National Aviation University

Department of Electronics, Robotics, Monitoring and IoT Technologies

Course: “Analog and Digital Instrumentation”

Experiment 4

“Operational Amplifier Astable Multivibrator Circuits”

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Kyiv 2020

OBJECTIVES

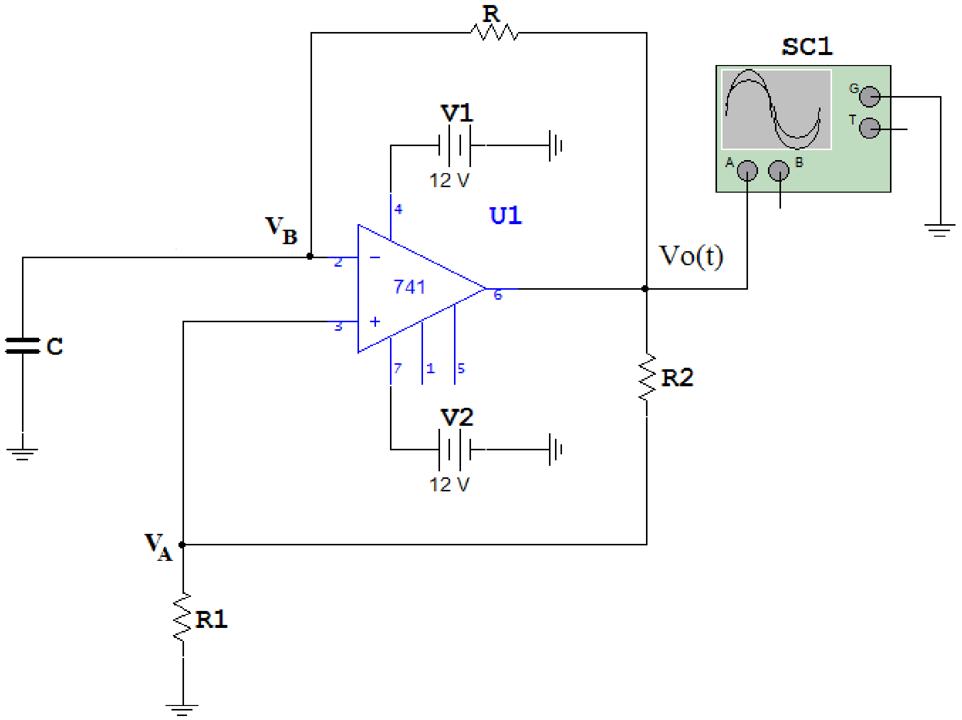
1. To study an OPA astable multivibrator circuit and to measure the parameters of the output waveform.
2. To simulate the astable multivibrator circuits using MULTISIM software.

EQUIPMENT REQUIRED:

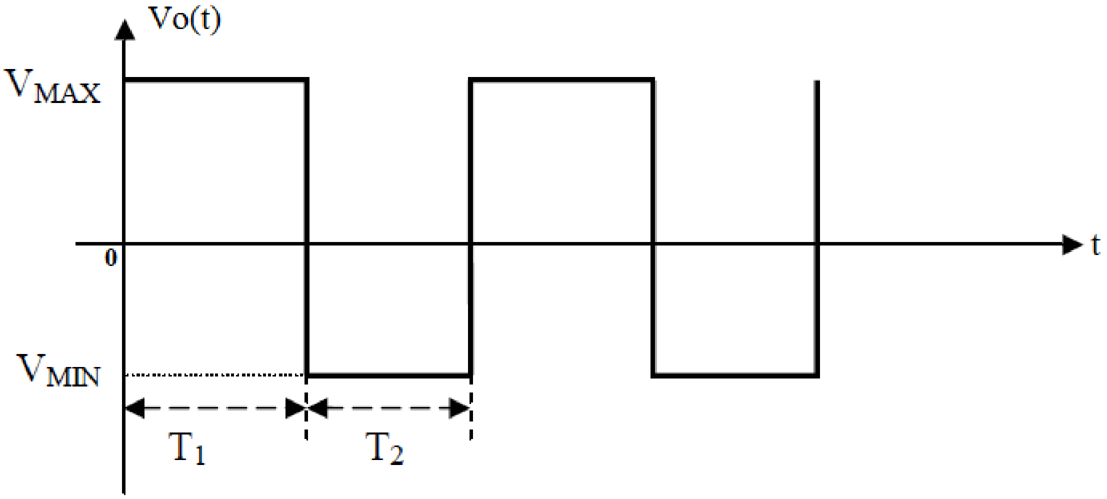
1. Digital multimeter Agilent 34401A
2. Solderless breadboard BB830T
3. Oscilloscope Agilent 54622D
4. Power Supply +12V, 0, -12V
6. Resistors: 3×10 kΩ, 3.9 kΩ, 1.8 kΩ, 1 kΩ
7. Capacitors: 3x330 nF, 1 µF, 10 µF
8. uA741 (УД708) op-amp
9. Diode 1N4007

Theory

With an astable multivibrator, the op amp operates only in the non-linear region. So its output has only two voltage levels, $V_{\min}$ and $V_{\max}$. The astable continually switches from one state to the other, staying in each state for a fixed length of time. The circuit of an astable multivibrator is shown in figure Fig. 1.



(a)



(b)

Fig. 1 The astable multivibrator circuit based on uA741 OPA (a), a symmetrical waveform generated at the OPA output (b)

Note that this circuit does not need an input signal. To find out the relations governing the operation of the astable multivibrator, we start with the usual hypothesis that the operational amplifier has an ideal behavior. Suppose the output is in the state where

$$V_o = V_{\max}$$

When V_o reaches this value the voltage V_{A1} of the non-inverting input is given by

$$V_{A1} = V_{\max} \times \frac{R_1}{R_1 + R_2}$$

The capacitor C starts charging through resistor R towards the value $V_{\max}$. This charging continues until the voltage V_B of the inverting input reaches the value V_{A1}. At this point, as the inverting input voltage is greater than the non-inverting input, the output switches low to $V_{\min}$. The voltage V_{A2} is now given by:

$$V_{A2} = V_{\min} \times \frac{R_1}{R_1 + R_2}$$

At this point, the capacitor C starts discharging through R towards the voltage $V_{\min}$ until it reaches the value V_{A2}. When it happens the output switches to $V_{\max}$ .The cycle then starts again.

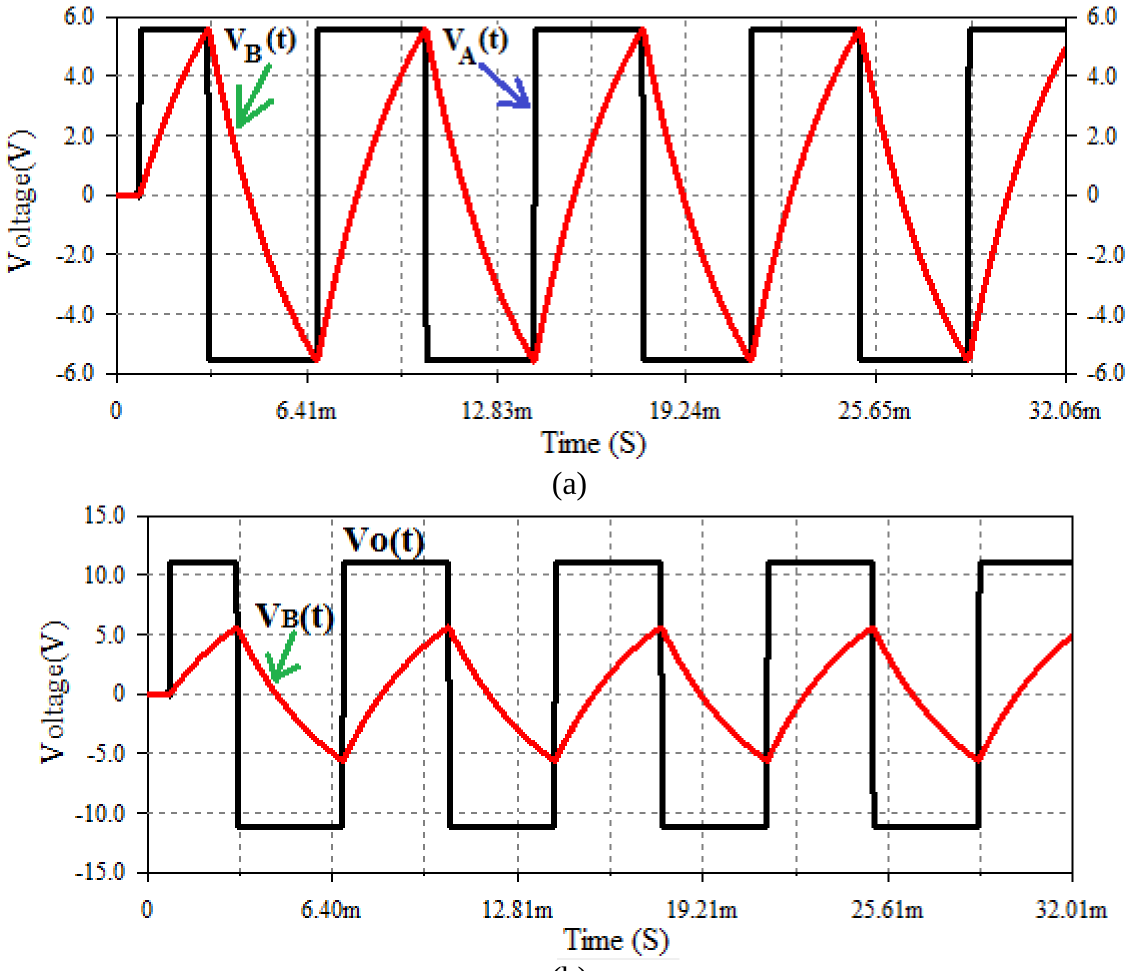
We have seen that the voltage across the capacitor C can vary from V_{A1} to V_{A2}, so in the period of time when the output is low, at $V_{\min}$, the voltage across the capacitor is given by:

$$V_B(t) = V_{\min} - \left(V_{\min} - V_{\max} \times \frac{R_1}{R_1 + R_2} \right) \times e^{\frac{-t}{RC}} \tag{1}$$

While in the period of time when the output is at $V_{\max}$, the capacitor voltage is:

$$V_B(t) = V_{\max} - \left(V_{\max} - V_{\min} \times \frac{R_1}{R_1 + R_2} \right) \times e^{\frac{-t}{RC}} \tag{2}$$

The voltage oscillograms at nodes A and B are shown in Fig. 2.



(a)

(b)

Fig. 2 Voltage oscillograms at the nodes A and B (a) and at the OPA output and node B (b)

As seen from Fig. 2, each time when voltage V_B becomes a little greater or a little smaller than voltage V_A the output voltage switches from $V_{\max}$ to $V_{\min}$ or from $V_{\min}$ to $V_{\max}$ respectively.

The period T_1 for which the output voltage is at $V_{\max}$ can be found by calculating the time when the capacitor voltage is equal to V_{A1}. So:

$$V_{\max} \times \frac{R_1}{R_1 + R_2} = \left(V_{\min} \times \frac{R_1}{R_1 + R_2} - V_{\max} \right) \times e^{-T1/RC} + V_{\max} \Rightarrow$$

$$\Rightarrow e^{-T_1/RC} = \frac{V_{\max} \times \left(\frac{-R_2}{R_1 + R_2} \right)}{V_{\min} \times \frac{R_1}{R_1 + R_2} - V_{\max}} \Rightarrow$$

$$T_1 = RC \times \ln\left(\frac{V_{\max} - V_{\min} \times \dfrac{R_1}{R_1 + R_2}}{V_{\max} \times \dfrac{R_2}{R_1 + R_2}} \right)$$

Similarly we can find the period T_2 for which the output node stays at $V_{\min}$:

$$T_2 = RC \times \ln\left(\frac{V_{\max} \times \dfrac{R_1}{R_1 + R_2} - V_{\min}}{V_{\max} \times \dfrac{R_1}{R_1 + R_2}} \right)$$

Supposing that $V_{\min} = -V_{\max}$ gives

$$T_1 = T_2 = RC \times \ln\left(\frac{1 + \dfrac{R_1}{R_1 + R_2}}{1 - \dfrac{R_1}{R_1 + R_2}} \right)$$

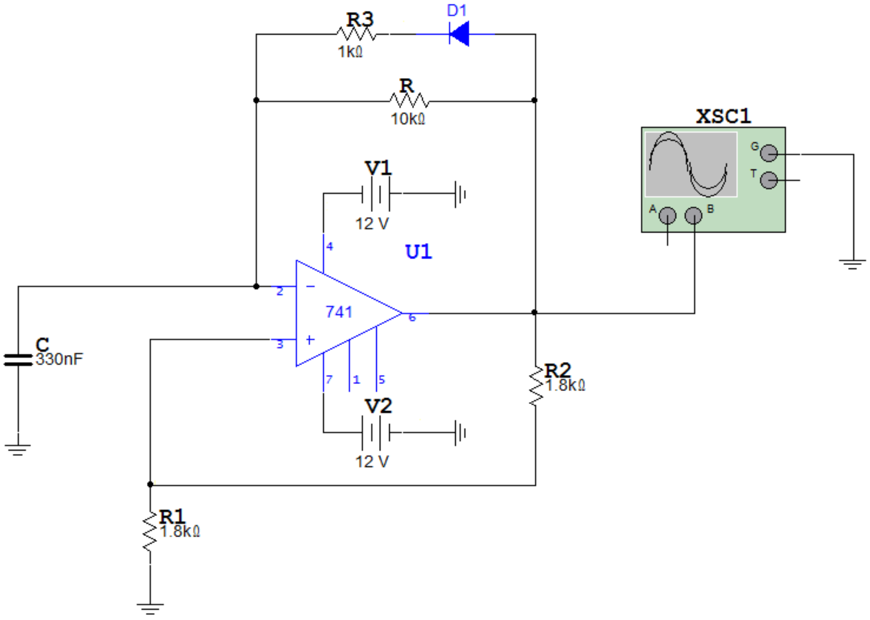
The total period T of the square-wave is given by the sum of T_1 and T_2 , that is

$$T = T_1 + T_2$$

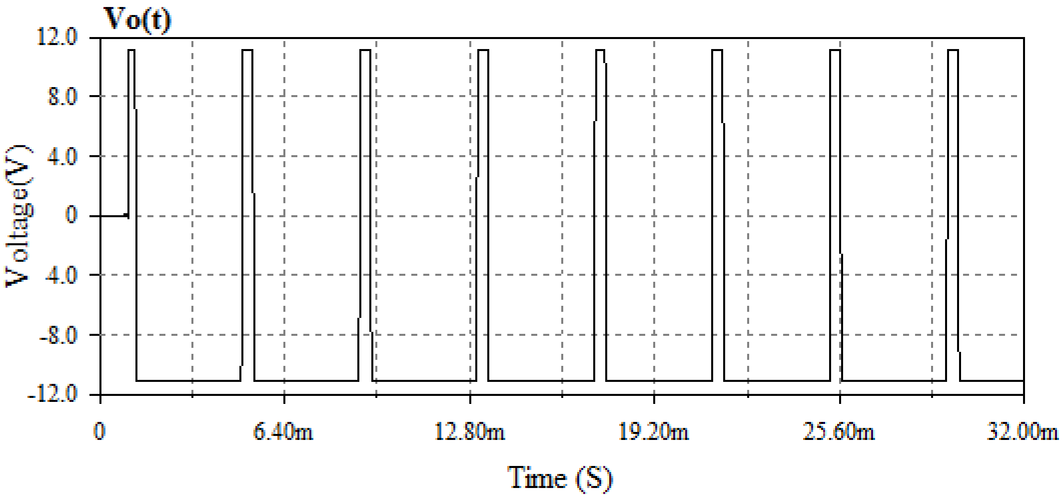
We can see that the square-wave period and so the frequency can be varied by varying the values of R_1, R_2, R and C. If $R_1 = R_2$ than

$$\boldsymbol{T = 2 \times RC \times \ln(1.5/0.5) \approx 2.2 \times RC \Longrightarrow f \approx 1/(2.2 \times RC)} \qquad (3)$$

To obtain an asymmetrical square-wave (duty cycle not 50%) we can make the capacitor charge and discharge through resistors of different values as shown in Fig. 3.



(a)



(b)

Fig. 3 Astable multivibrator circuit with asymmetrical square-wave voltage (a), a waveform generated at the OPA output node

PROCEDURE

Step 1. Assuming R_1=R_2=10 kΩ and C=0.33μF construct the astable multivibrator circuit as shown in Fig. 4 and measure the period and frequency of the generated square-wave signal when R is set to 1 kΩ, 1.8 kΩ, 3.9 kΩ, and 10 kΩ. Fill in Table 1 with the results of measurements.

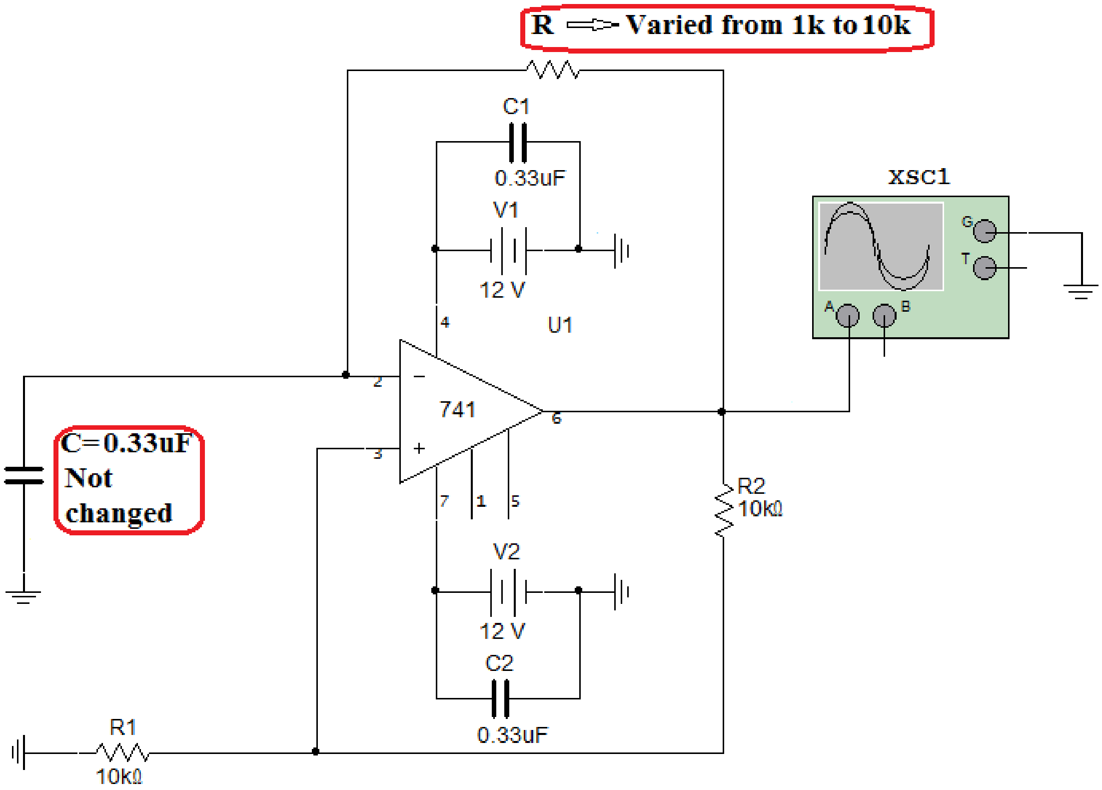


Fig. 3

Table 1

R	1kΩ	1.8kΩ	3.9kΩ	10kΩ
$T_{measured}$				
$f_{measured}$				
$T_{calculated}$				
$f_{calculated}$				

Step 2. Assuming R_1=R_2=10 kΩ and R=1 kΩ, construct the astable multivibrator circuit as shown in Fig. 5 and measure the period and frequency of the generated square-wave signal when *C* is set to 0.33µF, 1 µF and 10 µF. Fill in Table 2 with the results of measurements.

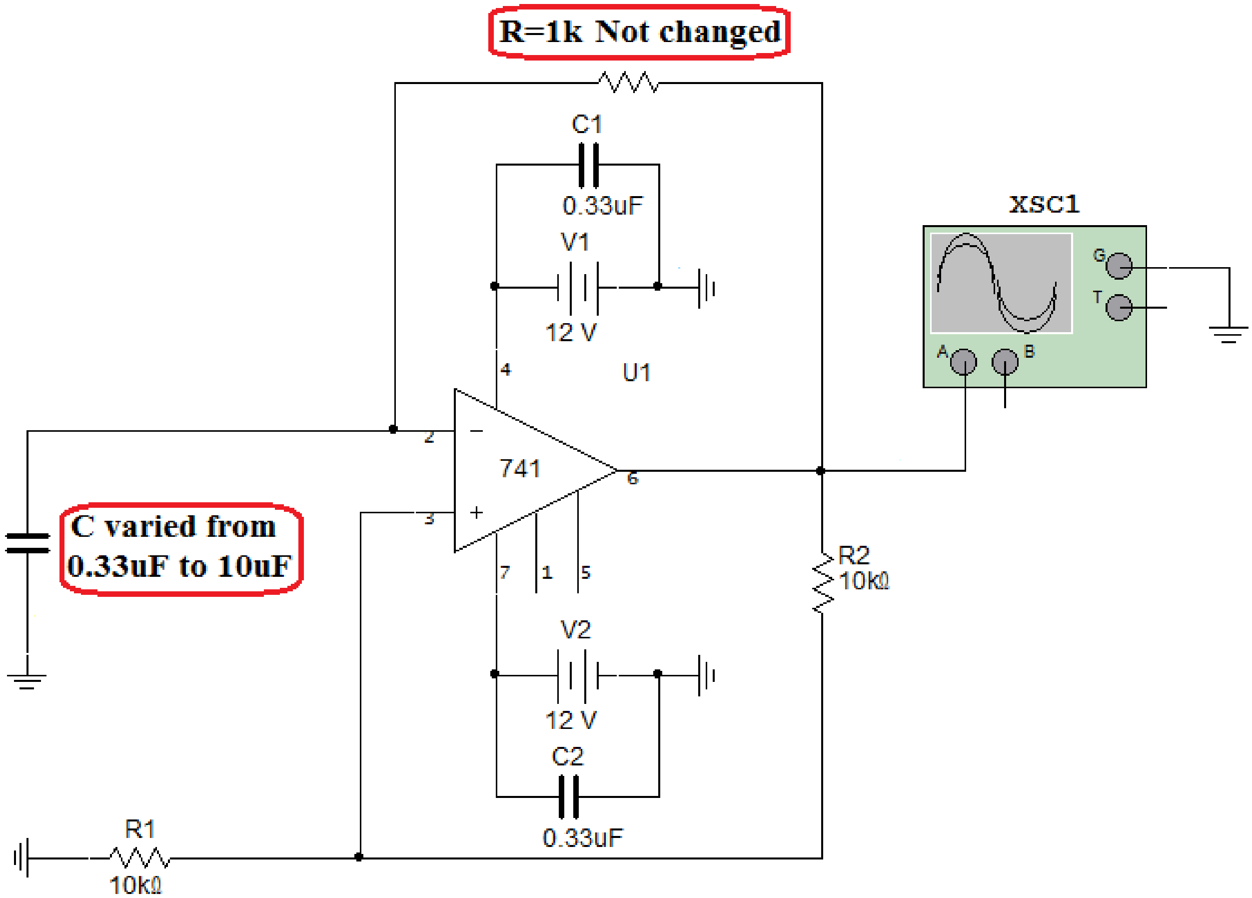
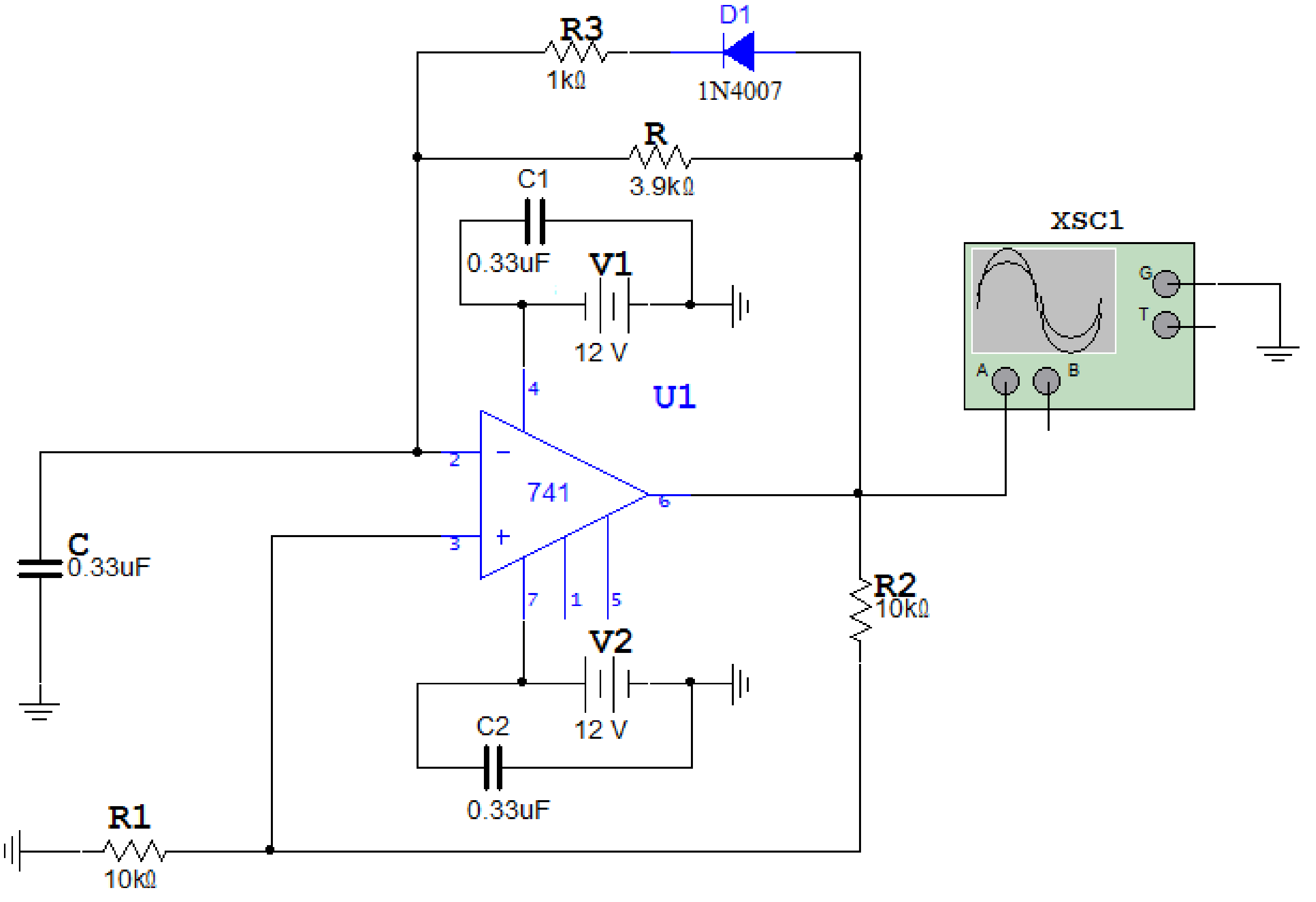


Fig. 5

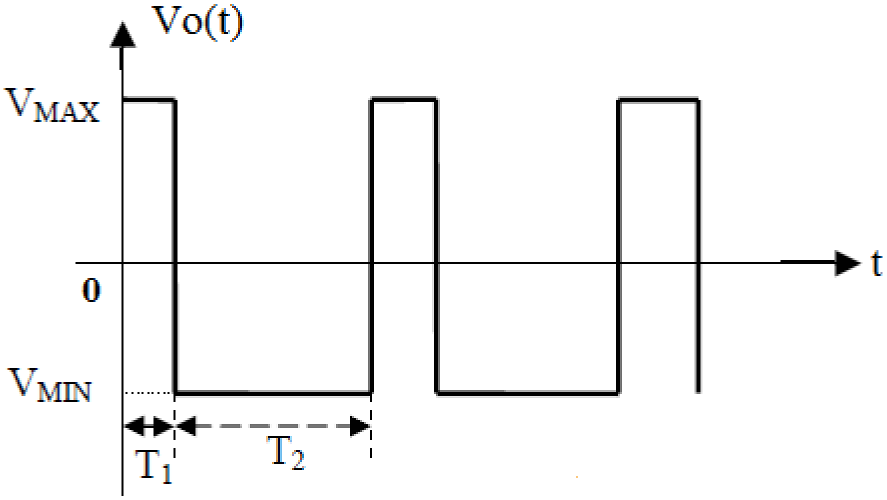
Table 2

C	0.33 µF	1 µF	10 µF
$T_{measured}$			
$f_{measured}$			
$T_{calculated}$			
$f_{calculated}$			

Step 3. Referring to the circuit of Fig. 6 (a) and (b), measure T_1, T_2 and $T=T_1+T_2$ and calculate the duty cycle.



(a)



(b)

Fig. 6

HOMEWORK

1. Referring to Step 1, calculate the period of the square-wave voltage for different values of resistance "**R**" using Equation (3) and fill in Table 1.
2. Referring to Step 2, calculate the period of the square-wave voltage for different values of capacitance "**C**" using Equation (3) and fill in Table 2.
3. Simulate circuits of Fig. 4, 5 and 6 using MULTISIM or PSPICE software for all values of variables given in Table1 1 and 2.

REFERENCE

1. A.S. Sedra and K.S. Smith, "Microelectronic circuits", 5th ed., New York: Oxford University Press, 2004, 1283 p.