CHEMISTRY 425 Dr. Petr Vanýsek, Instructor
Analytical Chemistry II

01
INTRODUCTION TO THE USES OF AN OSCILLOSCOPE AND
AMPLIFICATION FUNCTION OF AN OPERATIONAL AMPLIFIER

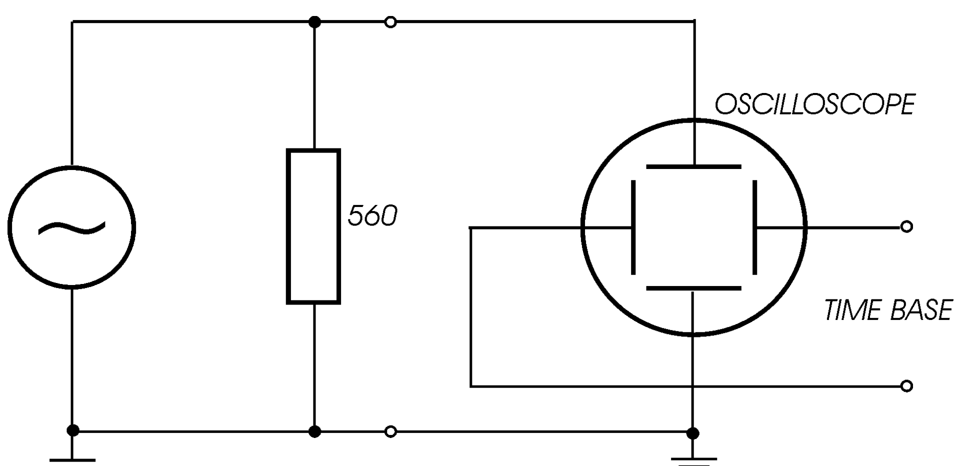
Purpose: To determine the waveform of two AC signals (sinusoidal and triangular) with an oscilloscope. The period, frequency, U_{pp}, U_p, U_{ave} and U_{rms} will also be identified. To become familiar with common operational amplifiers packages, and pin-out configuration. To setup an oscillator circuit using an operational amplifier.

Materials and equipment:

Oscilloscope
Function generator
Connectors
Resistors, two 270 Ω, 330 Ω, 560 Ω, 680 Ω, 2.2 kΩ
Capacitors, 4.7 nF, two 0.1 μF
Breadboard
Wires
Digital voltmeter (DVM)
Operational Amplifier, 8-lead mini-DIP (dual in-line package)
Power Supply, ±15 V

Part 1:

Set up the circuit shown below. Adjust the function generator as follows: function - sine wave; amplitude - approx. 25% of maximum.



Now connect the probe and the ground clip of the oscilloscope in such a way that potential across the resistor is measured. Obtain a stable trace on the oscilloscope. Adjust the horizontal (time base) and the vertical (input amplifier) settings of the oscilloscope to obtain an on-scale trace. Sketch the trace on graph paper (you can trace from the screen using a vellum paper). Be sure to indicate on the sketch the vertical potential scale and the horizontal time scale. From the sketch determine the following: U_{pp} (the peak-to-peak potential), U_p (the peak potential) and T (the period). From these values calculate U_{ave}, U_{rms} (compare with digital voltmeter) and determine f. U_{rms} is the root-mean-square value of an AC signal.

Repeat the above procedure with following change: Instead of sine wave a triangular wave should be used.

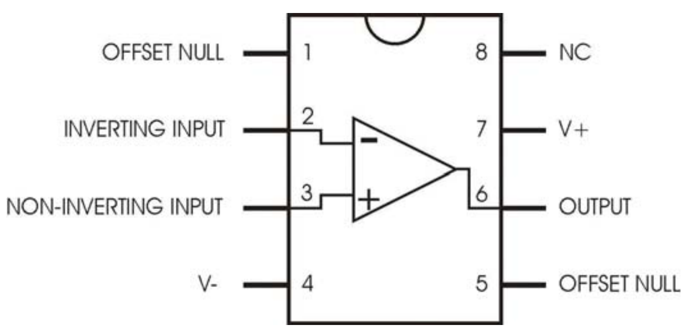
Do not forget to show the mathematical procedure you used to determine U_{ave} and U_{rms} in terms of U_p (i.e., derive U_{ave} and U_{rms}).

Questions:

1. How much power was dissipated in the 560 Ω resistor when:
   a) sine wave was applied?
   b) triangular wave was applied?
2. Show mathematically that for a triangular waveform:
   $U_{ave} = U_p/2$ and $U_{rms} = U_p/\sqrt{3}$

Part 2:

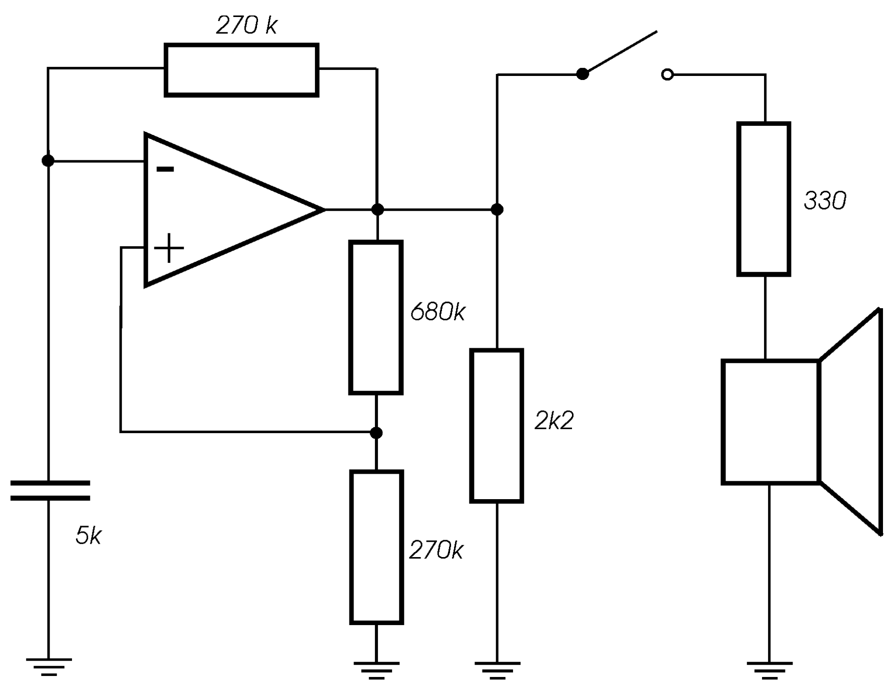
An operational amplifier is a very high gain amplifier, which commonly comes in three packages - the 8-lead mini-DIP (dual in-line package, used in our laboratory), standard 16-lead DIP (they are rare, since most of the leads are not needed) and the TO-99 metal round can. They have a more-or-less standardized pin-out arrangement. The 8-pin arrangement is shown below:



8-pin form used in the lab. (NC - not connected)

Note that pins 7 and 4 are used to connect power to the device. In schematics this connection is not usually shown, but you have to make the connection to a bipolar + and – 15 V source.

1. Set up the circuit as shown:



Carefully sketch the circuit diagram for the circuit and included the ±15 V source (not shown) in your notebook. In this diagram show the meaning of the pin numbers. In electrical diagrams a unit for capacitance is considered to be a picofarad. Thus 5k means 5000 pF = 5nF. Similarly, M1 means 0.1 x 10^6pF. Build the circuit on the breadboard.

Note: Cleaner (less noisy) signal can be often achieved by bypassing the supply pins of the operational amplifier to ground with 0.1 μF capacitors, i.e., connect a capacitor on the breadboard between each supply bus and the ground.

2. Test for open/circuits or short circuits within the operational amplifier. This can be done by measuring the current supplied to the operational amplifier by the positive power supply. It should be 1 mA < I_{cc+} < 5 mA.

3. Test for amplification. The amplification should be tested under "no load" and "heavily loaded" conditions. The output of the operational amplifier will depend upon the loading and the supply potential. The supply potential is defined as:

$U_{supply} = U_{cc+} - U_{cc-}$

The unloaded output potential should be at least 2/3 of the supply potential. The heavily loaded output potential should be at least 1/3 the supply potential. Observe the output potential using an oscilloscope. Carefully sketch the output waveform. Record the peak-to-peak output potential and the frequency. Now heavily load the output of the operational amplifier by connecting the speaker to the output. Observe the output and sketch the waveform.

4. Test the output potential null capability. Note: When U_{i+} and U_{i-} are both zero, one would expect the U_o would also be zero. Due to asymmetries within the device and to differences in the magnitude of the positive and negative supply potentials, this is not usually the case.

Question:

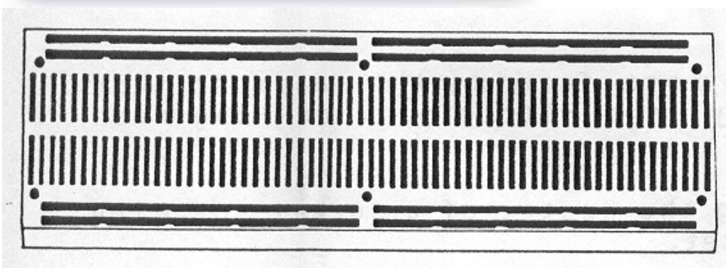
1. What effect would changing the 0.0047 μF capacitor to a smaller value have on the frequency of the output signal? Why?

Note on making prototypes using the breadboard (From Global Specialties material)

Before using your proto-board there are a few points of information worth noting.

BINDING POSTS
The binding posts facilitate power, and ground connections to and from external sources on the proto-board. These posts can accept banana plugs, pin jacks, and spade lugs. They can also accept alligator clips, solid and stranded wire.

BUSES
Horizontal and vertical buses are provided on each proto-board. Depending on the proto-board model, both the number of buses and the number of contacts on each bus will vary. Typical Tie-point matrix schemes are shown in Figure 3. If in doubt, a quick check with an ohmmeter will clarify the bus scheme for you.



Typical tie-point matrix

COMPONENT INSERTION
IC's are mounted by lining up the leads with the contact holes on each side of the center of a socket, then pressing gently at the center of the IC until it clicks into position..
Withdrawing the IC can be tricky. You should use a thin-bladed screwdriver or similar object. Slide the end of the screwdriver blade under one end of the IC and lift gently. Repeat on the other side. Then remove the IC from the socket. By following this procedure, you will not bend the leads of the IC.
Pre-forming the leads so they resemble a DIP pack can accommodate TO-5 case IC's. This is easily done with a pair of long nose pliers.
Transistors can be inserted bridging the center of a socket, or with leads-in-line on one side -of the socket. .
Diodes, resistors, and capacitors may be inserted in the same manner as jumper wires.
Special components such as switches, potentiometers, etc. can be used with sockets by simply soldering short lengths of #20-24 gauge solid wire to their terminals and then inserting them into a socket or bus strip.

JUMPER WIRE
The jumper wires should be #20-24 gauge solid hook-up wires. We suggest that the insulation on the

jumper wires be stripped 1/4" to 3/16" from each end to insure easy insertion into the sockets and bus strips.
After you have built up a few circuits. You will have a good collection of pre-stripped jumper wires. Save them. By reusing these wires, you can save even more time and effort in assembling future circuits.
For your convenience, Global Specialties provides a kit of 350 pre-cut, pre-stripped, #22 gauge wires in 13 different lengths. The manufacturer of the board also supplies precut wires in a WK-1 Wire kit.

RECOMMENDED PROCEDURES FOR BREADBOARDING
The following steps and procedures should be followed when breadboarding circuits. However, you must make a judgment call between how much time you spend on neatness, and how much time you spend getting the circuit functioning correctly. Recommendation: lay out components neatly, then connect with jumper wires as quickly as possible. When circuit works, go back and route jumper wires, shortening and rerouting where necessary, using the balance of your time to improve neatness.

1. Remove any components or wires left from previous projects.

2. Place components on the breadboard in a visually pleasing manner, as closely as possible to the layout on the schematic. This makes troubleshooting easier for you and for the judges.

3. Trim leads of components so that components rest on or near the surface of the board. Use jumpers to connect components to other components rather than using leaded components (resistor, capacitors, diodes, transistors) as jumpers. This eliminates possible short circuits between bare leads.

4. Leaded components (resistor, capacitors, diodes) should be mounted either vertically or horizontally (not diagonally), and oriented in a consistent direction (i.e., with the first band of the color code, anode, or cathode at the top or on the left). Transistors should each be mounted into three consecutive rows (or every other row) with the collector at the top, base in the center, and emitter at the bottom.

5. Component leads should be bent in a rounded 90% turn (see comment on bending jumper leads) and be inserted straight down into the board, not angled out or in.

6. IC's should be aligned in a row where possible, with pin one on each chip at the upper left position.

7. Strip approximately 1/4" of insulation from jumper wires (never more than 5/16" nor less than 3/16") so as to allow as little bare wire to show between the insulation of the wire and the breadboard socket as possible, in no case should more than 1/8" of bare wire be exposed out of the breadboard socket. If prestripped wires are used, use the shortest wire which will make the connection. Neatly bend the excess out of the way or cut the wire and strip to an exact fit.

8. Jumper wires should be placed as flat and as close to the breadboard as possible, running parallel to each other and not crossing any more than necessary.

9. Jumper wires should be run neatly beside and between components, as straight and as short as possible. Do not use excessively long wires when short ones will do. Excessive wire causes electrical problems and makes troubleshooting more difficult.

10. Bends in jumper wires should be slightly rounded, to avoid stressing wire or insulation, but as tight as possible. Technically, minimum bend radius should be 1.5 times the wire diameter (National Electrical Code, 1996, National Fire Protection Association).

11. NEVER cross components with jumper wires. Routing wires around components simplifies measuring voltages at component leads and removing components for testing or replacement.