

ECE 651: Electronic Design II

Homework #4

Due: Wednesday, October 18th, 2023

Student Name: _____

Note: Please use this as a cover page for your paper submission.

Build the following 2-stage differential amplifier on Multisim and simulate the circuit to find the overall voltage gain (A_v). For input signal (v_{id}), use a sinusoidal voltage source with a frequency of 1 kHz and a voltage amplitude of 1 mV. For BJTs, use the NPN silicon transistor (model: 2N2222A) for Q_1 and Q_2 , and use PNP transistor (2N3906) for Q_3 .

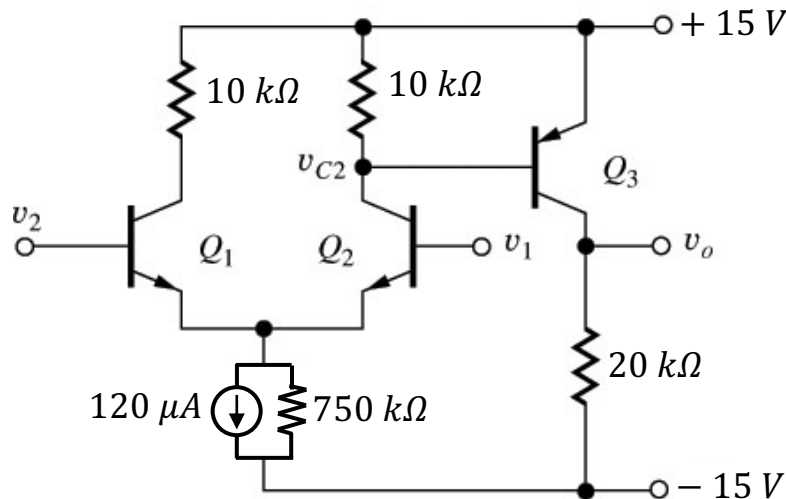


Figure 1. A 2-Stage Differential Amplifier.

- Apply a differential input to $v_1 (= +v_{id}/2)$ and $v_2 (= -v_{id}/2)$. Use the oscilloscope to display both input and output voltage waveforms for: (a) stage #1 only; and (b) stage #1 and #2 combined. Make sure to use different colors for the plots so that the two waveforms are distinguishable. Label each waveform accordingly. Use the waveforms to estimate the overall voltage gain ($A_{dm} = v_o/v_{id}$).
- Apply a common-mode input to both v_1 and v_2 . Use the oscilloscope to display both input and output voltage waveforms for: (a) stage #1 only; and (b) stage #1 and #2 combined. Make sure to use different colors for the plots so that the two waveforms are

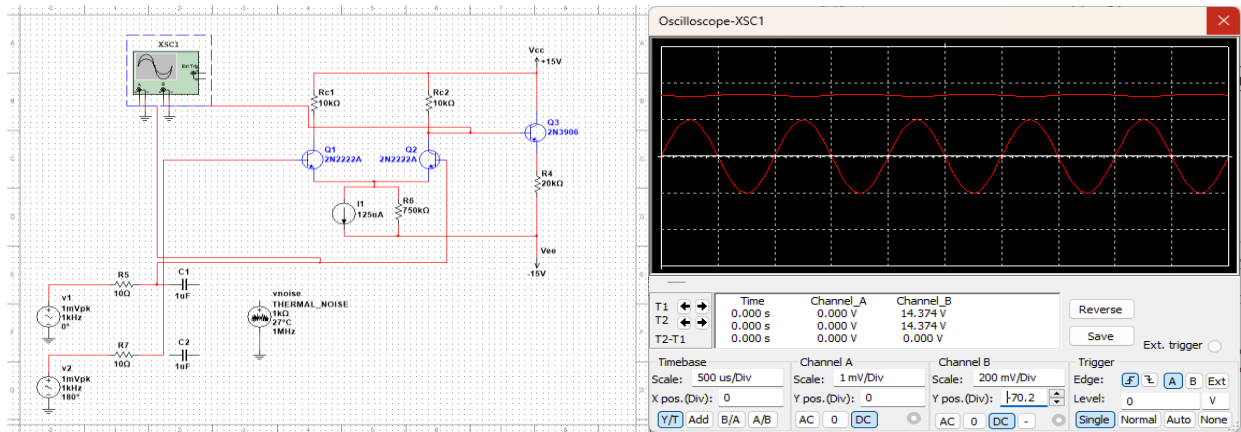
distinguishable. Use the waveforms to estimate the overall common-mode voltage gain ($A_{cm} = v_o/v_{ic}$).

- (c) Inject a noise signal into the differential input using a Thermal Noise Voltage Source. First, display the noisy differential inputs (v_1 and v_2) on oscilloscope to confirm that the same noise has been added to both inputs. Then, use the oscilloscope to display both the input signal (v_1) and output (v_o) voltage waveforms for: (a) stage #1 only; and (b) stage #1 and #2 combined. Make sure to use different colors for the plots so that the two waveforms are distinguishable.
- (d) Adjust the value of the 20 k Ω resistor at Stage #2 so that the output waveform is centered at 0 V. Display the oscilloscope waveforms to support your answer.
- (e) What is the maximum amplitude of the input signal v_{id} (at 1 kHz) that can be amplified without signal distortion at the output (v_o)? Use the oscilloscope waveforms to support your answer.

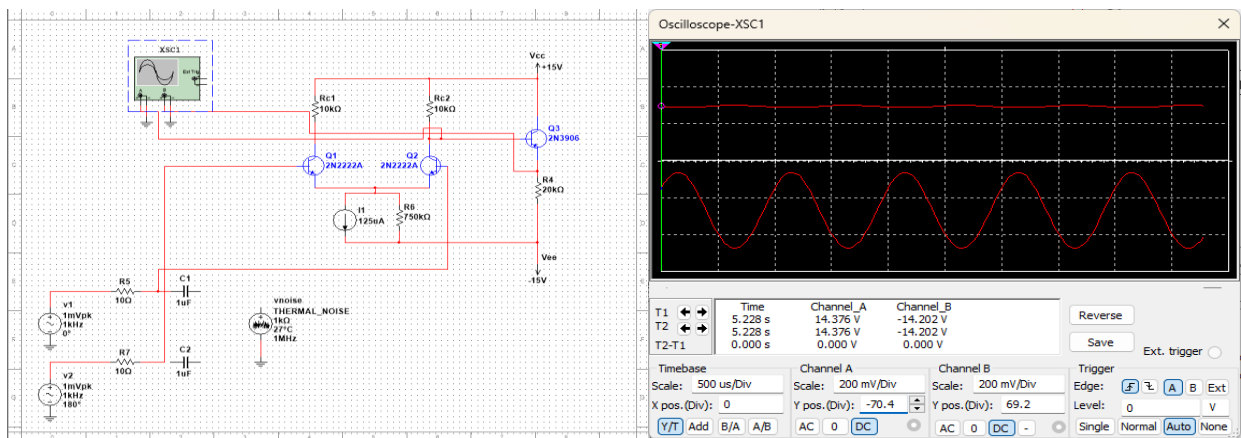
Note:

- All plots and waveforms must be properly labeled with units provided.
- For submission, convert all your worksheets (including this cover page with your name, all handwritten work, schematics, plots, etc.) into a PDF format and submit electronically on Canvas.
- Also, submit your Multisim files (file extension: .ms14) along with your PDF worksheets.

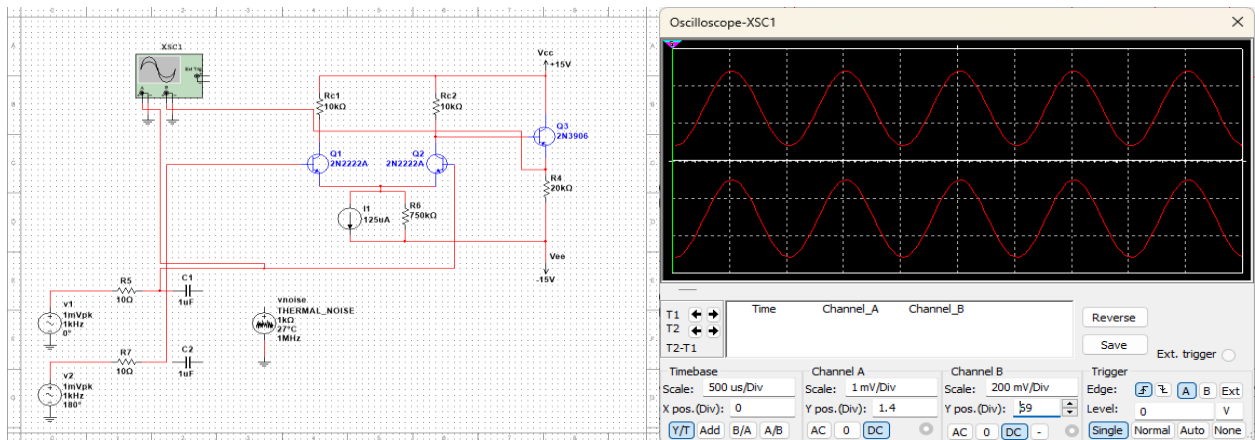
a.a.



a.b.

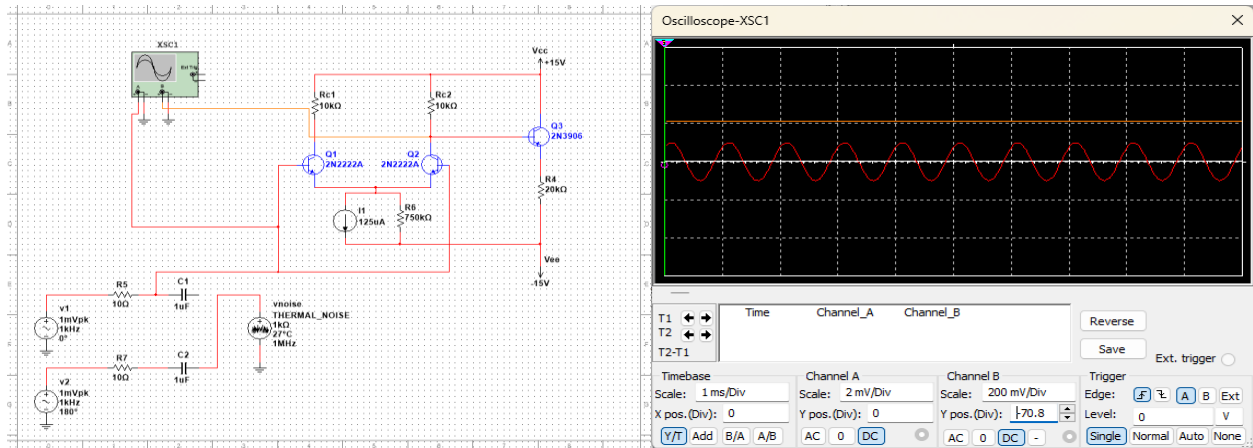


a.c.

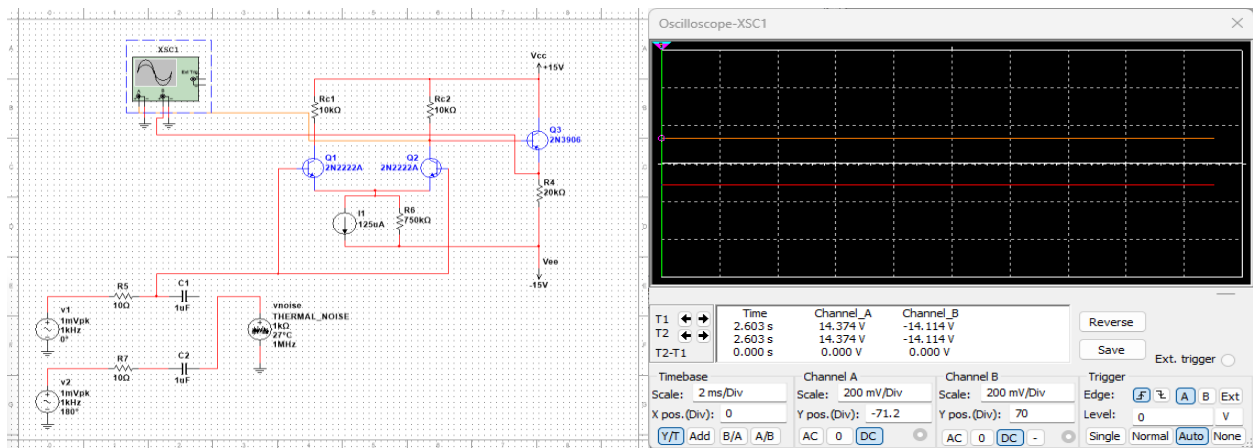


$$v_{id} = 1\text{mV} \quad v_{out} = 14.114\text{V} \quad A_{dm} = 14114$$

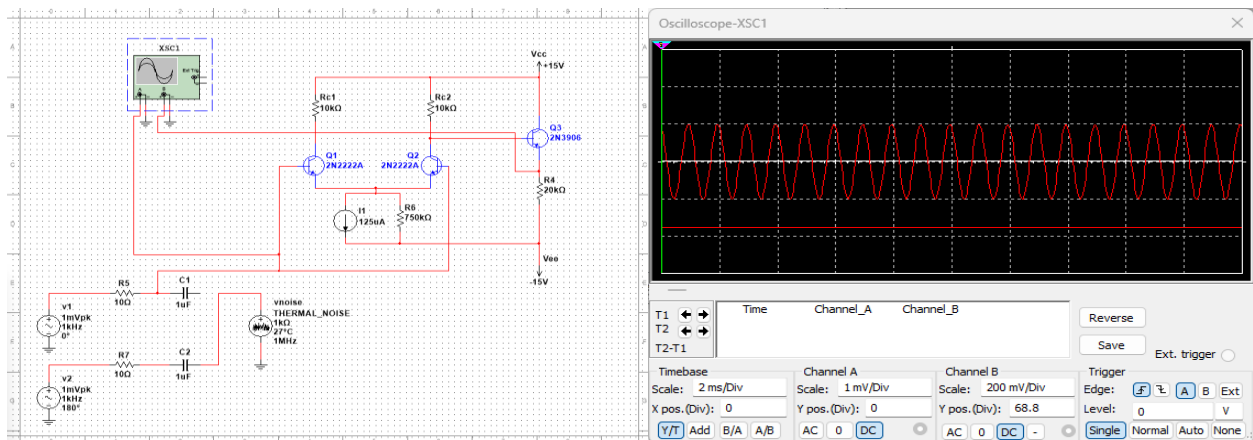
b.a.



b.b.



b.c.

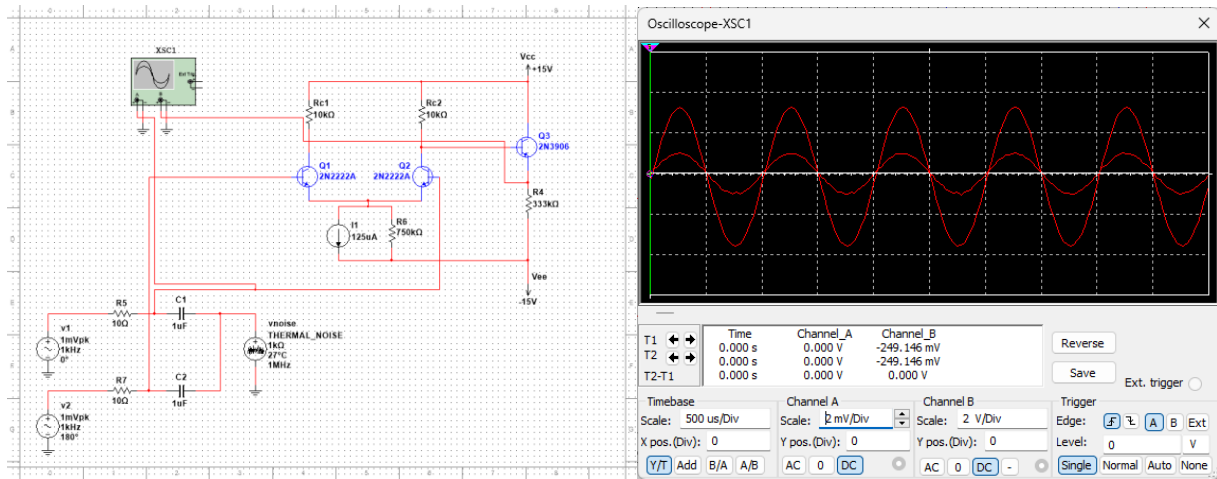


$$V_{ci} = 1\text{mV} \quad V_{out} = 14.114\text{V} \quad A_{cm} = 14114$$

The circuit diagram shows a Class B push-pull amplifier. The input stage consists of a 1mVpk 1kHz sine wave source (V1) and a 1mVpk 1kHz thermal noise source (V2). The input signal is coupled through a 100Ω resistor (R5) and a 1μF capacitor (C1) to the base of a 2N2222A NPN transistor (Q1). The base of Q1 is biased with a 10kΩ resistor (R7) to ground. The emitter of Q1 is connected to ground through a 100Ω resistor (R6). The collector of Q1 is connected to a 10kΩ resistor (R1) to the +15V supply and to the base of a 2N2222A PNP transistor (Q2). The emitter of Q2 is connected to ground through a 10kΩ resistor (R2). The collector of Q2 is connected to the +15V supply through a 10kΩ resistor (R3). The output of the amplifier is taken from the collector of Q2, which is connected to a 20kΩ load resistor (R4) to the -15V supply. The output signal is measured across the load resistor (R4). The oscilloscope screenshot shows the output signal (Channel A) and the input signal (Channel B). The output signal is a distorted sine wave, indicating clipping. The input signal is a clean sine wave. The oscilloscope settings are: Timebase 2 ms/Div, Channel A Scale 200 mV/Div, Channel B Scale 200 mV/Div, Trigger Edge F, Trigger Level 0, and Trigger Mode Normal.

The screenshot displays a circuit simulation of a differential amplifier. The circuit includes two 2N2222A NPN transistors (Q1, Q2) configured in a differential pair. The base of Q1 is connected to a 10kΩ resistor (R1) and a 1250A current source (I1). The base of Q2 is connected to a 10kΩ resistor (R2) and a 10kΩ resistor (R3). The emitter of Q1 is connected to a 10kΩ resistor (R4) and a 1250A current source (I1). The emitter of Q2 is connected to a 10kΩ resistor (R5) and a 1250A current source (I1). The collector of Q1 is connected to a 10kΩ resistor (R6) and a 15V supply (Vcc). The collector of Q2 is connected to a 10kΩ resistor (R7) and a -15V supply (Vee). The output of the circuit is measured at the collector of Q1 (G3) and the collector of Q2 (G4). The oscilloscope (XSC1) shows the output waveforms for Channel A (G3) and Channel B (G4). The waveforms are sinusoidal and out of phase, indicating differential mode operation. The oscilloscope settings are: Timebase 1ms/Div, Channel A Scale 2mV/Div, Channel B Scale 200mV/Div, Trigger Edge: Rising, Level: 0, Single trigger.

d.



e.

