \text{Vi+} \]

\[ \text{Vi-} \]

\[ \text{Vo} \]

\[ \text{VBP2} \]

\[ \text{Mtail} \]

\[ \text{Vtail} \]
Current Mirror Cascode Op-Amp