EE203 - Electrical Circuits Laboratory

Experiment - 9 Simulation

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Feedback Circuits

Preliminary Work

1-) a-) Mechanism

If V_o drops ;

=> Voltage on Zener drops.
=> that causes higher current on resistor.
=> which results in higher I_B and I_C.
=> Rise on I_C pulls V_o up back.

b-) $V_o = V_Z - V_{BE}$

$4 = V_Z - 0.7 \implies V_Z = 4.7V$

2-) a-) $f = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi R_2 C_2}$

b-) By the equation above,

$16\times10^3 = \frac{1}{2\pi R_4 10^{-3}} \implies R_4 = \frac{10^3}{2\pi\cdot16\times10^3} = 9.947k\Omega \cong 10k\Omega$

c-) $T(j\omega) = 1 = (1+\frac{R_3}{R_1})\left[\frac{1}{3+j\omega_0 RC + (1/j\omega_0 RC)}\right]$

$Im\{T(j\omega)\} = 0 \implies \omega_0 = \frac{1}{RC}$

$1 = (1+\frac{R_2}{R_1})(\frac{1}{3}) \implies \frac{R_2}{R_1} = 2$

$\implies \frac{R_3}{R_4} > 2 \implies R_3 > 20k$

=> To obtain stable oscillation $R_3 = R_4$.

3-) a-) $\frac{R_3}{R_3+10k} = \frac{2}{9} \implies R_3 = 2.857k\Omega$

b-) $V_n = V_H + (-V_P - V_H)e^{-\frac{t}{\tau}} \xRightarrow{\text{for } t_1} 7 = 11e^{-\frac{t_1}{\tau}}$

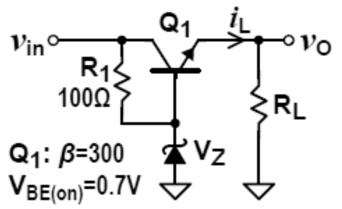
$t_2 - t_1 = 2\cdot\ln(\frac{11}{7})\cdot R_1C_1$

$\frac{1}{f} = 2\cdot\ln(\frac{11}{7})\cdot10\times10^{-9}\cdot R_1 \implies R_1 = 110.623k$

Procedure

AD795 operational amplifier model will be used instead of **LM741** to obtain the simulation results on LTspice. Although **AD795** has much better characteristics compared to **LM741**, both of the devices satisfy the basic requirements of an operational amplifier. You should keep in mind that **AD795** has much higher output slew rate compared to **LM741** and this significantly changes the high-frequency response.

1. Build the voltage regulator circuit given on the right using **BC547B** transistor as **Q1**. Connect a **10 kΩ** resistor in place of $\mathbf{R_L}$.

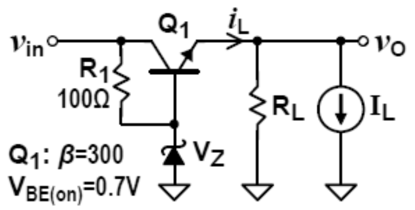


1.1 Determine line regulation when middle value of v_{in} is $\mathbf{V_{inDC} = 6.0\ V}$. Set v_{in} source to obtain **1 kHz 1 Vp-p** sinusoidal voltage with **6.0 V** DC offset and measure peak-to-peak AC component of v_O. Repeat line regulation measurement when $\mathbf{V_{inDC}}$ is **8.0 V**.

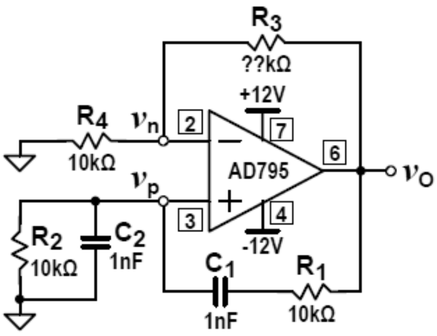
V_{inDC} value of v_{in} (V)	AC component of v_O (Vp-p)	**line regulation (V/V)**
6.0	40.799544mV	0.0408
8.0	16.666926mV	0.0167

1.2 Determine load regulation when i_L increases by **100 mA** for v_{in} **= 6.0V** and v_{in} **= 8.0V**.

It is possible to measure load regulation and line regulation in the same simulation run. Add a **100 mA** pulsed current source $\mathbf{I_L}$ as an active load as shown on the right. Set simulation time to **10 ms** and turn on the $\mathbf{I_L}$ pulse at **5 ms**. Measure the step change in v_O when $\mathbf{I_L}$ turns on.



V_{inDC} value of v_{in} (V)	v_O (V) measured for i_L **= 0.4 mA**	v_O (V) measured for i_L **= 100 mA**	**load regulation (mV/mA)**
6.0	4.0454719V	3.8556016V	1.906
8.0	4.0945873V	3.9067553V	1.886



2. Build the **Wien bridge oscillator** given on the right. Set the opamp DC supplies to **+12 V** and **–12 V**.

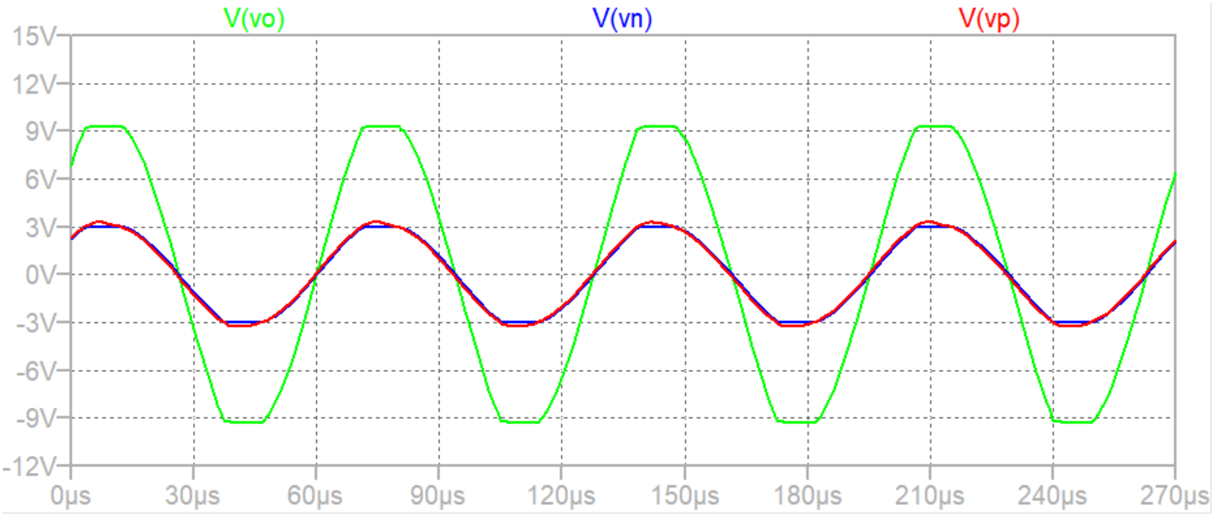
2.1 Find the lowest $\mathbf{R_3}$ value that enables oscillations. First change $\mathbf{R_3}$ in **10 kΩ** steps and then reduce step size to **1 kΩ**. Set simulation time to **20 ms** since it may take several milliseconds to start the oscillations.

$\mathbf{R_3}$ = _____**21k**______

Does this result agree with your $\mathbf{R_3}$ prediction in the preliminary work?

>>Yes, it does. My prediction was $\mathbf{R_3}$ supposed to be greater than 20kohm and we found out 21k in simulation which is pretty similar result.

2.2 Plot v_n, v_p and v_O waveforms below. Indicate units of amplitude and time axes on your plot. Measure and record the peak-to-peak output voltages and the oscillation frequency.

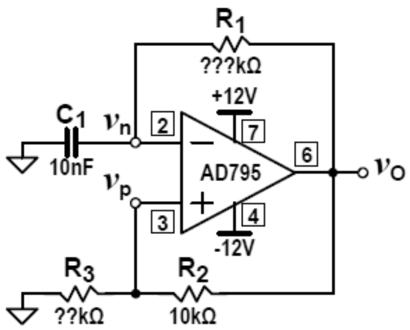


v_n : **5.99141V** v_p : **6.5359956V** v_O : **18.58762V** F_{osc} = **14.593725KHz**

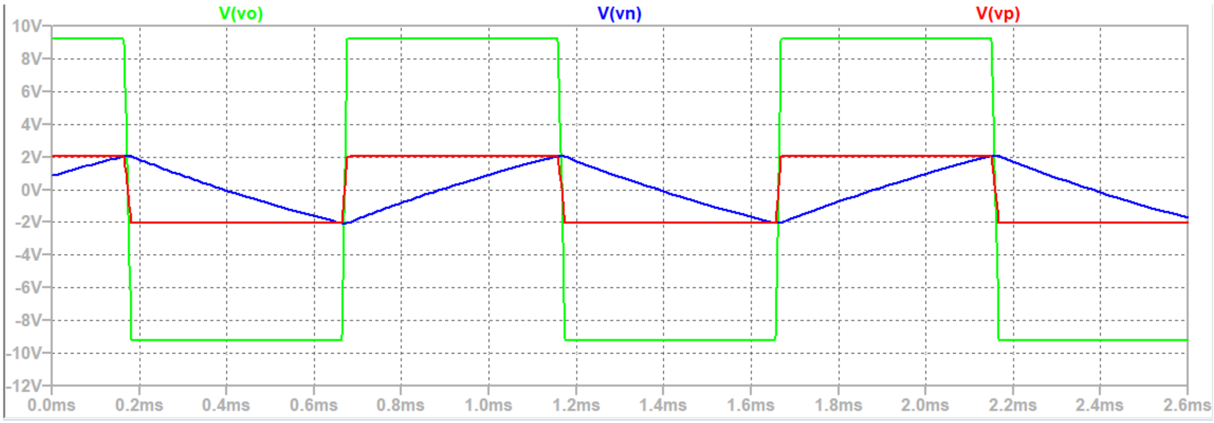
2.3 Measure the oscillation frequency obtained with the $\mathbf{R_2}$ resistance values listed in the following table. How does $\mathbf{R_2}$ affect the oscillation frequency?

R_2 (kΩ)	F_{osc} (Hz)
10	14.797345KHz
20	9.3698347KHz
30	7.0536829KHz
40	5.6282966KHz

3. Build the **Schmitt trigger oscillator** circuit given on the right. Use a standard resistor value closest to the $\mathbf{R_3}$ calculated in the preliminary work.



3.1 Adjust $\mathbf{R_1}$ to obtain **1 kHz** oscillation frequency at v_O. Plot v_n, v_p and v_O waveforms below indicating all critical amplitude and timing information. Compare your measurements with the results obtained in the preliminary work.



>>We desired to obtain 1kHz frequency and v_p as 4V(peak to peak). v_p is almost the same what we expect and we found out $\mathbf{R_1}$ as 107kohm which is 3.6% samaller than our expectation. Consequently, we almost observed the same result on our preliminary work.

Questions

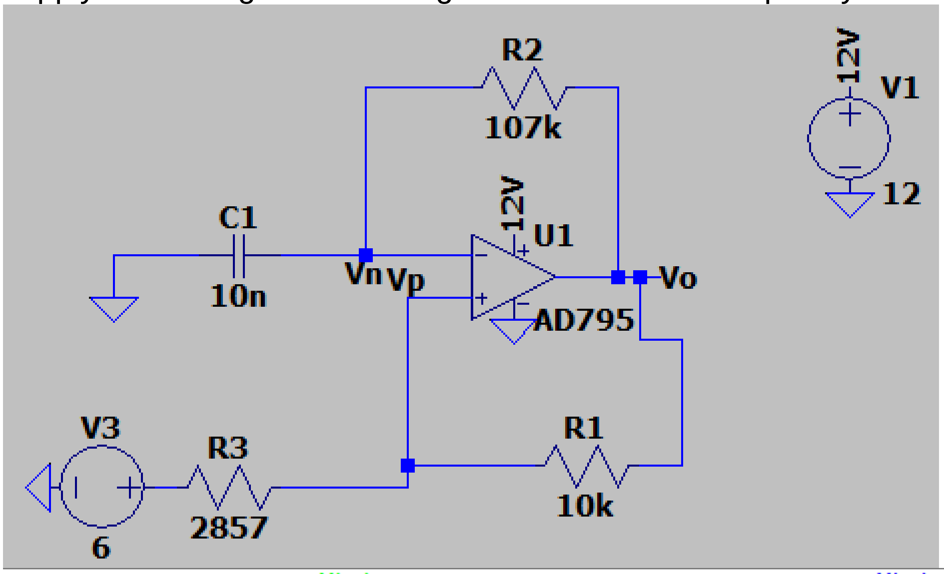
Q1. List the steps in designing a Wien bridge oscillator.

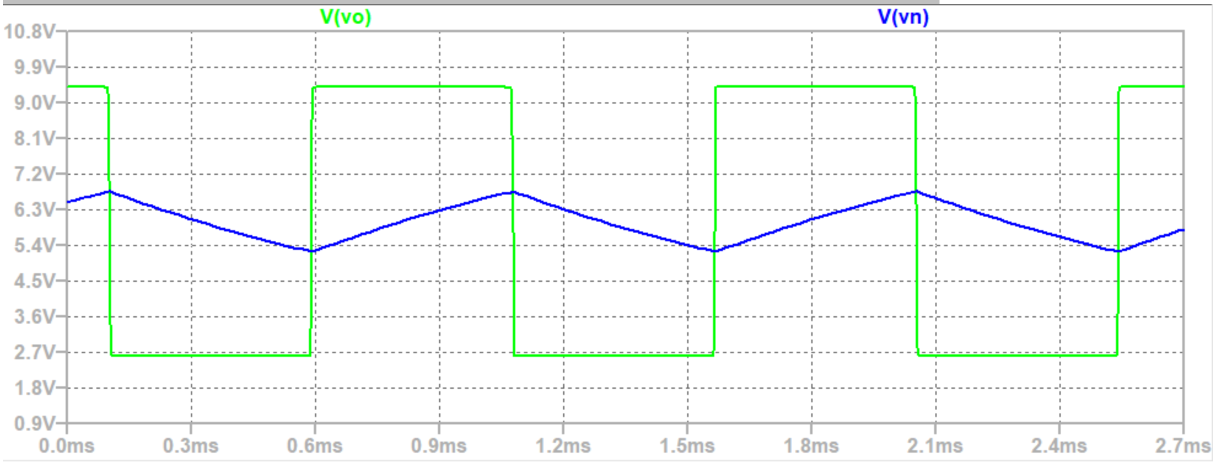
- Determine the frequency
- Determine the relationship among circuit parameters and frequency.
- Set reasonable value to resistor or capacitor
- According to relationship, find out the other(R1 or C1) one.
- According to our design, choose the rate of resistors that effects the gain. If we want stable oscillation, choose identical resistors. (R3, R4)

Q2. List the steps in designing a Schmitt trigger oscillator.

- Determine the frequency
- Determine the relationship among circuit parameters and frequency.
- Determine what value we want on at v_n.
- To obtain that value, calculate the rate of resistors (R2, R3) and give reasonable values.
- According to desired frequency, find out the capacitor and resistor (R1, C1).

Q3. Modify the circuit used in step-3 so that the opamp works with a single positive supply without significant change in the oscillation frequency.





Conclusion

>>In this laboratory session, we were exposed to feedback circuit mechanism. We learned 3 kind of feedback circuit which are voltage regulator, wien bridge oscillator and Schmitt trigger oscillator.

In the first part of this experiment, we observed the line regulation chance when we have different offset values at input. After that, to observe load regulation, we put a current source on the output node and see the difference on different offsets.

Secondly, we dealt with wien bridge oscillator which generates an oscillation according to its components. Thus, to observe asked oscillation, we found the resistance then potted the behavior of the circuit and lastly, we observed how the circuit responses different R2 values.

Lastly, we simulated Schmitt trigger oscillation. In this circuit we just observed the general behavior and compared it with our preliminary work which is quiet similar to the result.