SINUSOIDAL OSCILLATORS

I. OBJECTIVES

a) The adjustment of the value of the forward transmission *a* in order to fulfill the Barkhausen criterion in Wien bridge oscillators.
b) Understanding the amplitude stabilization mechanism of the oscillations, using amplitude stabilization circuits with diodes.

II. COMPONENTS AND INSTRUMENTATION

For the experiments, we use a breadboard and a 741 operational amplifier, two 1N4148 diodes, resistors and capacitors. In order to supply the experimental assembly, we use a dc voltage source. We will also need a sine wave signal generator. To visualize the ac voltages, we use a dual channel oscilloscope.

III. PREPARATIONS

P.1. The Wien bridge sinusoidal oscillator

The oscillator circuit is presented in Fig.2.

- Which is the frequency of the sine wave signal generated by the oscillator? What is the value of $|r|$ at the frequency of oscillation? What about the phase of *r*?
- What should be the value of the forward transmission (basic amplifier's gain) *a* in order to ensure the oscillation? What happens with the output signal v_O if *a* decreases under this value? What if *a* increases over this value?
- As you can see from the scheme in Fig. 2, the circuit doesn't have an input signal, only the power supply. Despite this, we will obtain a sine wave signal at the output of the circuit. Explain the mechanism by which the sine wave signal v_O at the output of the oscillator is generated.
- In order to obtain at the output of the oscillator a sine wave signal in the absence of an external input signal, is it sufficient to set a at the value specified in the Barkhausen criterion, a_0? How must the value *a* be with respect to a_0 after powering up the supply? Why? How does the waveform $v_O(t)$ look like if *a* takes this value different from a_0? How must the value *a*

be modified after the oscillations have appeared in order to obtain at the output a sine wave signal?

- The condition for oscillation start-up and then for maintaining the oscillation after start-up implies the achievement of a:
  - Constant and infinite gain in the circuit.
  - Constant and finite gain, given by the Barkhausen criterion.
  - Larger gain than the one from the Barkhausen criterion, at start-up (after power up), followed by the decrease of the gain until it reaches the value from the Barkhausen criterion.

P.2. The amplitude stabilization in Wien bridge oscillators

- On the oscillator with Wien Bridge from Fig.2, we will study now the amplitude stabilization mechanism.

In a sinusoidal oscillator with OpAmp there is no input signal, and the sinusoidal oscillation is generated when the circuit is powered up.

- For the circuit in Fig. 2, plot the waveform of the differential input signal $v_{OUT\ WIEN}(t)$ after the circuit's power up. Also plot the output signal, if the basic amplifier's gain is $a>a_0$, where a_0 is the basic amplifier's gain that fulfils the Barkhausen criterion.

P.2.1. Amplitude stabilization with diodes

- The oscillator circuit with OpAmp and Wien Bridge, for which the amplitude stabilization is done using two anti-parallel diodes, is presented in Fig. 3.
- In what state (on or off) are the diodes D_1 and D_2 during the transient regime, just after the power up? Compute the gain of the basic amplifier *a*, in this case. Plot $v_O(t)$ and $v_{OUT\ WIEN}(t)$ in this case.
- In permanent regime, when we already have at the output a sine wave signal $v_O(t)$, are D_1 and D_2 on? Which is the condition for D_1 and D_2 to be on? Compute the basic amplifier's gain *a* in this case.
- Why is it necessary the use of two anti-parallel diodes in the circuit from Fig. 3?
- What is the role of the resistor R_5 in parallel with D_1 and D_2 in the circuit?

IV. EXPLORATIONS AND RESULTS

1. The Wien Bridge sinusoidal oscillator

Explorations

- Build the circuit from Fig. 1. Supply the assembly with ±15V dc.
- Apply at the input of the Wien bridge a sine wave signal $v_I(t)$ from the signal generator, $v_I(t)=9\sin 2\pi\nu_0 t$ [V], where $\nu_0=1.6$KHz, frequency where the absolute value of the Wien Bridge transfer function is maximum (1/3).
- Using the oscilloscope visualize the signals $v_I(t)$ and $v_O(t)$ (between OUT and the ground).
- Using potentiometer P_{OT}, adjust the value of the forward transmission *a* until the amplitude of the signal $v_O(t)$, $\hat{V}_O$, equals the amplitude of the signal $v_I(t)$, $\hat{V}_I$.

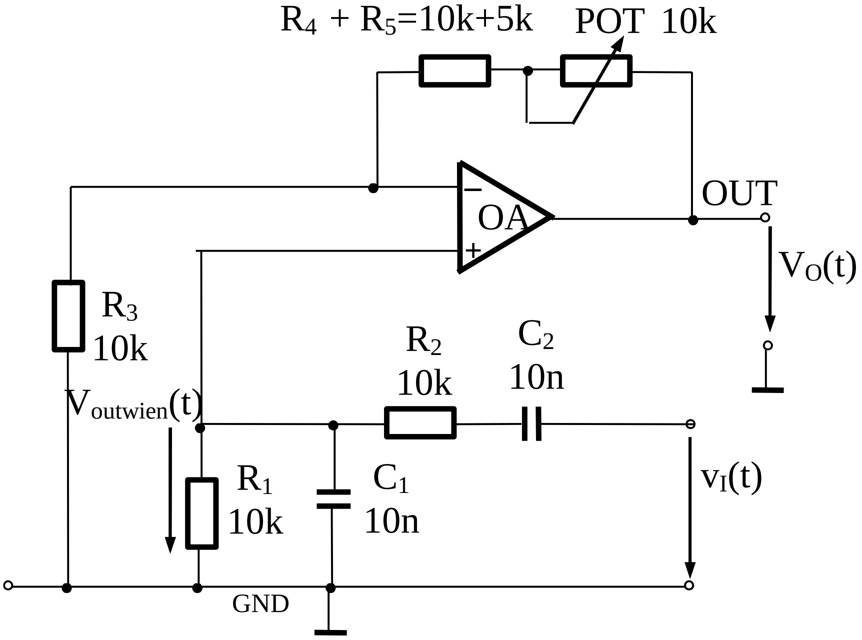

Fig. 1. OpAmp and Wien bridge circuit

- From this point on, no signal will be applied from the signal generator. The new circuit (Fig. 2) is obtained by connecting capacitor C_2 with the output of the OpAmp – the feedback loop is now closed.
- Modify the position of the cursor of POT in order to obtain at the output a sine wave signal $v_O(t)$, visualizing simultaneously $v_O(t)$ and $v_{OUT\,WIEN}(t)$ on the oscilloscope.
- Plot the signals $v_O(t)$ and $v_{OUT\,WIEN}(t)$. Measure and write down:
  - the amplitude and frequency of $v_O(t)$;
  - the amplitude and frequency of $v_{OUT\,WIEN}(t)$.

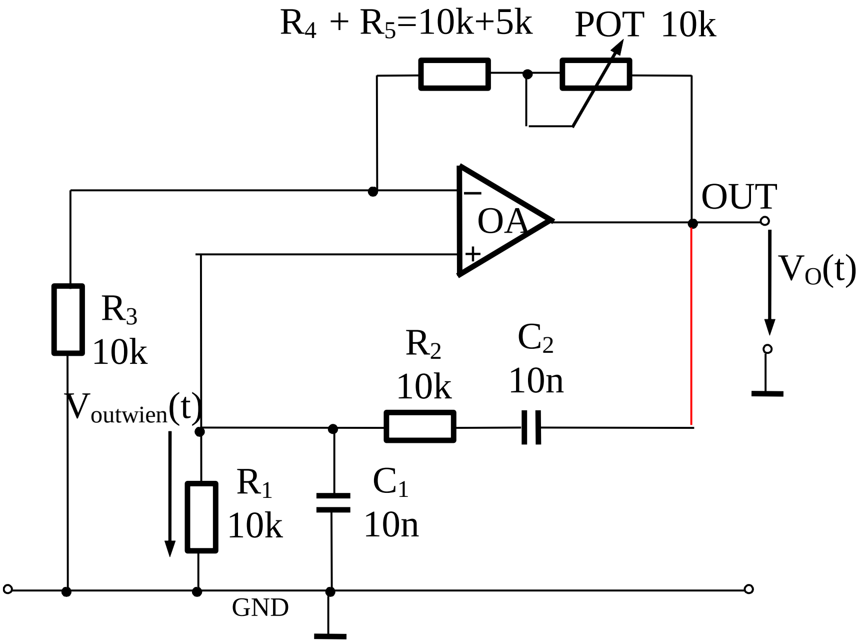

Fig. 2. Wien bridge oscillator

Results

- Determine *r* from the plots of $v_{OUT\,WIEN}(t)$ and $v_O(t)$.
- Determine the value of the phase shift between $v_{OUT\,WIEN}(t)$ and $v_O(t)$. Using your measurements, check the fulfillment of the Barkhausen criterion.

2. The amplitude stabilization in Wien Bridge oscillators

2.1. Amplitude stabilization with diodes

Explorations

- Use the circuit in Fig. 3 by adding two diodes.
- Visualize $v_O(t)$ on the oscilloscope. If needed, modify the cursor position of Pot until you obtain a sine wave on the output. Plot $v_O(t)$ and measure the amplitude and frequency of $v_O(t)$;
- Visualize and plot $v_{OUT\ WIEN}$ (t). Measure its amplitude and frequency.
- Now visualize $v_O(t)$ while you decrease the value of Pot, and notice the change in $v_O(t)$. Plot $v_O(t)$ for a randomly selected position of the cursor of POT, other than the one in the previous exploration step.
- Increase the value of POT and notice the change in $v_O(t)$. Redraw $v_O(t)$ for a randomly selected value of Pot, other than the ones in the previous exploration steps.
- Visualize the voltage across the group D_1, D_2, R5, and $-v_O(t)$ with the oscilloscope and plot them.

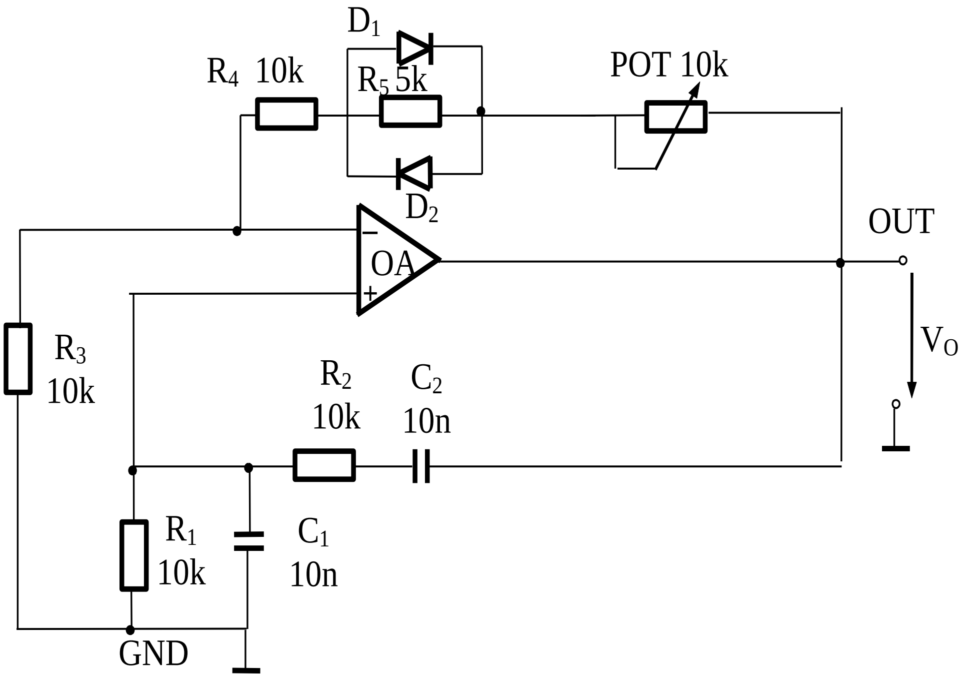

Fig. 3. Wien bridge oscillator: amplitude stabilization with diodes

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Results

- Compare the frequency ν_0 of the signal $v_O(t)$ in this Wien Bridge oscillator with amplitude stabilization with the frequency of $v_O(t)$ in the basic Wien bridge oscillator measured before.
- How can you modify $v_O(t)$ amplitude, $\hat{V}_O$ at the oscillator output? Give an approximate expression of $\hat{V}_O$.
- Is $v_O(t)$ a “clean” sine wave (without any distortions)? Why?
- Find the value of the phase shift between $v_{OUT\ WIEN}(t)$ and $v_O(t)$.
- How could you determine, using only the plots of $v_O(t)$ and $v_{OUT\ WIEN}(t)$, the value of the forward transmission *a* of the circuit? Compute it.
- What process takes place in the circuit if the value of Pot decreases and how does it influence the output $v_O(t)$? Answer the same question if the value of POT increases.

REFERENCES

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