UM-SJTU JI 2024FA VE215 Lab#7

<u>In this lab, we will learn to build an oscillator and evaluate its characteristics.</u>

- Please hand in your post-lab assignment before the due date. Please do your post-lab assignment following the requirements in each problem. Both hand-written and printed are accepted.
- You are encouraged to print this lab manual and then finish the post-lab questions on it. For pictures or diagrams, you may print it in a paper, cut it down and paste on this worksheet.
- Always attach the pictures or screenshots of your waveforms if using the oscilloscope.

Instruments

DC power supply (**Agilent E3631A** or **MOTECH LPS 305**)

Oscilloscope with coaxial cables

Multimeter

Breadboard and Wires

LM-741 Op Amp Chip

Capacitors of $\mathbf{0.033\mu F}$ and $\mathbf{0.1\mu F}$

200Ω

Resistors of ~~**50Ω** and **100Ω**~~

3 ~~Two~~ Rheostat of $\mathbf{0\Omega \sim 1000\Omega}$

LM-741 Structure

Fig. 1 shows the pin numbers of LM-741 Op Amp Chip.

Not using source generator in this lab ←

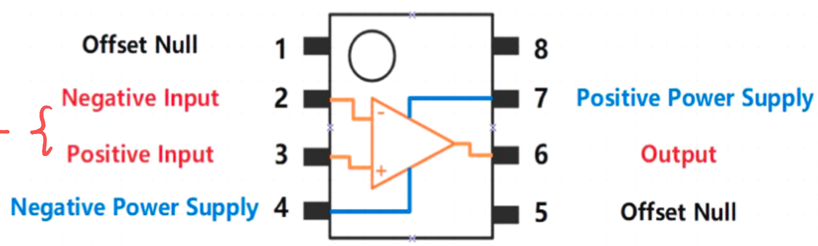


Fig. 1 Pin numbers for LM-741 Op Amp

The functions of each pin:

- **Pin 1 and Pin 5:** Offset Null for zero setting of LM-741. In this lab, we will not use these two pins and please leave them open.
- **Pin 2 and Pin 3:** Negative and Positive Input ports for signals, which are corresponding to "-" and "+" ports of ideal Op-amp models.
- **Pin 6:** Output port for signals, which is corresponding to the output port or "top end" of ideal Op-amp models.
- **Pin 4 and Pin 7:** Negative and Positive DC power supply ports. We mark these two pins as –Vcc (Pin 4) and +Vcc (Pin 7).
- **Pin 8:** It has no effect to the circuit and please leave it open in this experiment.

Problem #1 Wien-Bridge Oscillator

Wien-Bridge Oscillator

The Wien-Bridge Oscillator is widely used for generating sinusoids in the frequency range below 1MHz. As shown in Fig. 2, it is essentially an RC op amp circuit consisting of a noninverting amplifier with two feedback paths. The positive feedback path to the noninverting input port creates oscillations, while the negative feedback path to the inverting input port controls the gain. For detailed quantitative analysis, you may want to refer to **10.9.2 Oscillators** in the textbook, which will be used in the post-lab questions.

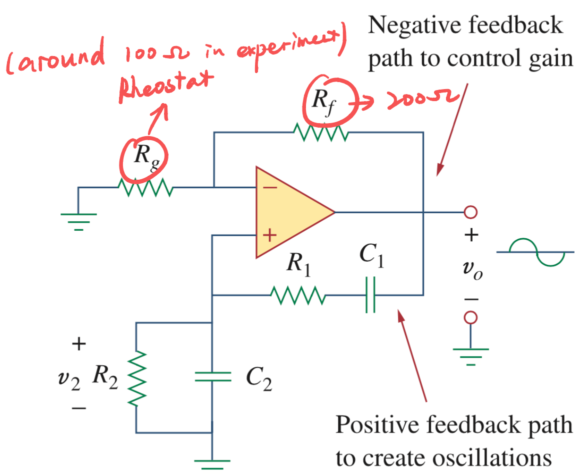


Fig. 2 Wien-Bridge Oscillator

Caution for the construction of Wien-Bridge Oscillator:

- We use the LM-741 Op Amp Chip to construct the oscillator in this lab. Please connect it in the circuit according to its pin numbers shown in Fig. 1 and the corresponding instructions. Do not mistake the negative "-" and positive "+" input ports. **In this lab, we set Vcc = 5V and -Vcc = -5V.**
- "V_o" in Fig. 2 is the output signal of the oscillator, where we connect the oscilloscope to get the output waveform.
- We use two Rheostats as R_1 and R_2 in this lab so that we can adjust their resistance easily.
- In order to satisfy the first Barkhausen criterion, in this lab, we **always connect R_g = ~~50Ω~~ 100Ω (rheostat) and R_f = ~~100Ω~~ 200Ω.**
- Please **choose the COM port on the power supply as the ground.**

Post-Lab Questions for (P1)

(1) Given $R_1 = R_2 = R$ and $C_1 = C_2 = C = 0.1\mu F$ in the Wein-Bridge Oscillator circuit above, calculate the value of R if the output frequency $f_0 = 5kHz$. You may refer to **10.9.2 Oscillators** in the textbook.

Note: Since this part hasn't been covered in the lectures, the answer is provided here.

According to formula (10.14) in the textbook (cf. page 440)

$$f_0 = \frac{1}{2\pi RC}$$

Plugging all given values into the formula, we reach

$$R = 318.3 [\Omega]$$

(2) Adjust two Rheostats and measure their resistances using a multimeter. Ensure their resistances are close to R calculated in (1). Record the value of R_1 and R_2 in the table below. Connect them in the Wein-Bridge Oscillator circuit as R_1 and R_2, respectively. Assume the capacitance of C_1 and C_2 are all $0.1\mu F$.

Hint: R_1 and R_2 should be close to $318\,\Omega$.

$R_1(\Omega)$	$318\,\Omega$
$R_2(\Omega)$	$419\,\Omega$
$C_1(\mu F)$	0.1
$C_2(\mu F)$	0.1

(3) Calculate the theoretical value of output frequency according to the measurement you get in (2). (Hint: you should not assume $R_1 = R_2 = R$ here; list the formula first and then calculate.)

According to formulae (10.12) and (10.13) in the textbook (cf. page 440), we have

$$f_o = \frac{\omega_o}{2\pi} = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$

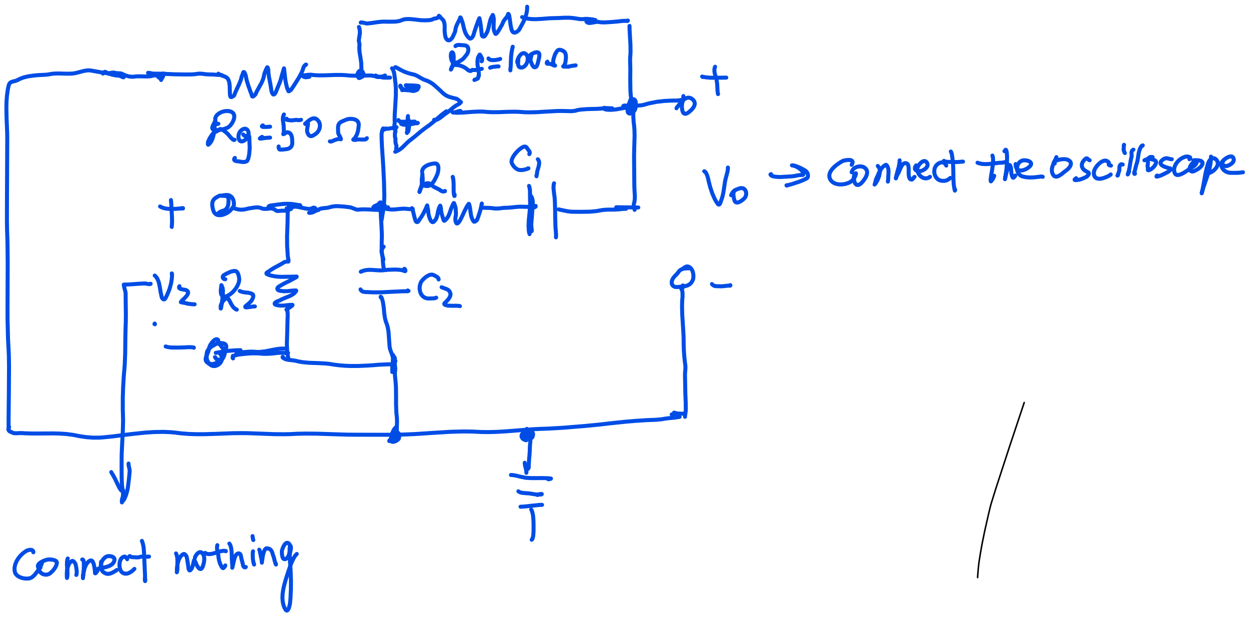
C_1 and C_2 are given: $0.1\,\mu F$

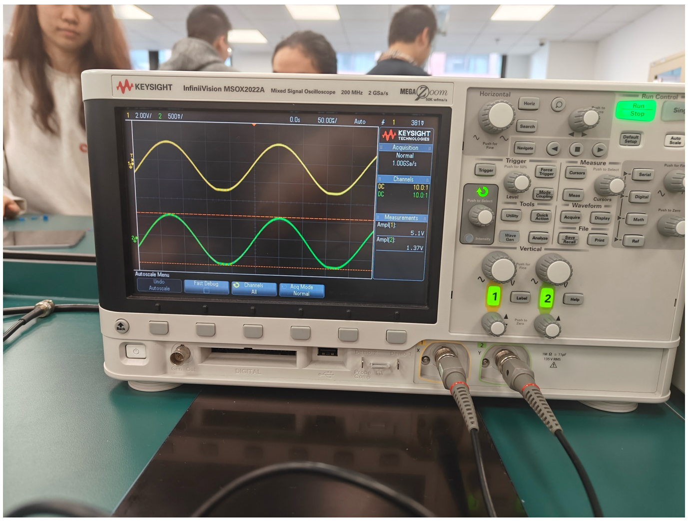
Plug in your R_1 and R_2 values and then calculate.

$$f_o = \frac{1}{2\pi\sqrt{318\times419\times(0.1\times10^{-6})^2}} = 4360.13\ Hz$$

(4) Construct the Wien-Bridge Oscillator on your breadboard and capture the output waveform using the oscilloscope. Attach your photo of the output waveform here and compare between the actual output frequency and the theoretical output frequency.

The schematic is attached here ;





The frequency is close to the theoretical value, verifying that our experiments are correct.

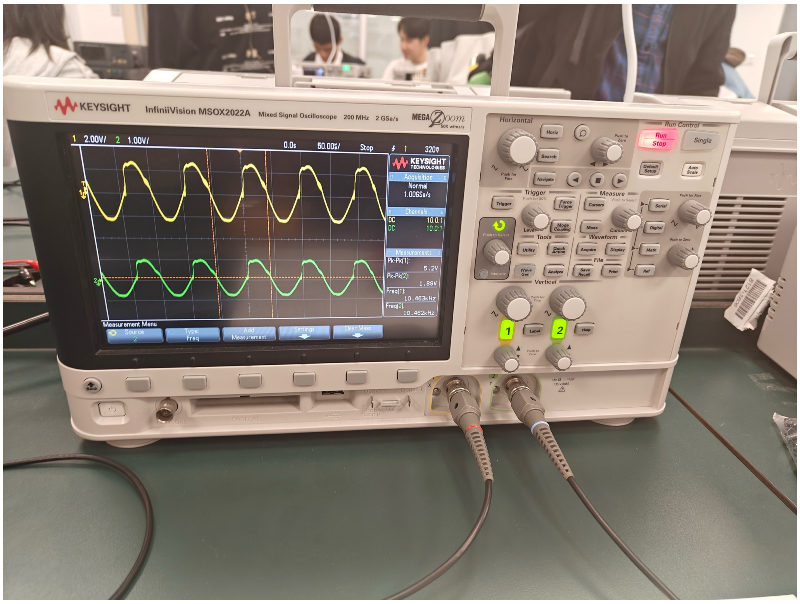
Problem #2 Adjust the Output Frequency

In this part, you are going to find the relationship between the capacitance, the resistance and the output frequency of the Wien-Bridge Oscillator quantitively. Please use the same circuit as you connect in Problem #1.

Post-Lab Questions for (P2)

(5) Get new capacitors that has capacitance $0.033\mu F$. Replace all capacitors in the circuit with those new capacitors. Attach your photo of the output waveform here; point out the changes quantitatively in comparison to the photo in (4); explain the reason.

Hint: refer to the formula in (3)!



The frequency is much higher, as C_1 and C_2 become smaller, according to formula 3, the frequency should be much higher.