Analog Electronics II
Laboratory
Exercise 4
Operational Amplifier 2

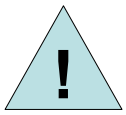
Aim of the exercise

The aim of this laboratory exercise is to become familiar with the operation of the operational amplifier with opened loop of the negative feedback and with the positive feedback. The operational amplifier can be used as a comparator in such circuits. The following circuits will be discussed in this laboratory exercise: zero-cross detector, regenerating and nonregenerating amplitude discriminator.

Equipment

- Oscilloscope;
- Measurement set: function generator, digital multimeter, frequency meter, power supply;
- Soldering toolbox;
- Measurement toolbox;
- Soldering station;
- Prototype board.

Before the exercise please check the contents of the toolbox with the checklist on the box. If anything is missing report it to your teacher.



Warning! Soldering iron is heated to the temperature above 300ºC. Please use it carefully in order to prevent getting burn.

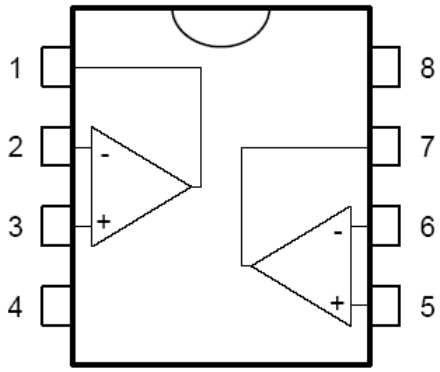


Fig. 1 TL072 operational amplifier pinning. Top view. Power supply $4V_{CC-}$, 8 V_{CC+}

Tasks

1. Comparator

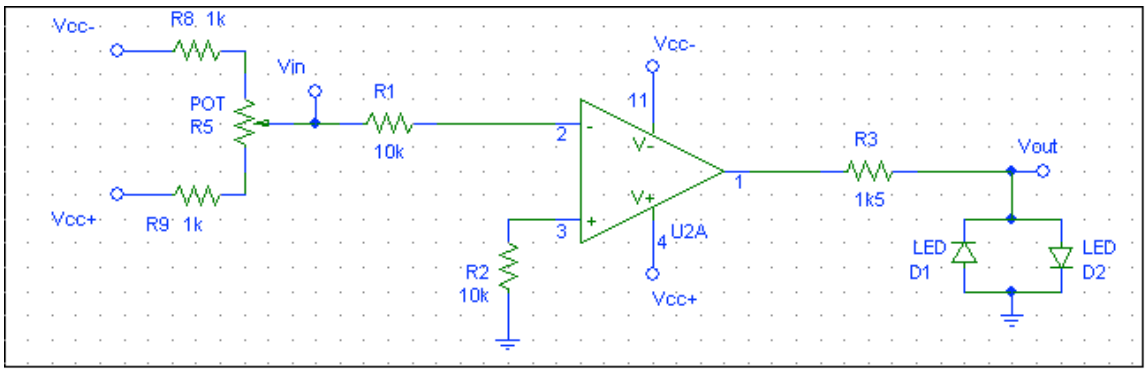


Fig. 2 Comparator

1. Solder circuit illustrated in fig. 2 using one of the amplifiers from TL072. Potentiometer *R5* = 10kΩ. **Warning! The pinning in fig. 2 is incorrect. Please use fig. 1.**
2. Connect the universal counter to measure the V_{in} voltage.
3. Supply the circuit from the function generator V_{CC+} = 15V, V_{CC-} = -15V. To do this connect the (+) terminal of the nonregulated generator 15V with (-) terminal of the regulated generator. Set 15V on the regulated generator. The (+) terminal of the regulated generator becomes the V_{CC+} source, the (-) terminal is the V_{CC-} source. Connect the ground to the connected terminals (nonregulated (+) and regulated (-)).
4. Find the input voltage value for which the diodes are switching. Do this by changing the value on the *R5* potentiometer. Write the proper V_{in} values.

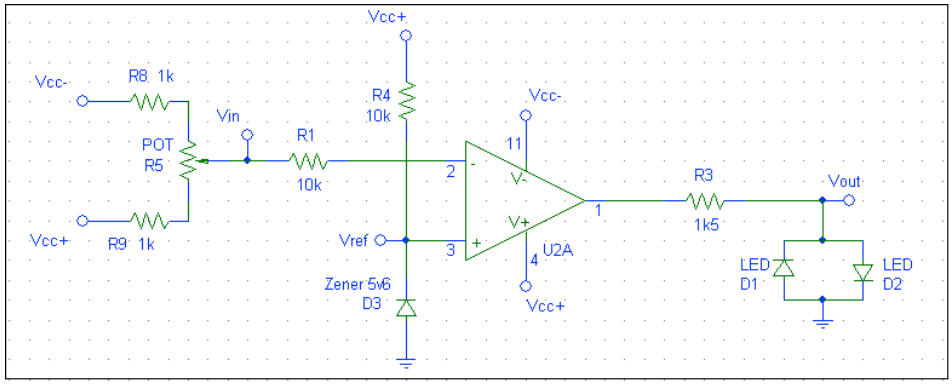


Fig. 3 Comparator

5. Solder circuit illustrated in fig. 3. Connect the universal counters so that they show V_{in} and V_{ref} voltages.
6. Changing the input voltage value (V_{in}) using *R5* potentiometer find the voltage values for which the diodes switch (when increasing and decreasing voltage). Write observed values of V_{in} and V_{ref}.

2. Zero cross detector

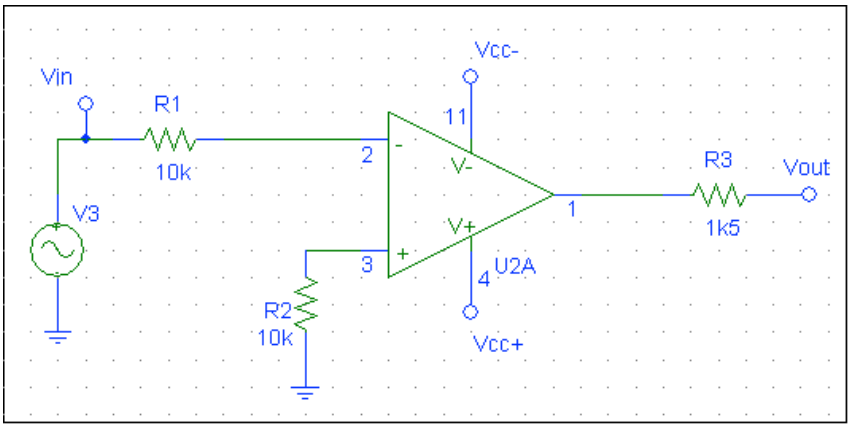


Fig. 4 Zero cross detector

1. Solder circuit illustrated in fig. 4. Connect the oscilloscope and observe V_{in} on channel B and V_{out} on channel A.
2. Set the oscilloscope to dual channel mode. Turn the knobs fully clockwise.
3. Set the signal from generator to be a sine signal with frequency f = 1kHz and amplitude V_{in} = 5V.
4. Draw voltages V_{in} and V_{out} observed on the oscilloscope.
5. Set the oscilloscope to XY mode. Draw thw output characteristics of the circuit $V_{out} = f(V_{in})$.

3. Non-regenerative amplitude discriminator

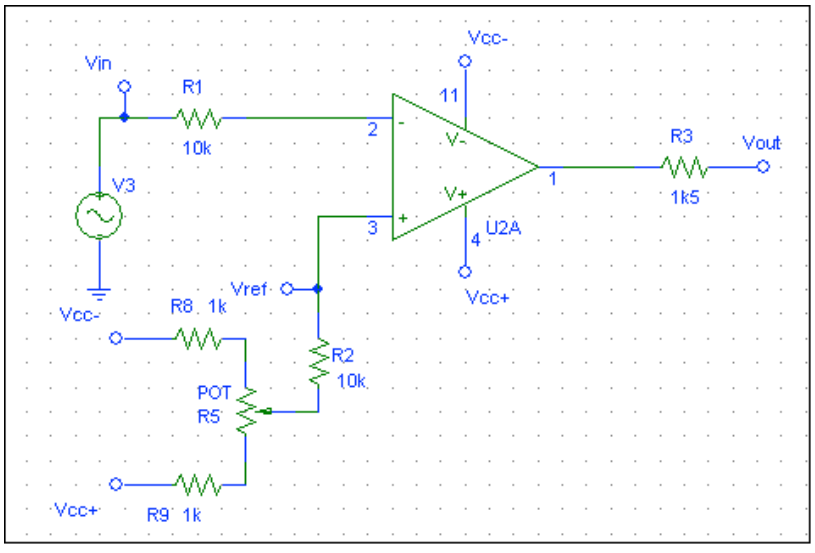


Fig. 5 Nonregenerative amplitude discriminator

1. Solder circuit illustrated in fig. 5.
2. Connect the oscilloscope and observe V_{in} on channel B and V_{out} on channel A.
3. Connect the universal counter to measure voltage V_{ref}.
4. Set the oscilloscope to dual channel mode. Turn the knobs fully clockwise.
5. Set the signal from generator to be a sine signal with frequency f = 1kHz and amplitude V_{in} = 5V.

6. Observe the output signal V_{out} while changing the resistance on potentiometer *R5*.
7. Draw the voltages V_{in} and V_{out} observed on the oscilloscope for three different values of V_{ref}.
8. Set the oscilloscope to the XY mode. Draw the output characteristics of the circuit $V_{out} = f(V_{in})$ observed on the oscilloscope for 3 different settings of *R5* potentiometer.

4. Regenerating amplitude discriminator (Schmitt trigger)

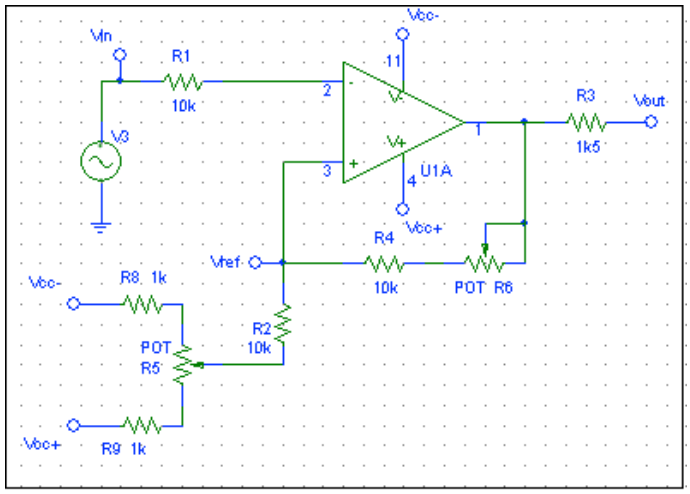


Fig. 6 Schmitt trigger

1. Solder circuit illustrated in fig. 6. Potentiometer *R6* = 100kΩ.
2. Connect the oscilloscope and observe V_{in} on channel B and V_{out} on channel A.
3. Connect the universal counter to measure voltage V_{ref}.
4. Set the oscilloscope to dual channel mode. Turn the knobs fully clockwise.
5. Observe the output signal V_{out} while changing the resistance on potentiometer R5.
6. Draw the voltages V_{in} and V_{out} observed on the oscilloscope for three different values of V_{ref}.
7. Set the potentiometer *R6* to have minimum resistance.
8. Set the level of V_{in} to obtain the rectangular signal at the output of the circuit. Draw the voltages V_{in} and V_{out} observed on the oscilloscope.
9. Set the oscilloscope to the XY mode. Draw the output characteristics of the circuit $V_{out} = f(V_{in})$ observed on the oscilloscope for 3 different settings of *R5* potentiometer.
10. Set the resistance of the potentiometer *R6* in the middle. Repeat points 8 and 9.
11. Set the potentiometer *R6* to have maximum resistance. Repeat points 8 and 9.
12. Connect the oscilloscope and observe V_{in} on channel B and V_{out} on channel A.
13. Observe the value of V_{ref} while changing resistances of *R5* and *R6*.
14. Compare the operation of regenerative and nonregenerative amplitude discriminator.

Control questions

1. What are the basic differences in the operation of nonregenerative and regenerative comparators? Discuss the differences in characteristics $V_{out} = f(V_{in})$.

Additional information

Parameters, documentation and SPICE models of TL072 operational amplifier:
http://focus.ti.com/docs/prod/folders/print/tl072.html

Report preparation

The report must be delivered in electronic form to your teacher. Each page in header should have named and id numbers of persons carried out the exercise. Oscilloscope plots should be drawn by hand on earlier prepared grid. Each report should include:

- schematics of the examined circuits (e.g. prepared in SPICE);
- measurements results;
- oscilloscope plots and marks of reference to appropriate plot in the report text;
- simulation results;
- comparison of the obtained measurement results and oscilloscope plots with SPICE simulation results;
- comments and conclusions;
- answers to control questions.