ELECENG 3EJ4: Electronic Devices and Circuits II

Lab 4: Feedback Circuits

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Questions for Part 1

Question 1

(1) Based on the simulated data from Step 1.2, the low-frequency voltage gain for the first-stage differential amplifier is 7.39dB, for the second-stage CE amplifier is 70.05dB, and for the third-stage CC amplifier is 0.00dB.

(2) The overall voltage gain for the differential-mode signal is 77.43dB, or 7442.9 V/V.

(3) V2 is the non-inverting input of the operational amplifier as the input phase matches the output phase.

(4) When the phase decreases by 45 degrees (from 179 to 134 degrees), the corresponding frequency is approximately 6.3384 kHz.

Question 2

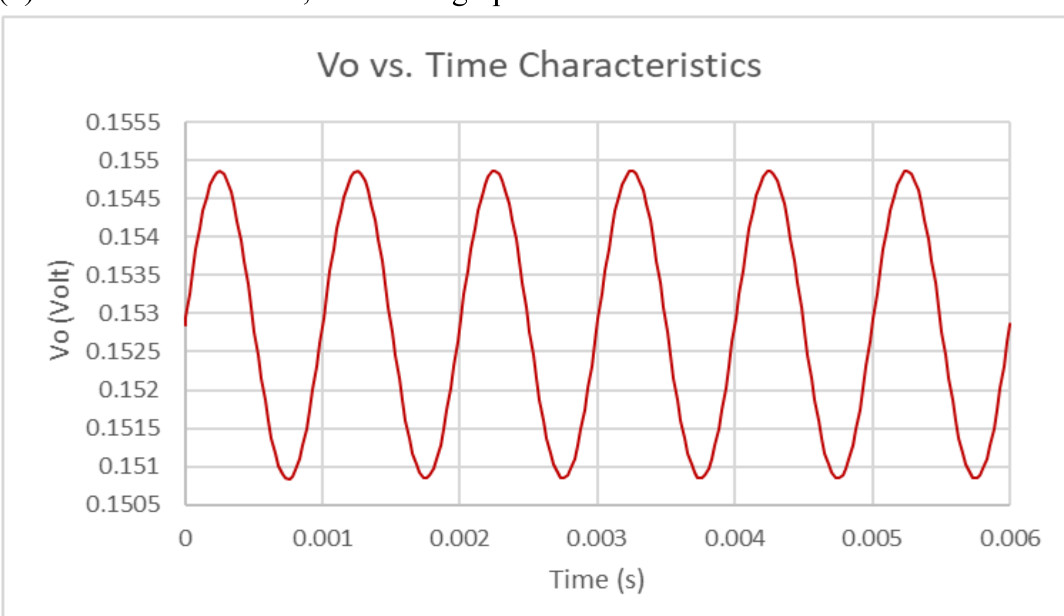
In Lab 4, Ad1 = 7.39 dB compared to Ad = 70.07dB found in Q5 of Lab 3. This lower gain can be attributed to the feedback network present in part 1 of Lab 4, which reduces and stabilizes the amplifier's gain.

Question 3

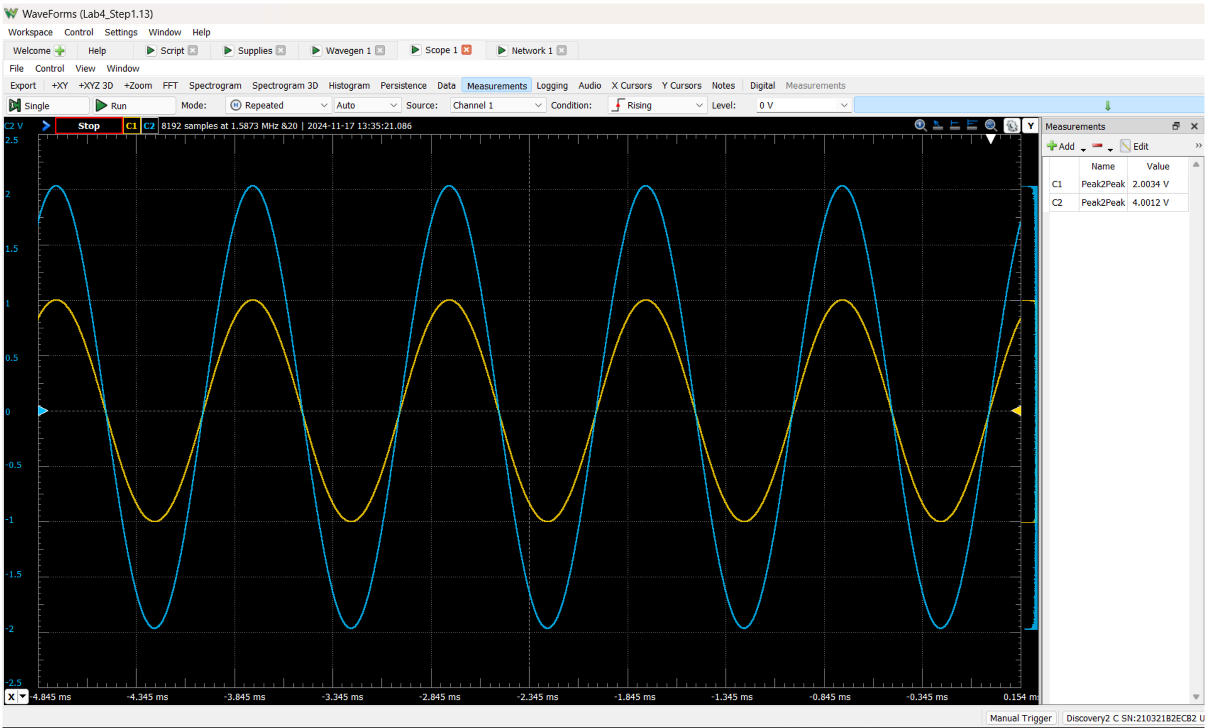
Based on the simulation results in Step 1.2, Rin = 81757.3Ω. Based on the results obtained in Step 1.3, Rout = 460.8Ω.

Question 4

(1) From the simulation, the below graph shows Vo vs. Time Characteristics.



The measured values for Vo vs. Time Characteristics are shown in the Waveforms graph below:



(2) The calculated results for each scenario are as follows:

<u>Simulated Data</u>

$$Vpp = 0.154866 - 0.150844 = 0.004V$$

$$Vp = \frac{0.004}{2} = 0.002V$$

$$Vdc = \frac{0.154866 + 0.150844}{2} = 0.1528V$$

<u>Measured Data</u>

$$Vpp = 4.0012V$$

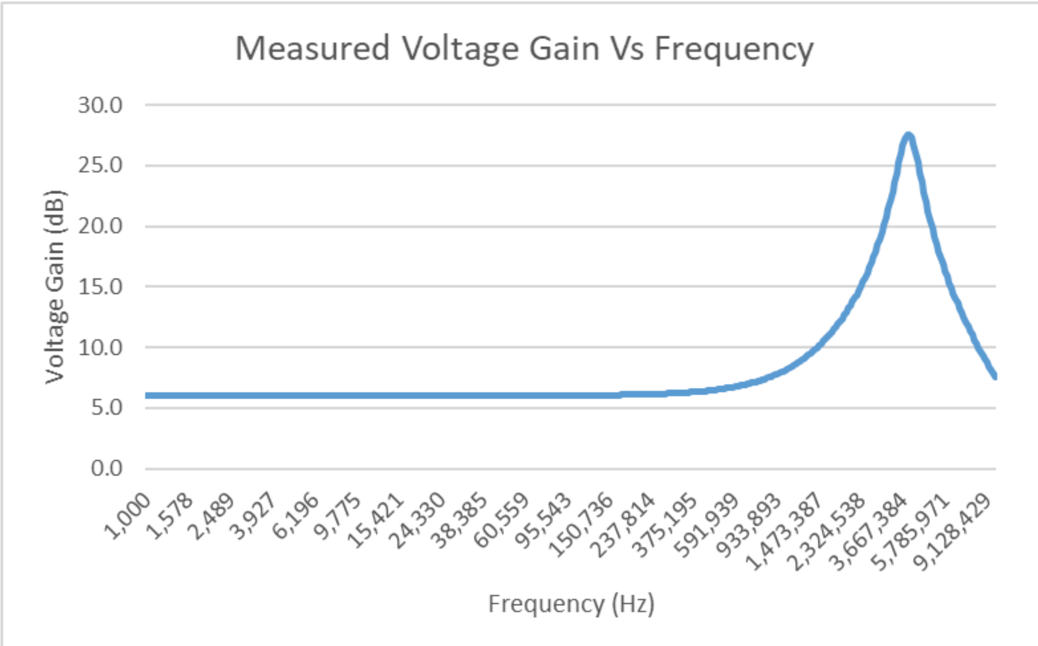
$$Vp = \frac{4.0012}{2} = 2.000V$$

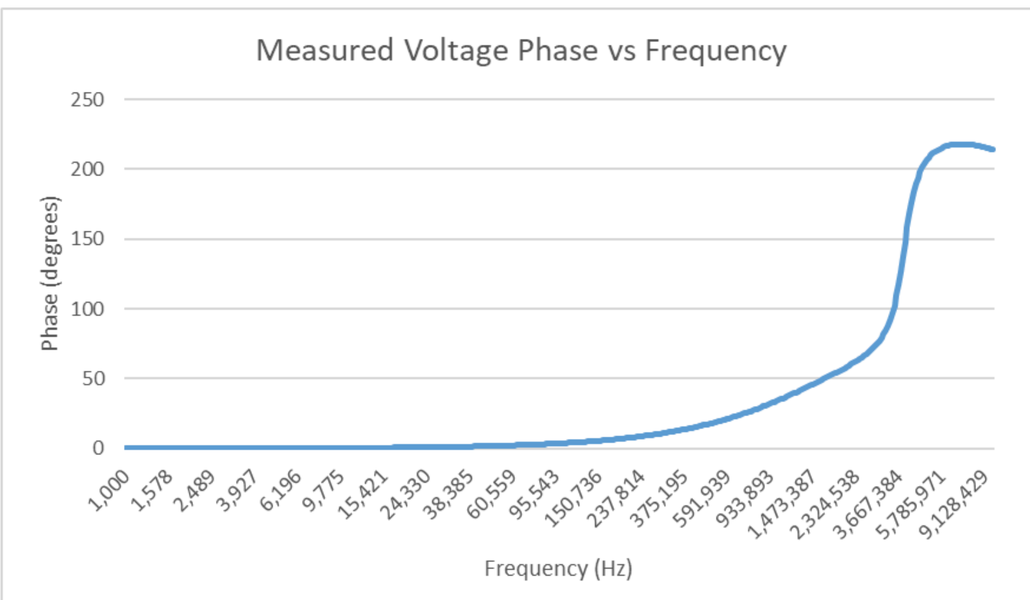
$$Vdc = \frac{4.0012}{2} = 0.061V$$

In step 1.6, a source of 1mV is applied. In step 1.13, a source of 1V is applied. As the source is 1000x greater in the physical build compared to the simulations, the Vpp and Vp follow, and are 1000x greater in the measured data.

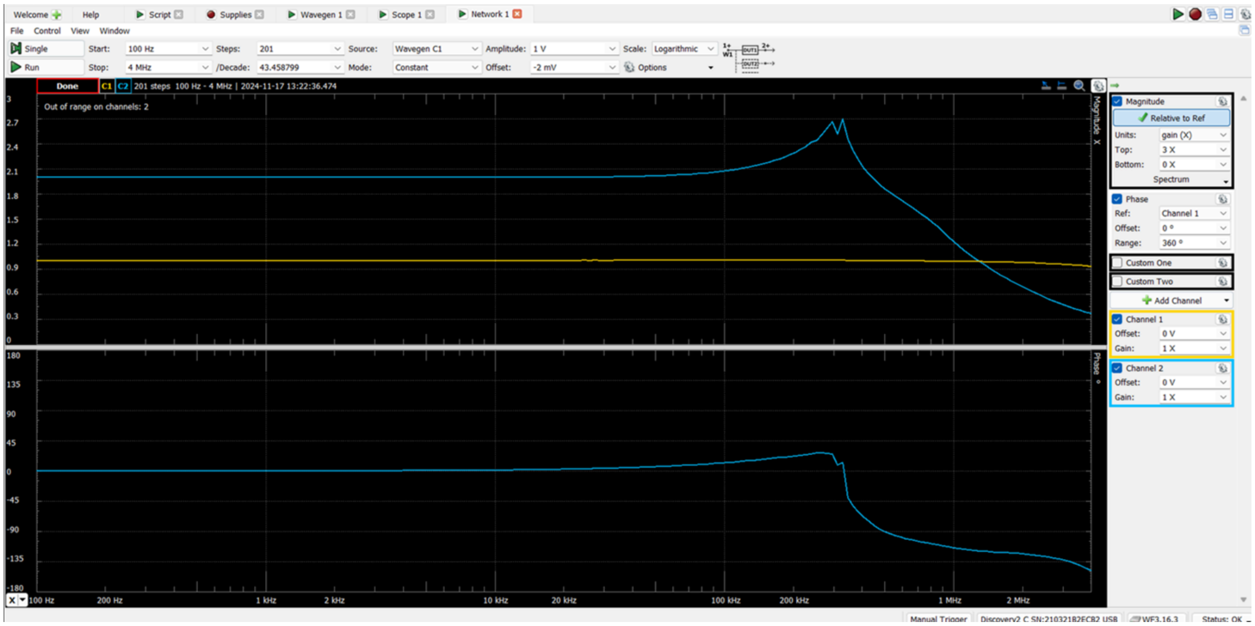
Question 5

(1) Graphs were created for the simulated values to demonstrate the voltage gain magnitude and phase vs. frequency characteristics from step 1.7.





The graphs showing measured data from step 1.14 were captured:



The low frequency gain is 2.0V/V or 6dB.

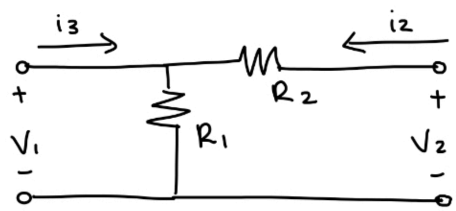
(2) The amplifier's highest operating frequency to provide a constant gain is approximately 100kHz.

Question 6

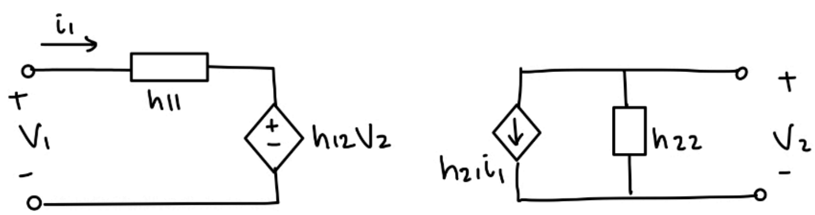
In figure 2, the amplifier has a series-shunt feedback configuration. There is a series connection at the input of the amplifier, and a branch-out at the output, indicating a shunt connection.

Question 7

The β network:



Using h parameters:



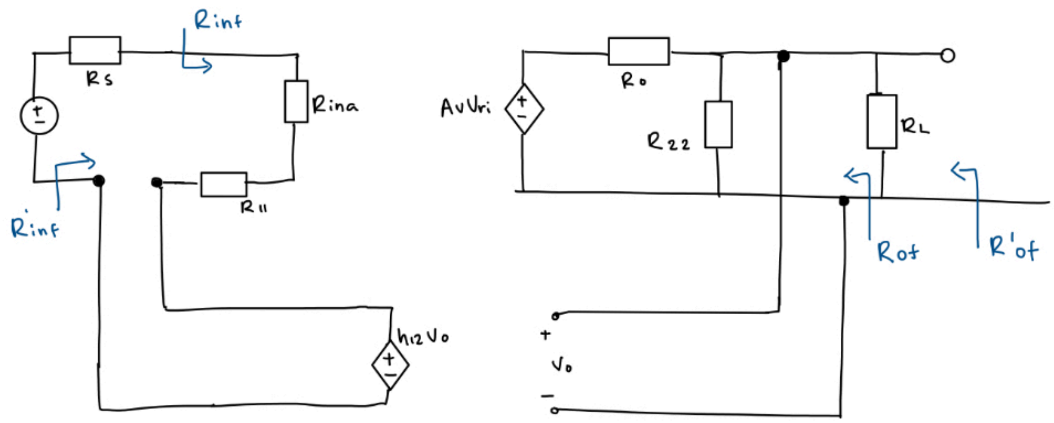
voltage division

$$\beta = \frac{R_1}{R_1 + R_2} = \frac{100k}{200k} = 0.5$$

$$R_{11} = R_1 \| R_2 = \frac{100k}{2} = 50k\Omega$$

$$R_{22} = R_1 + R_2 = 100k + 100k = 200k\Omega$$

Question 8



Calculations

$$A'_v = \frac{V_o}{V_s} = A_o\left(\frac{R_{22}\,||\,R_L}{R_{out} + R_{22}\,||\,R_L}\right)\left(\frac{R_{in}}{R_{in}+R_{11}}\right)$$

$$= 7442\left(\frac{200k\,//\,240k}{460.8 + 200k//240k}\right)\left(\frac{81757}{81757+50k}\right)$$

$$= 4607 \text{ V/V}$$

$$R'_{of} = \frac{R_{out}}{1+A'_v\beta} = \frac{460.8}{1+(4607(0.5))} = 0.200\Omega$$

$$R_{of} = \frac{1}{\frac{1}{R'_{of}} - \frac{1}{R_L}} = \frac{1}{\frac{1}{0.200} - \frac{1}{240k}} = \boxed{0.200\Omega}$$ output resistance

$$R'_{in} = R_{ina} + R_{11} = 81757\Omega + 50k\Omega = 131.757k\Omega$$

$$R'_{inf} = R'_{in}(1+A'_v\beta)$$

$$= 131.757k\Omega\,(1+4617(0.5))$$

$$= 303.634\ M\Omega$$

$$R_{in} = r'_{inf} - R_s = 303M\Omega - 0 = \boxed{303M\Omega}$$ input resistance

$$A'_{vf} = \frac{A'_v}{1+A'_v\beta} = \frac{4607}{1+4607(0.5)} = \boxed{2\ V/V}$$ voltage gain

Questions for Part 2

Question 9

$R = R_3 = R_4$
$C = C_1 = C_2$

$$V_o = V_+\left(1+\frac{1}{sCR}\right) + RV_+\left(\frac{1}{R} + sC\left(1+\frac{1}{sCR}\right)\right)$$
$$= V_+\left(1+\frac{1}{sCR}\right) + V_+(2+sCR)$$

$$\frac{V_+}{V_o} = \frac{\frac{s}{CR}}{s^2+s\left(\frac{3}{CR}\right)+\left(\frac{1}{CR}\right)^2} \qquad \therefore L(s) = \left(1+\frac{R_2}{R_1}\right)\frac{\frac{s}{CR}}{s^2+s\left(\frac{3}{CR}\right)+\left(\frac{1}{CR}\right)^2}$$

$\therefore$ zero loop phase $\omega_0 = \frac{1}{CR}$

$$|L(j\omega)| = \frac{1}{3}\left(1+\frac{R_2}{R_1}\right)$$
$\frac{1}{3}\left(1+\frac{R_2}{R_1}\right) \geq 1$ for oscillation, occurs when $\frac{R_2}{R_1} \geq 2$

Question 10

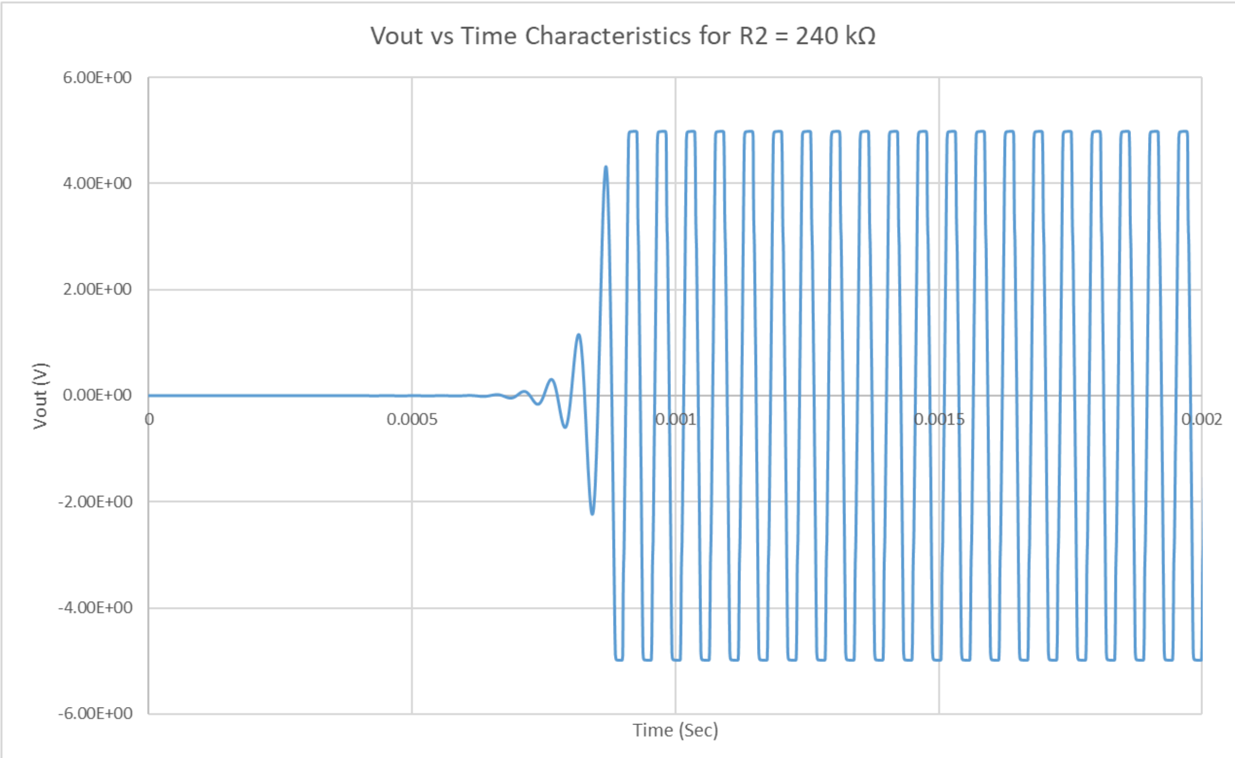
Based on the simulation results in 2.4, the settling times are as follows

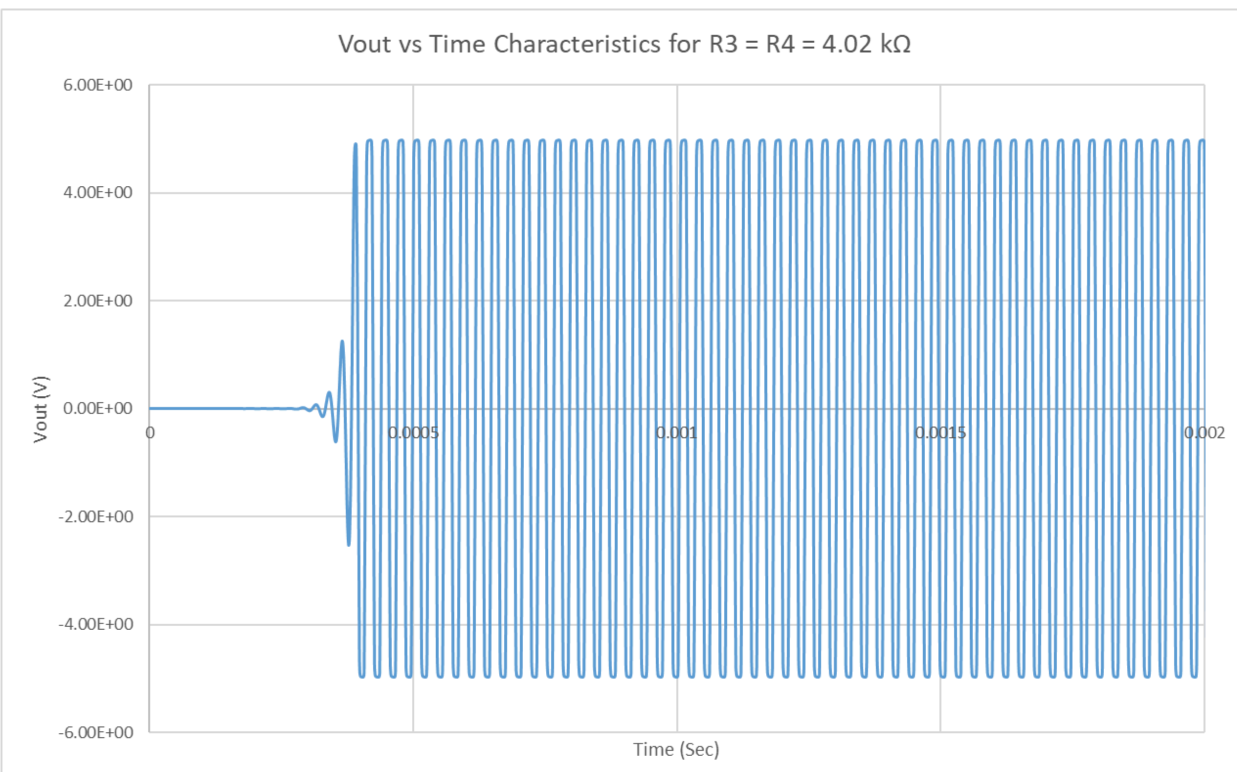
R2 Value	Settling time
220 kΩ	1.879738921ms
240 kΩ	0.092335169ms
280 kΩ	0.049388294ms

From this data, it can be observed that as the R2 resistance increases, the settling time decreases. Increasing R2 increases the feedback factor, which increases the loop gain L(s). This higher feedback can cause the system to respond faster, resulting in lower time to reach saturation.

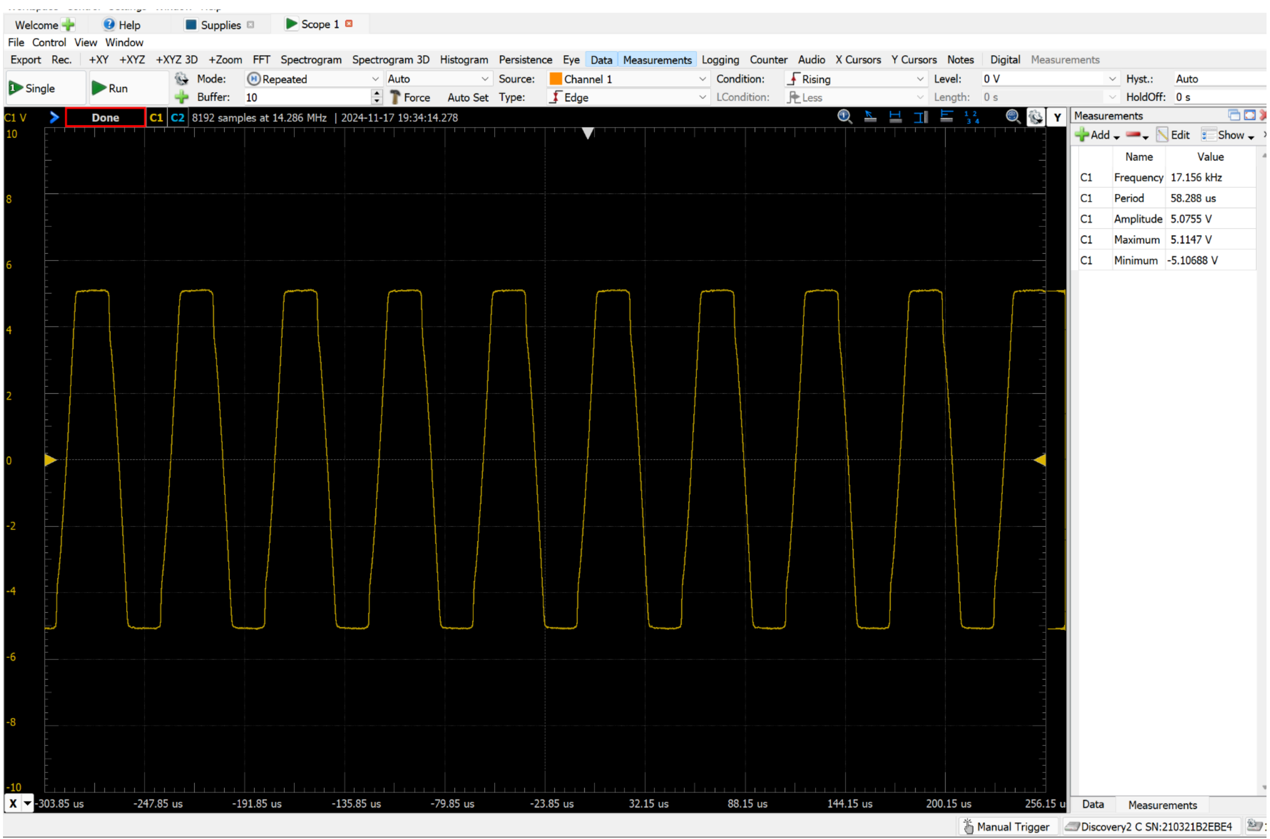
Question 11

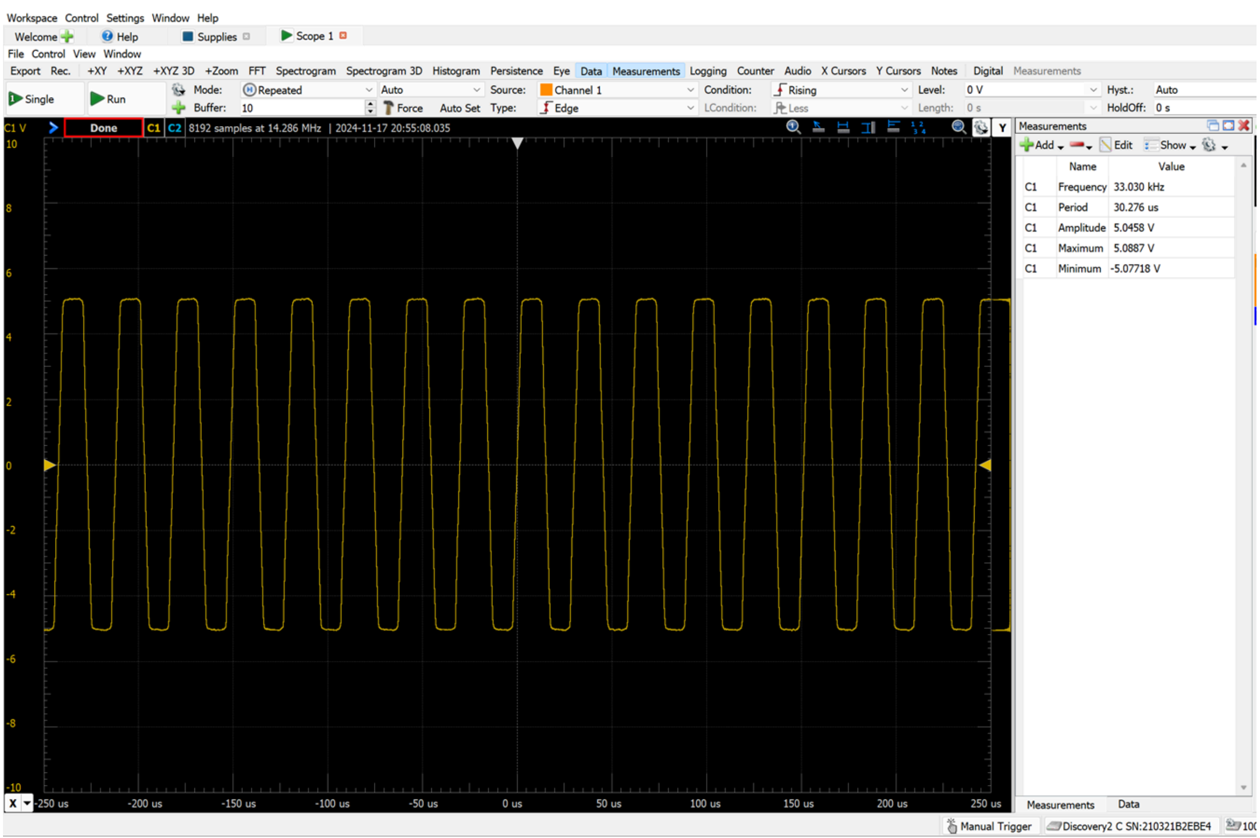
(1) The simulated results from 2.3 and 2.5 are shown in the graphs below:





The graphs generated from the measurements are shown below:


Welcome
Help
Supplies
Scope 1
File Control View Window
Export Rec. +XY +XYZ +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Eye Data Measurements Logging Counter Audio X Cursors Y Cursors Notes Digital Measurements
Single
Run
Mode: Repeated
Buffer: 10
Auto
Force
Auto Set
Source: Channel 1
Type: Edge
Condition: Rising
LCondition: Less
Level: 0 V
Length: 0 s
Hyst.: Auto
HoldOff: 0 s
Done
8192 samples at 14.286 MHz | 2024-11-17 19:34:14.278
Measurements
Add
Edit
Show
Name Value
C1 Frequency 17.156 kHz
C1 Period 58.288 us
C1 Amplitude 5.0755 V
C1 Maximum 5.1147 V
C1 Minimum -5.10688 V
-303.85 us -247.85 us -191.85 us -135.85 us -79.85 us -23.85 us 32.15 us 88.15 us 144.15 us 200.15 us
Data
Measurements
Manual Trigger
Discovery2 C SN:210321B2EBE4


Workspace Control Settings Window Help
Welcome
Help
Supplies
Scope 1
File Control View Window
Export Rec. +XY +XYZ +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Eye Data Measurements Logging Counter Audio X Cursors Y Cursors Notes Digital Measurements
Single
Run
Mode: Repeated
Buffer: 10
Auto
Force
Auto Set
Source: Channel 1
Type: Edge
Condition: Rising
LCondition: Less
Level: 0 V
Length: 0 s
Hyst.: Auto
HoldOff: 0 s
Done
8192 samples at 14.286 MHz | 2024-11-17 20:55:08.035
Measurements
Add
Edit
Show
Name Value
C1 Frequency 33.030 kHz
C1 Period 30.276 us
C1 Amplitude 5.0458 V
C1 Maximum 5.0887 V
C1 Minimum -5.07718 V
-250 us -200 us -150 us -100 us -50 us 0 us 50 us 100 us 150 us 200 us 250 us
Measurements
Data
Manual Trigger
Discovery2 C SN:210321B2EBE4

(2) For the simulation R2 = 240kΩ, the frequency was 17.958kHz, and for the simulation R3 = R4 = 4.02kΩ, the frequency was 33.742kHz.

For the measurement R2 = 240kΩ, the frequency was 17.156kHz, and for the measurement R3 = R4 = 4.02k, Ω, the frequency was 33.030kHz.

When comparing the simulated values to the measured values for each case, the frequencies are very similar. This data displays the same trend of inverse proportionality as was derived in the questions above. When the resistance is decreased from 8.25kΩ to 4.02kΩ, the simulated frequency increases from 17.958kHz to 33.742kHz. Therefore, when the resistance is halved, the frequency is doubled. This trend was observed and confirmed with the simulated data as well, as the frequency doubled (from 17.156kHz to 33.030kHz) when the resistors were reduced to 4.02kΩ.