Audio frequency oscillators

1. General overview

The audio frequency oscillator (Fig.1) uses as main element an operational amplifier (LM741, ßA741, uA741) in a non-inverting configuration. The positive feedback circuit is formed by a Wien bridge (R4,C1, R3, C2) which works as a voltage divider.

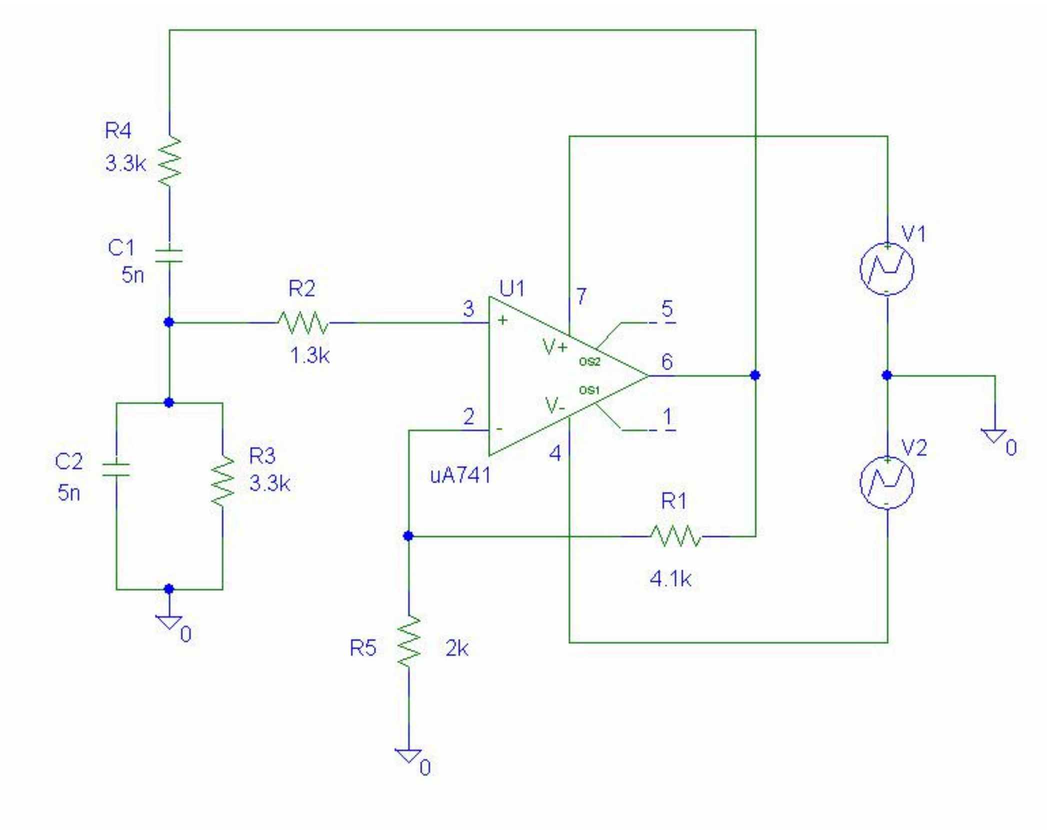

Fig.1 The Wien bridge oscillator with uA741 operational amplifier

The components used in the simulation are listed in table 1. The supply of the oscillator is provided by two voltage sources (V1, V2). The circuit has two feedback networks:
- a positive feedback circuit (the elements of the Wien bridge –C1, C2, R3, R4);
- a negative feedback circuit (R1, R5).

To obtain the same input impedance on the non-inverting input, a resistor ($R_2=R1||R_5$) is mounted in series with the input. The base amplifier is formed by R_2, U_1, R_5, R_1. The gain of the non-inverting amplifier is:

$$A_V = \frac{V_O}{V_i} = 1 + \frac{R_1}{R_5} \tag{1}$$

The operational amplifier has the following features:
- the open loop voltage gain a_V is very high (ranging from tens of thousands to hundreds of thousands);
-the differential input impedance Z_i is very high (mega ohms);
-the output impedance Z_O is very low (hundreds of ohms);
-the input currents are very low (pA);

-the mathematical relationship between the output voltage and the differential input voltage $u_{id} = v_{i+} - v_{i-}$ (the difference between the potentials applied between the non-inverting and inverting inputs) is:

$$v_O = a_V \cdot (v_{i+} - v_{i-}) \quad (2)$$

- a very low differential input voltage ($u_{id} = v_{i+} - v_{i-} \approx$ few mV), so:

$$v_{i+} = v_{i-} \quad (3)$$

Table 1

Name	**Component**	**Value**	**Library**
V_1 , V_2	VPWL	T1=0 ; V1=0; T2=5us; V2=11	Source.slb
Rx (x=1…n)	R	- only the numerical value for ohms range - for kilo ohms range a “k” should be placed after the numerical value (no space between characters)	Analog.slb
Px (x=1…n)	POT	5k The cursor position may be adjusted by changing the SET parameter between 0 and 1.00	Breakout.slb
Cx (x=1…n)	C	- For picofarads range: a p should be placed immediately after the numerical value - For nanofarads range: a n should be placed immediately after the numerical value - For microfarads range: a u should be placed immediately after the numerical value	Analog.slb
J1	J2N3819	JFET	Eval.slb
U1	uA741	Operational amplifier	Eval.slb
Ground	GND_ANALOG	0	Port.slb

The negative feedback amplifier used inside the oscillator is presented in Fig.2. Because the input current into the inverting input of LM741 is low (hundreds of nA), it can be written:

$$v_{i-} = \frac{R_2}{R_1 + R_2} \cdot v_O \quad (4)$$

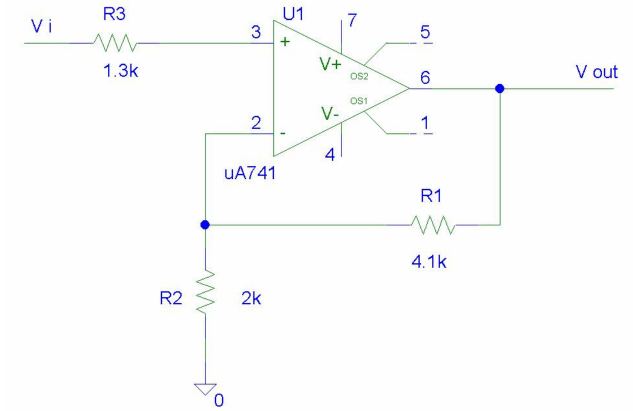

Fig.2: The negative feedback amplifier used in the oscillator circuit

Because $v_{i-}=v_{i+}-u_{id}$ we have:

$$A_V=\frac{v_O}{v_{i+}}=\frac{v_O}{v_{i-}+u_{id}}=\frac{1}{\frac{v_{i-}}{v_O}+\frac{u_{id}}{v_O}}=\frac{1}{\frac{R_2}{R_1+R_2}+\frac{1}{a_v}} \quad (5)$$

Whereas:

$$\frac{1}{a_v}\ll\frac{R_2}{R_1+R_2} \quad (6)$$

It can be concluded that:

$$A_V=1+\frac{R_1}{R_2} \quad (7)$$

The eq. (7) asserts that the closed loop gain is independent of the open loop voltage gain, the load, the frequency and the power supply values. But in real life, the closed loop gain decreases to frequency increase (by 20dB per octave), when the load value decreases too much or when the supply voltage is too low. The relationship is valid when the ratio R1/R2 is small enough (much smaller than the open loop gain, a_V).

2. Laboratory work

A. The Wien bridge

The Wien bridge is formed by the C_1, C_2 capacitors and the R_4, R_3 resistors. We will study the circuit behavior in the frequency domain. For this we will apply an ideal AC voltage source (V1) with an amplitude of 1V and we will measure the voltage across R3. Draw the circuit with the Schematics utility, selecting the simulation in the 1Hz-10MHz frequency range (Figure 4). After running the simulation (F11), the output voltage of the Wien network (V2) is measured: Trace-Add Trace: V2 (R3). The frequency where the voltage amplitude has its maximum value is the oscillation frequency.
The data from the simulation is noted in *Table 2*.

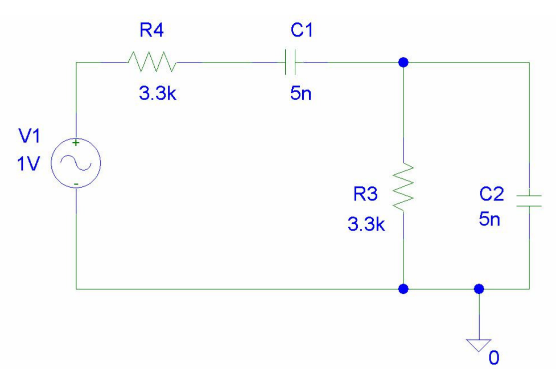

Fig.3 The schematic of the Wien circuit

Table 2

$V_1=1V$	f_o								
f/f_o	0.05	0.1	0.2	0.5	1	2	5	10	20
$V_2(R_3)$									
$F_W=V_2/V_1$									

Then, the real part and the imaginary part of the voltages on the R3 terminals are determined:

- R(V2(R3))
- Img(V2(R3)).

The simulations results are presented in Figs.4,5,6 and 7.

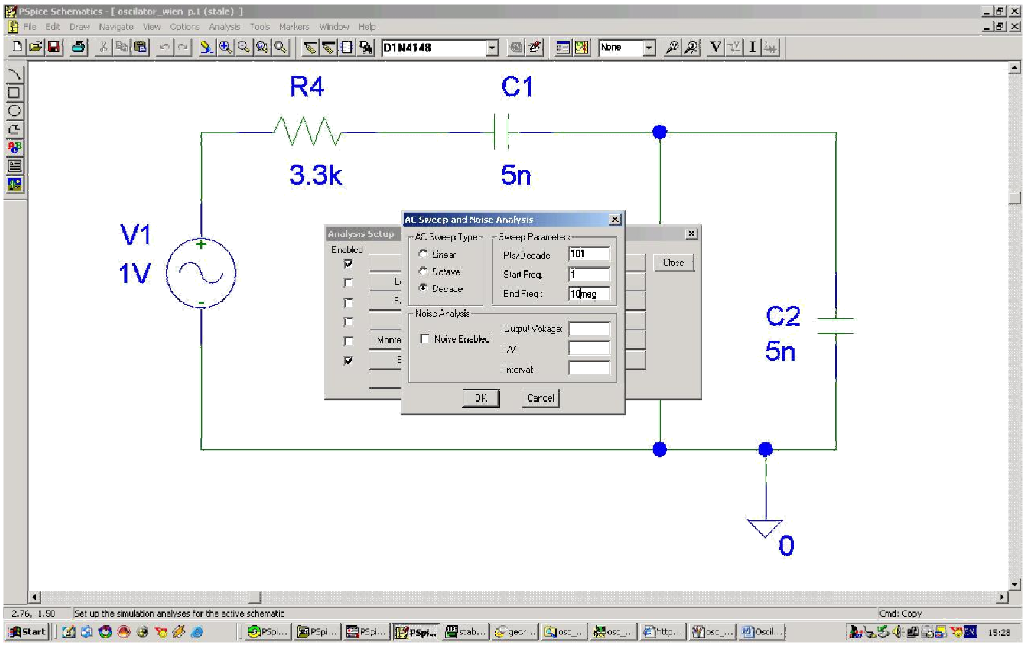

Fig.4: Choosing the simulation parameters of the Wien circuit in the frequency domain

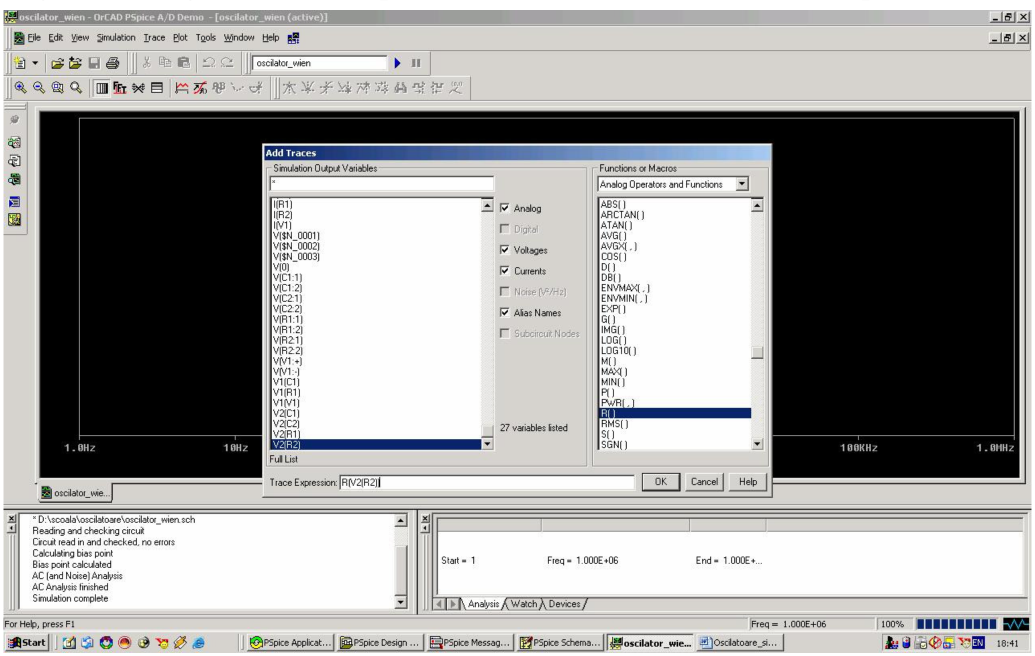

Fig.5: The representation of the real part of the voltage on R_2

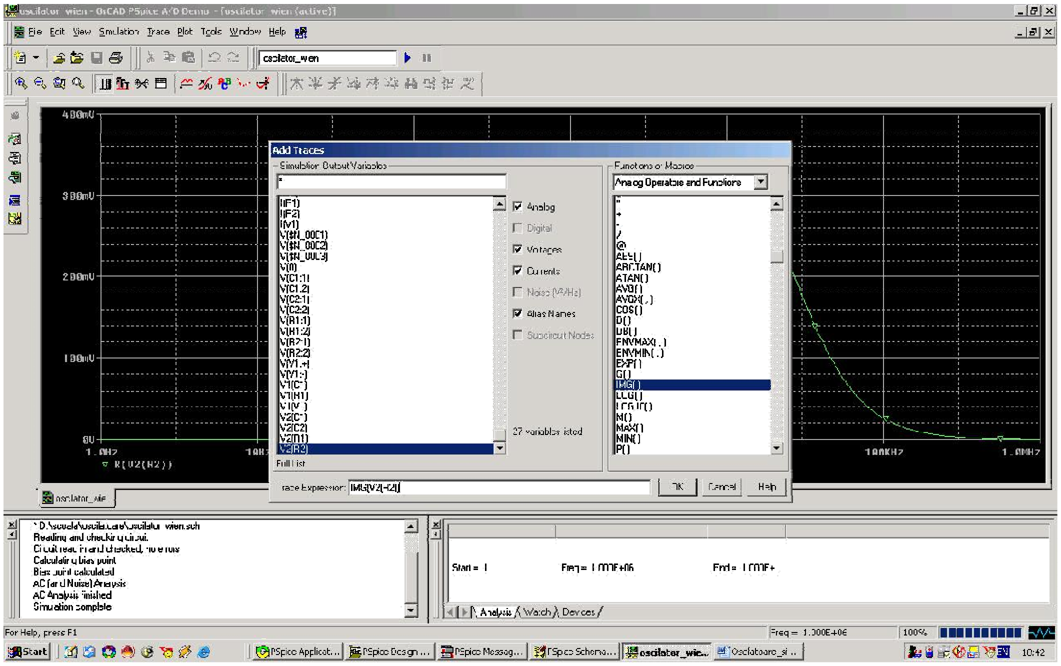

Fig.6. The representation of the imaginary part of the voltage on R_2

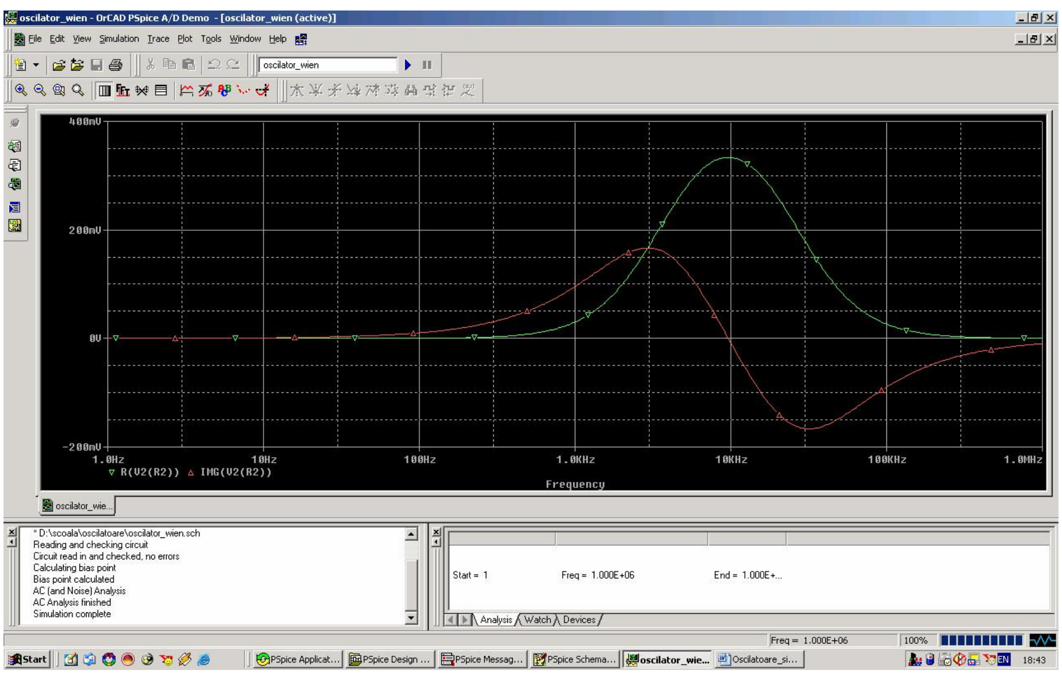

Fig.7: The voltage and the phase values on the R_2 resistor in the frequency domain

B. The Wien bridge oscillator

The load of the oscillator (Rl=1KΩ) is connected between the output of the operational amplifier (terminal 6) and the ground (Fig. 8).

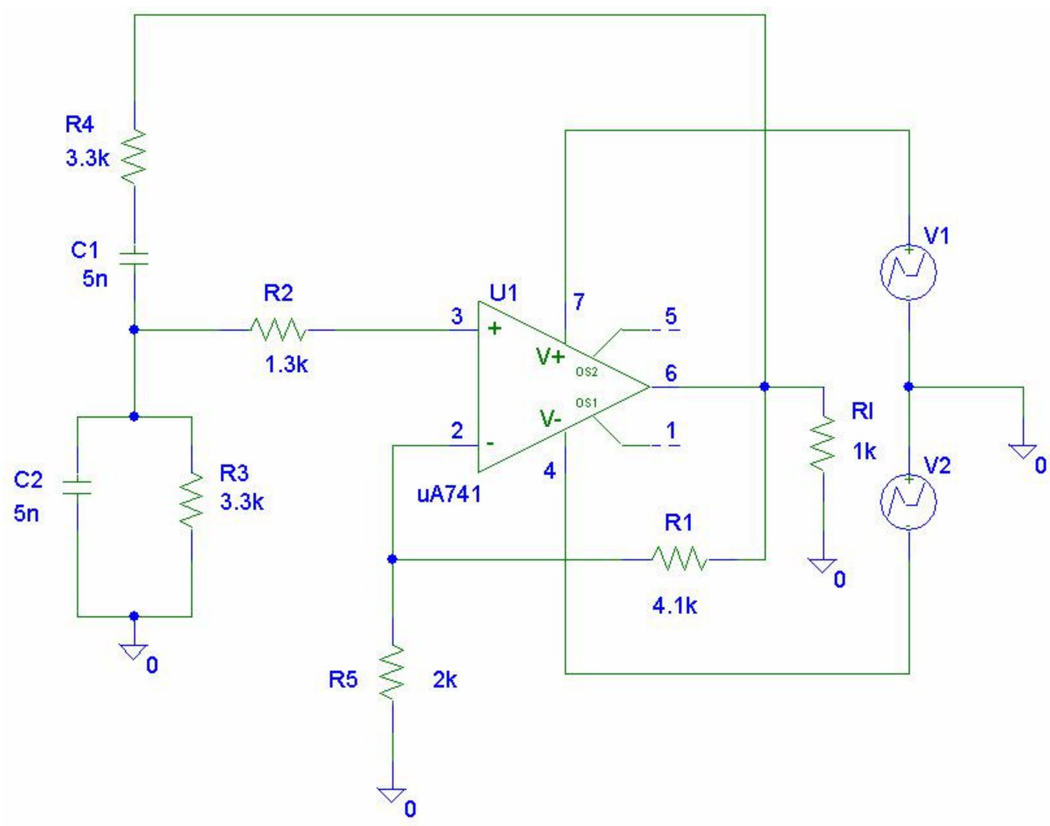

Fig.8. The schematic of the Wien bridge oscillator

The amplitudes of the output voltages will be measured for different values of the load resistor (Rl) and of the supply voltage (V1, V2). The data is stored in table 3.

Table 3

V_{cc} /R_l	f_{osc}=				
	R_l=330Ω	R_l=470Ω	R_l=1kΩ	R_l=2.4kΩ	R_l=8kΩ
+7/-7					
+11/-11					
+15/-15					

By slowly modifying the value of R_1=4,1KΩ , the shape of the output signal will be studied:

- R_1= 3.9KΩ ;
- R_1= 4.1KΩ ;
- R_1 =4.4KΩ .

What is happening in each situation?

C. The amplitude stabilization of the output signal of the Wien bridge oscillator by using a junction field effect transistor (JFET)

Instead the negative feedback circuit formed by R1 and R5 resistors (Fig.8), a circuit with a JFET (2N3819) is introduced (Fig.9) .After the schematic is drawn by using the Schematics Editor, a time domain simulation should be performed. The results containing the output amplitude values are shown in the table 4.

Table 4

V_{cc} /R_l	f_{osc}=				
	R_l=330Ω	R_l=470Ω	R_l=1kΩ	R_l=2.4kΩ	R_l=8kΩ
+7/-7					
+11/-11					
+15/-15					

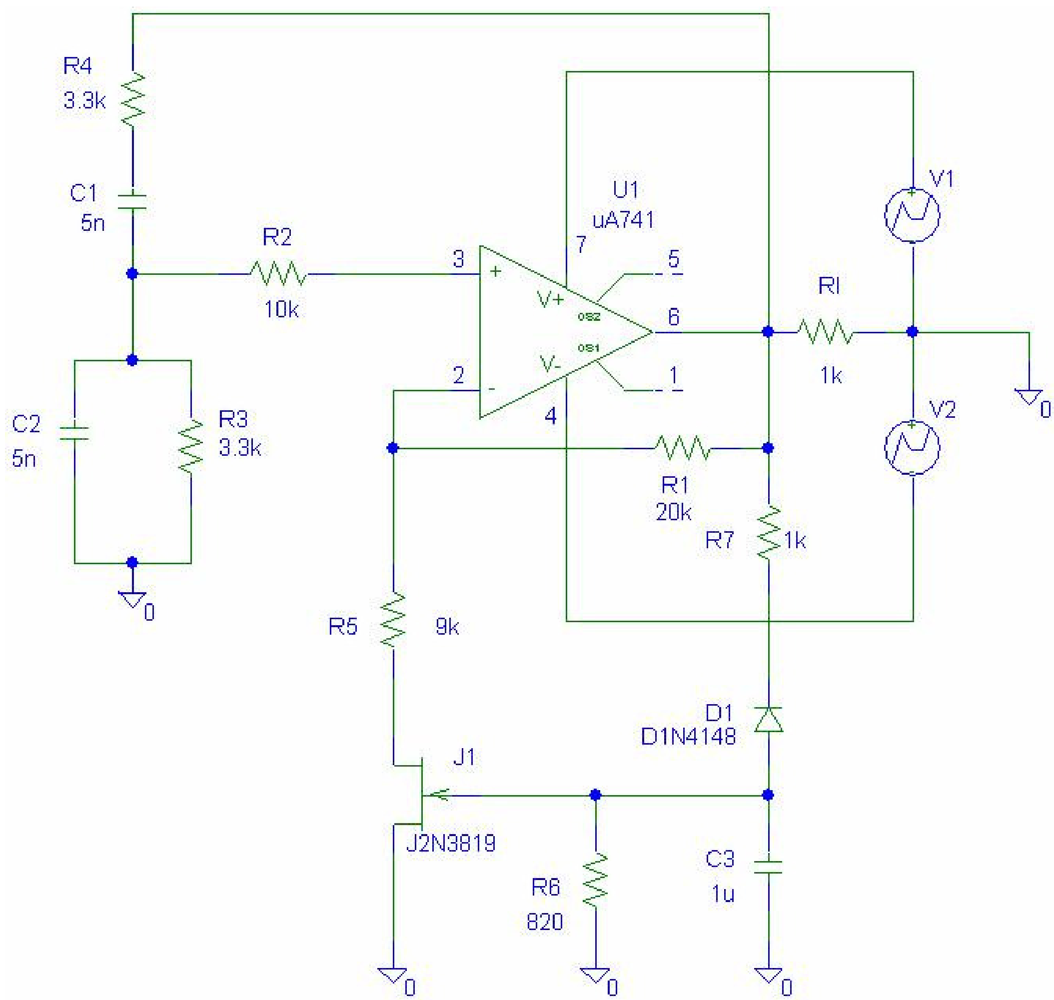

Fig.9. The Wien bridge oscillator with the limitation of the amplitude of the output signal by using a JFET