TOTAL: _____/10

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.

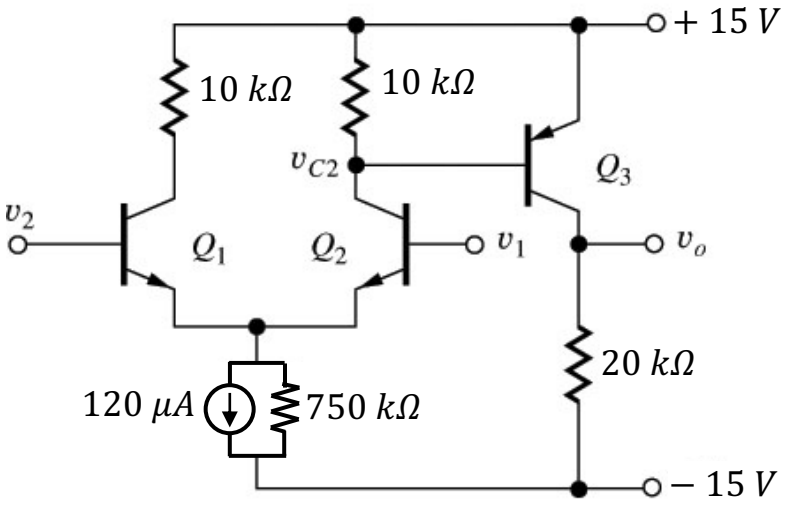


Figure 1. A 2-Stage Differential Amplifier.

(a) 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 ($A_{dm} = v_o/v_{id}$).

(b) 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_C) 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.

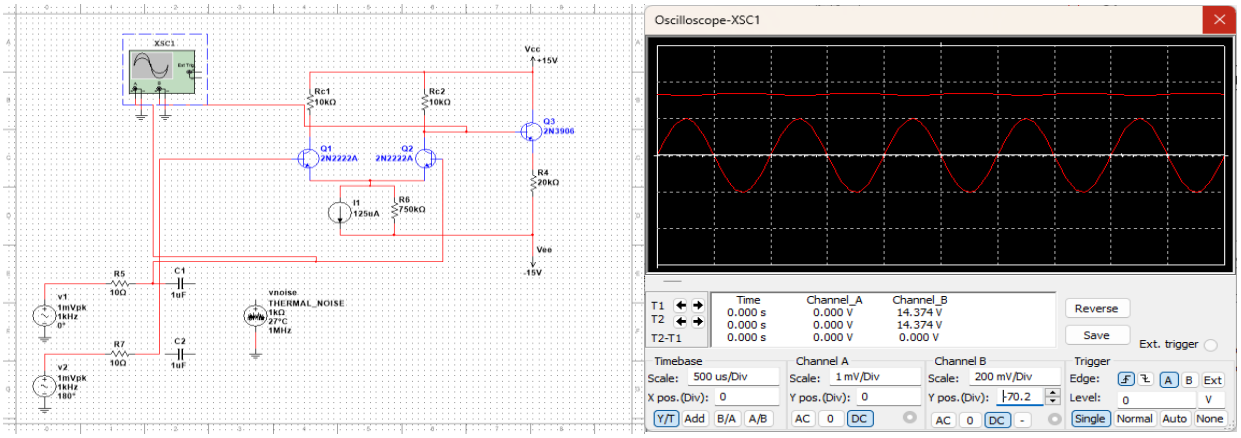
(d) Adjust the value of the 20 kΩ resistor at Stage #2 so that the output waveform is centered at 0 V. Display the oscilloscope waveforms to support your answer.

(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.

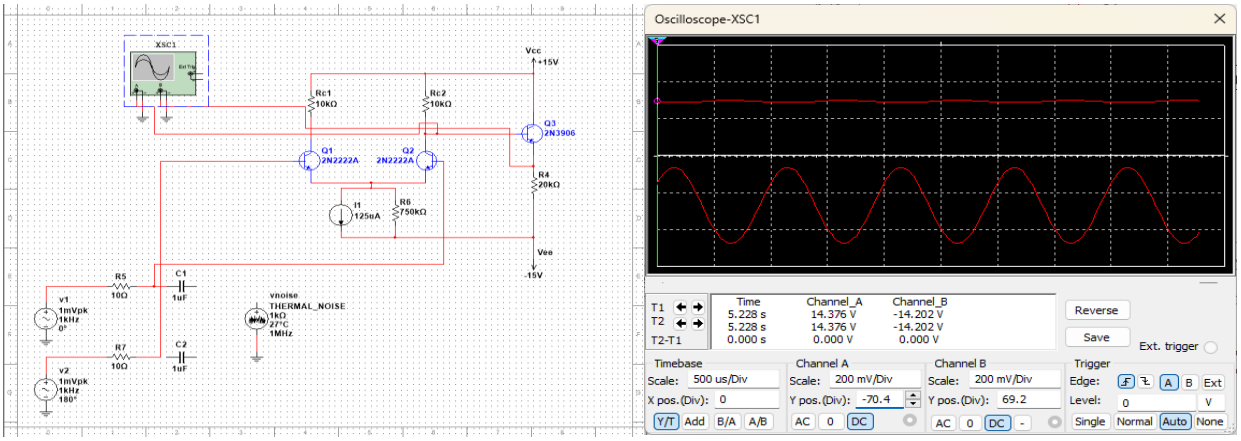
Note:

- 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.

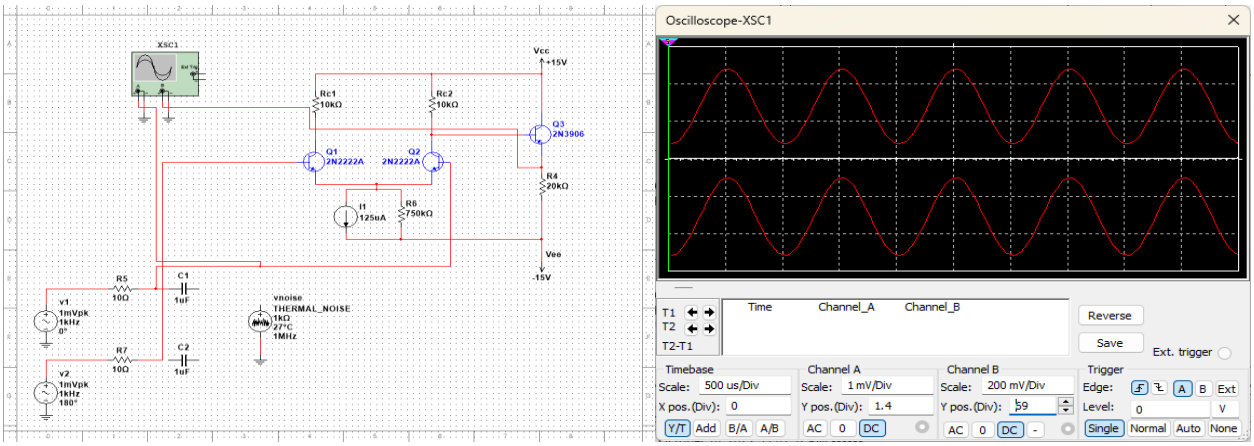
a.a.



a.b.

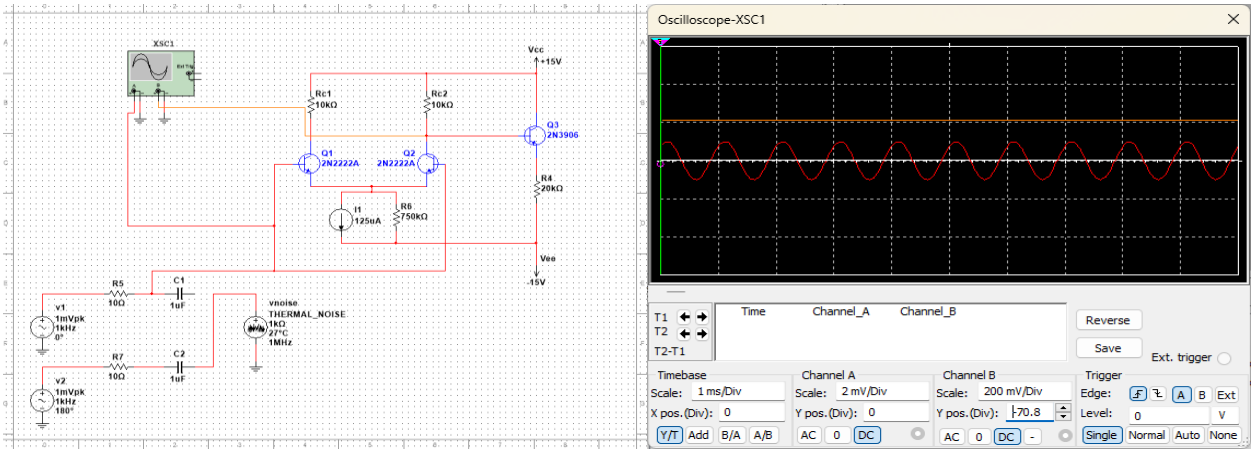


a.c.

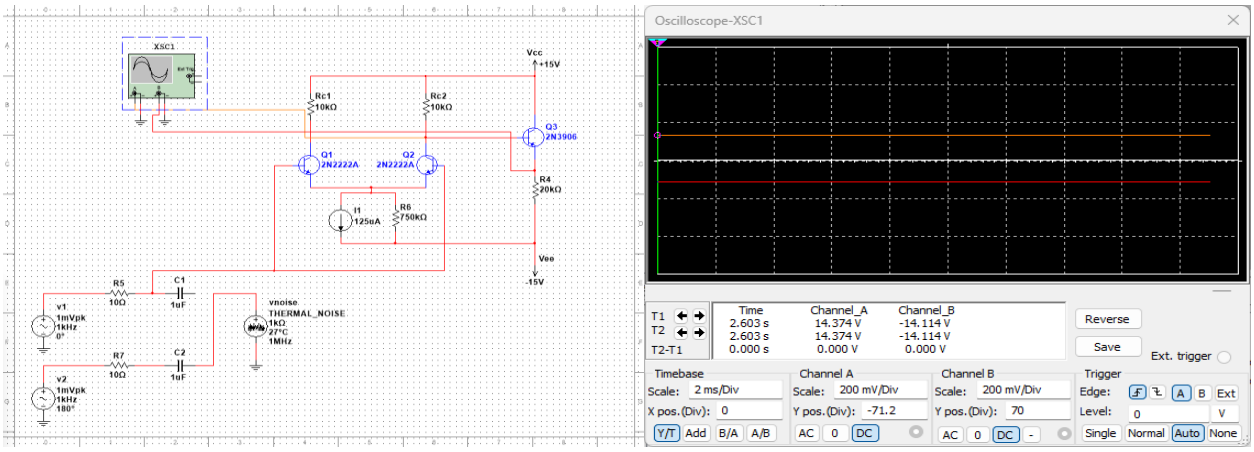


v_{id} = 1mV v_{out} = 14.114V A_{dm} = 14114

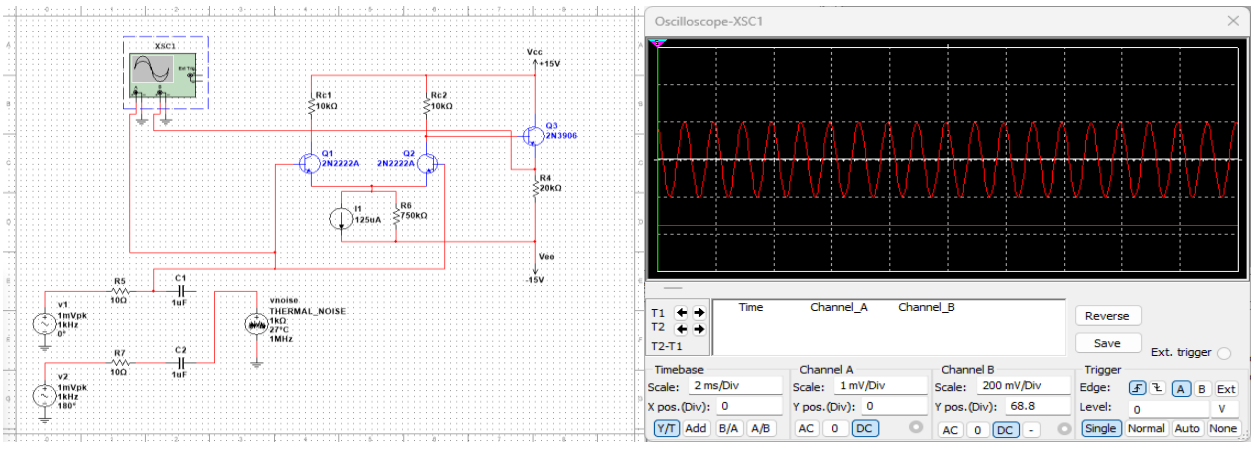
b.a.



b.b.

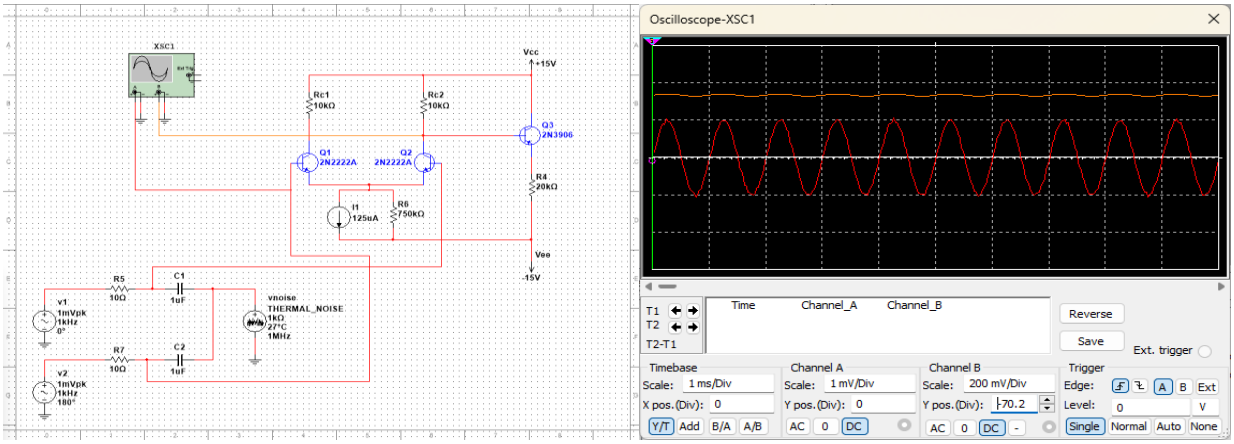


b.c.

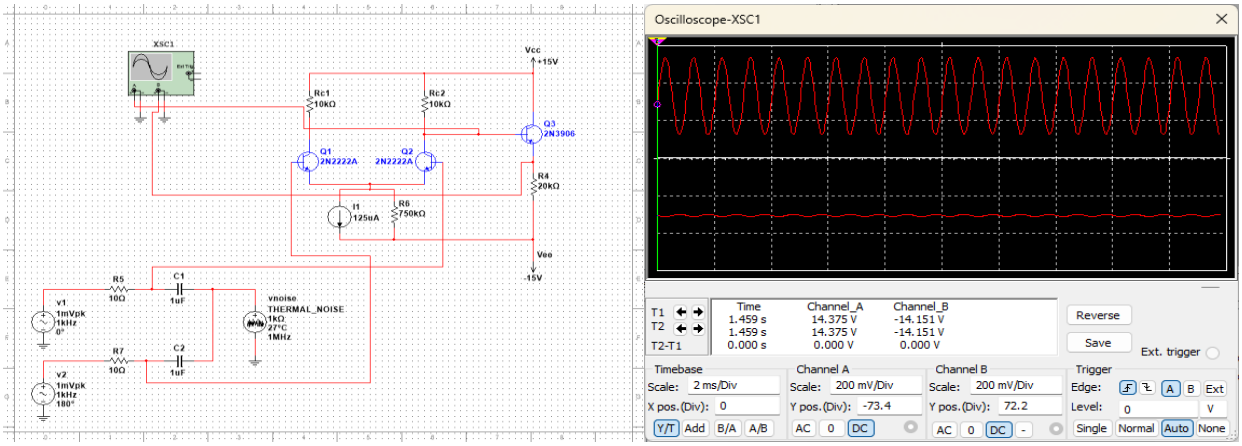


V_{ci} = 1mV v_{out} = 14.114V A_{cm} = 14114

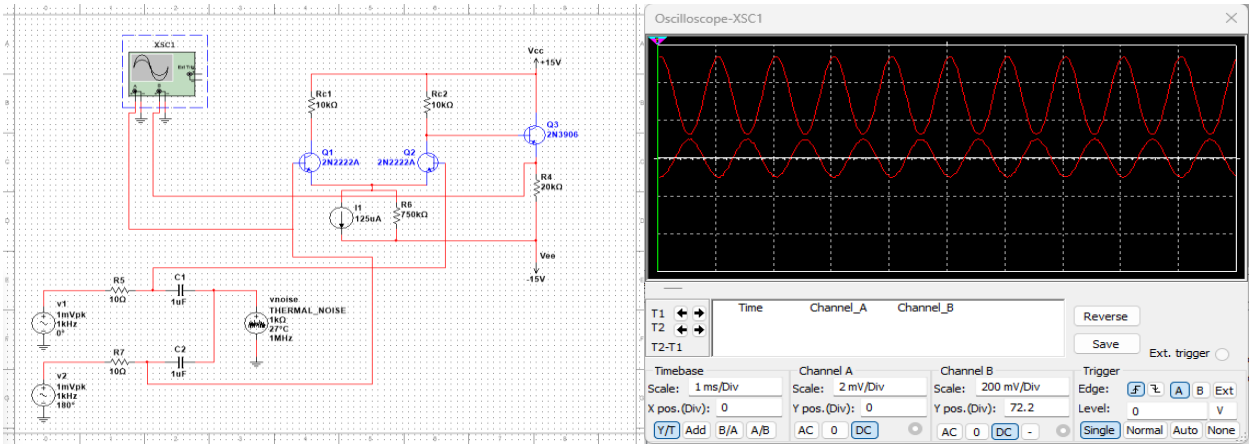
c.a.


XSC1
Vcc
+15V
Rc1
10kΩ
Rc2
10kΩ
Q3
2N3906
Q1
2N2222A
Q2
2N2222A
R4
20kΩ
I1
125uA
R6
750kΩ
Vee
-15V
R5
10Ω
C1
1uF
vnoise
THERMAL_NOISE
1kΩ
27°C
1MHz
v1
1mVpk
1kHz
0°
R7
10Ω
C2
1uF
v2
1mVpk
1kHz
180°
Oscilloscope-XSC1
Time
Channel_A
Channel_B
T1
T2
T2-T1
Reverse
Save
Ext. trigger
Timebase
Scale: 1 ms/Div
X pos.(Div): 0
Y/T Add B/A A/B
Channel A
Scale: 1 mV/Div
Y pos.(Div): 0
AC 0 DC
Channel B
Scale: 200 mV/Div
Y pos.(Div): 70.2
AC 0 DC
Trigger
Edge:
A B Ext
Level: 0 V
Single Normal Auto None

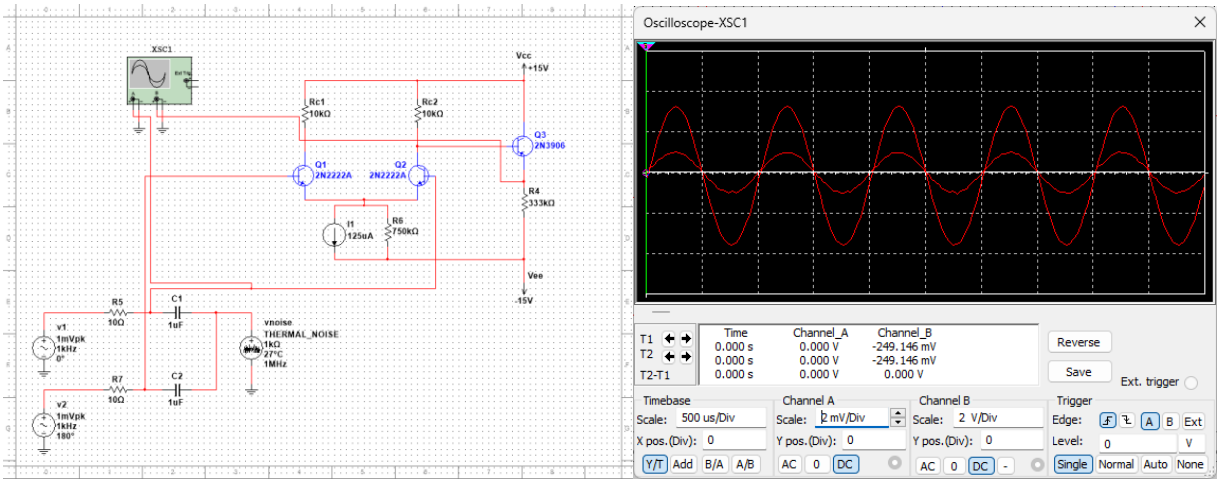
c.b.


XSC1
Vcc
+15V
Rc1
10kΩ
Rc2
10kΩ
Q3
2N3906
Q1
2N2222A
Q2
2N2222A
R4
20kΩ
I1
125uA
R6
750kΩ
Vee
-15V
R5
10Ω
C1
1uF
vnoise
THERMAL_NOISE
1kΩ
27°C
1MHz
v1
1mVpk
1kHz
0°
R7
10Ω
C2
1uF
v2
1mVpk
1kHz
180°
Oscilloscope-XSC1
Time
Channel_A
Channel_B
T1
T2
T2-T1
1.459 s
1.459 s
0.000 s
14.375 V
14.375 V
0.000 V
-14.151 V
-14.151 V
0.000 V
Reverse
Save
Ext. trigger
Timebase
Scale: 2 ms/Div
X pos.(Div): 0
Y/T Add B/A A/B
Channel A
Scale: 200 mV/Div
Y pos.(Div): -73.4
AC 0 DC
Channel B
Scale: 200 mV/Div
Y pos.(Div): 72.2
AC 0 DC
Trigger
Edge:
A B Ext
Level: 0 V
Single Normal Auto None

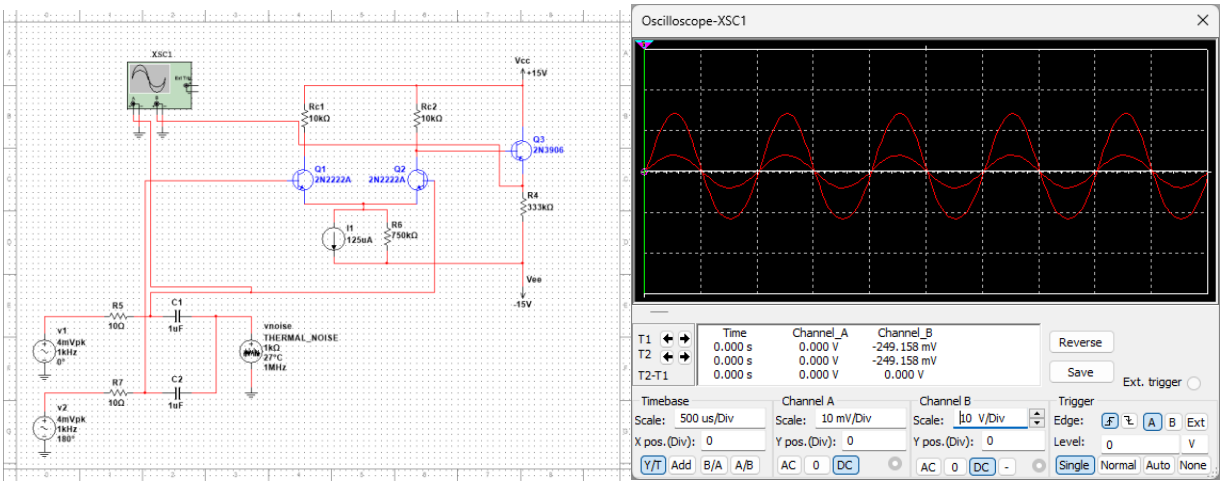
c.c.


XSC1
Vcc
+15V
Rc1
10kΩ
Rc2
10kΩ
Q3
2N3906
Q1
2N2222A
Q2
2N2222A
R4
20kΩ
I1
125uA
R6
750kΩ
Vee
-15V
R5
10Ω
C1
1uF
vnoise
THERMAL_NOISE
1kΩ
27°C
1MHz
v1
1mVpk
1kHz
0°
R7
10Ω
C2
1uF
v2
1mVpk
1kHz
180°
Oscilloscope-XSC1
Time
Channel_A
Channel_B
T1
T2
T2-T1
Reverse
Save
Ext. trigger
Timebase
Scale: 1 ms/Div
X pos.(Div): 0
Y/T Add B/A A/B
Channel A
Scale: 2 mV/Div
Y pos.(Div): 0
AC 0 DC
Channel B
Scale: 200 mV/Div
Y pos.(Div): 72.2
AC 0 DC
Trigger
Edge:
A B Ext
Level: 0 V
Single Normal Auto None

d.


XSC1
Vcc
+15V
Rc1
10kΩ
Rc2
10kΩ
Q3
2N3906
Q1
2N2222A
Q2
2N2222A
R4
333kΩ
I1
125uA
R6
750kΩ
Vee
-15V
R5
10Ω
C1
1uF
v1
1mVpk
1kHz
0°
vnoise
THERMAL_NOISE
1kΩ
27°C
1MHz
R7
10Ω
C2
1uF
v2
1mVpk
1kHz
180°
Oscilloscope-XSC1
Time
Channel_A
Channel_B
T1
0.000 s
0.000 V
-249.146 mV
T2
0.000 s
0.000 V
-249.146 mV
T2-T1
0.000 s
0.000 V
0.000 V
Reverse
Save
Ext. trigger
Timebase
Scale: 500 us/Div
X pos.(Div): 0
Y/T Add B/A A/B
Channel A
Scale: 2 mV/Div
Y pos.(Div): 0
AC 0 DC
Channel B
Scale: 2 V/Div
Y pos.(Div): 0
AC 0 DC -
Trigger
Edge:
A B Ext
Level: 0 V
Single Normal Auto None

e.


XSC1
Vcc
+15V
Rc1
10kΩ
Rc2
10kΩ
Q3
2N3906
Q1
2N2222A
Q2
2N2222A
R4
333kΩ
I1
125uA
R6
750kΩ
Vee
-15V
R5
10Ω
C1
1uF
v1
4mVpk
1kHz
0°
vnoise
THERMAL_NOISE
1kΩ
27°C
1MHz
R7
10Ω
C2
1uF
v2
4mVpk
1kHz
180°
Oscilloscope-XSC1
Time
Channel_A
Channel_B
T1
0.000 s
0.000 V
-249.158 mV
T2
0.000 s
0.000 V
-249.158 mV
T2-T1
0.000 s
0.000 V
0.000 V
Reverse
Save
Ext. trigger
Timebase
Scale: 500 us/Div
X pos.(Div): 0
Y/T Add B/A A/B
Channel A
Scale: 10 mV/Div
Y pos.(Div): 0
AC 0 DC
Channel B
Scale: 10 V/Div
Y pos.(Div): 0
AC 0 DC -
Trigger
Edge:
A B Ext
Level: 0 V
Single Normal Auto None