Measurement 4.

Building and measuring a simple electronic circuit

Aim of the measurement

The main goal is that the students get practical experiences concerning building, measuring and testing electronic circuits.

Keywords

Circuit design, measurement, test, operational amplifier

References

[1] Wikipedia: Operational amplifier and its applications (inverting, non-inverting amplifier, Integrator,Schmitt trigger)
http://en.wikipedia.org/wiki/Operational_amplifier
http://en.wikipedia.org/wiki/Operational_amplifier_applications

[2] Wikipedia: Frequency response: http://en.wikipedia.org/wiki/Frequency_response

[3] Amplification and its measurement – Measurement Lab. 3, measurement 3.

Measurement instruments:

Oscilloscope	Agilent 54622A
Power supply	Agilent E3630
Function Generator	Agilent 33220A
Digital multimeter (6½ digit)	Agilent 33401A
Digital multimeter (3½ digit)	Metex ME-22T
PC	

Parts used for circuit building:

- breadboard (2 pc.),
- tools: tweezers, pliers, crocodile clips, test probe, etc.
- op-amp ICs (TL082), passive parts (resistors, capacitances, diodes),

Laboratory exercises

Student A and Student B has separated building tasks, but the measurements should be done in pairs. Do all the measurements related to a certain circuit before you go further.

1. Basic amplifier circuits

1.1. Before building: measure the values of the received parts. Calculate the gain at the central frequency, check is it is between 1 and 10.

The gain can be calculated by means of Kirchoff's Laws (if the op-amp is assumed to be ideal.) Fig. 4-1. demonstrates this for the inverting circuit. The gain for the ideal op-amp is infinite, so U_N=0. The input impedance is also infinite, so the input current is 0, this means that I_5=-I_4. We obtain for the gain:

$$A_u = \frac{U_{ki}}{U_{be}} = -\frac{R_5 \cdot I_5}{R_4 \cdot I_4} = -\frac{R_5}{R_4}$$

If AC coupling is applied (See C1 in fig 4-3), for the gain and the lower cut-off frequency we obtain:

$$A_u = -\frac{R_5}{R_4 + \frac{1}{j\omega C_1}} \qquad f_l = \frac{1}{2\pi R_4 C_1}$$

Measuring at the central frequency, we do not have to care about C1.

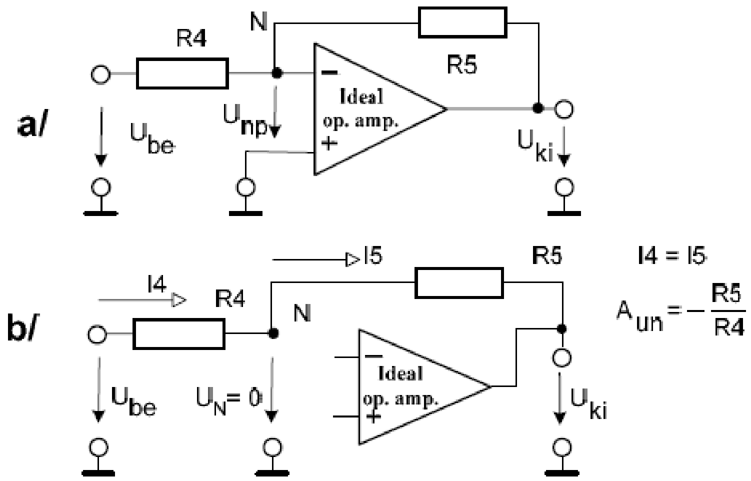

Figure 4-1: Calculation of the gain

1.2. Student A: using the breadboard and the parts obtained from the tutor, build the basic non-inverting amplifier circuit (See fig. 4-2.). The power supply should be ±15 V.

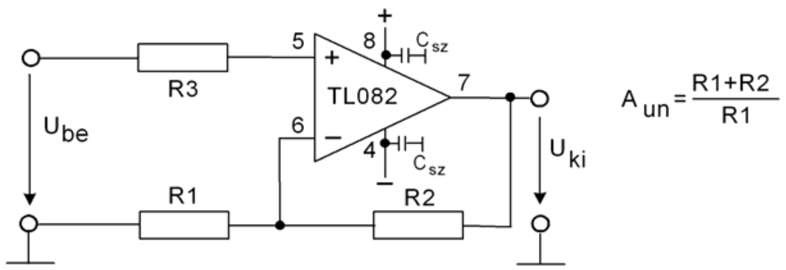

Figure 4-2. Basic non-inverting amplifier circuit

1.3. Student B: using the breadboard and the parts obtained from the tutor, build the basic inverting amplifier circuit (See fig. 4-3.). The power supply should be ±15 V. Use AC coupling on the input.

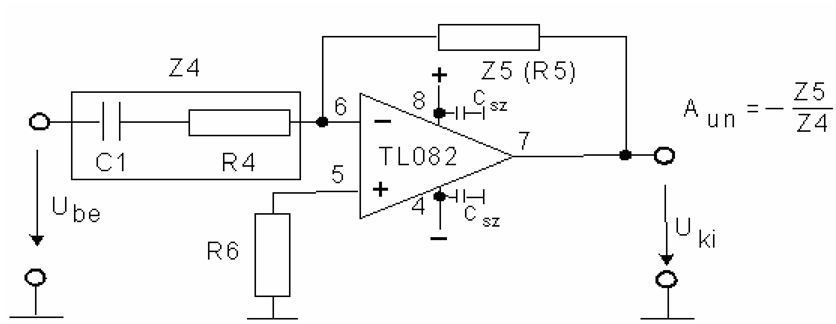

Figure 4-3. Basic inverting amplifier circuit with AC coupling on input

2. Measurements with the non-inverting amplifier

Double check the value of supply voltages (±15V) and the polarity of connections. Switch on the circuit ***only*** if the tutor has checked it.

2.1. Functional check. Using the function generator, set up a 1 kHz (0 V offset) sine wave and connect it to the input. The amplitude should be set based on the calculated gain so, that the output amplitude is approx. 5-10 V (10-20 Vpp). Check both the input and the output by means of the oscilloscope. Measure the gain and check if it is of the order of the calculated value.

2.2. Measurement of the saturation voltages: Trace the output by means of oscilloscope. Increase the input amplitude until the output distortion is notable. After that, decrease the amplitude until the distortion disappears. Measure the input and output voltages (RMS and PP values)!

2.3. Measure the voltage gain by means of the Agilent DMM. (Measure input and output voltage and calculate the gain.). Calculate gain as dB value.

2.4. Measuring the offset voltage of the amplifier (shortcut on the input). Measure the output voltage, if the input voltage is 0 (output offset)! Calculate the input offset! Evaluate the result: What is the reason for offset voltages? Is the measured value plausible (compare with datasheet values)? What is caused by the operation point bias current? How can you select the optimal value for *R3*?

3. Measurements with the inverting amplifier

3.1. Check the functionality as described in 2.1

3.2. Measure the gain as given in 2.3

3.3. Measure the phase shift at the lower corner frequency

3.4. Examine the impulse transfer! Measure rise- and fall-time! Use symmetric square signal as input. The measurement should be done at 1 kHz and at the lower cut-off frequency.

4. Additional task: Waveform generator

4.1. Build the circuit depicted in fig. 4-4! The parameter values should be determined by the tutor! (The integrator should be built by student A, the Schmitt-trigger (comparator) by student B)

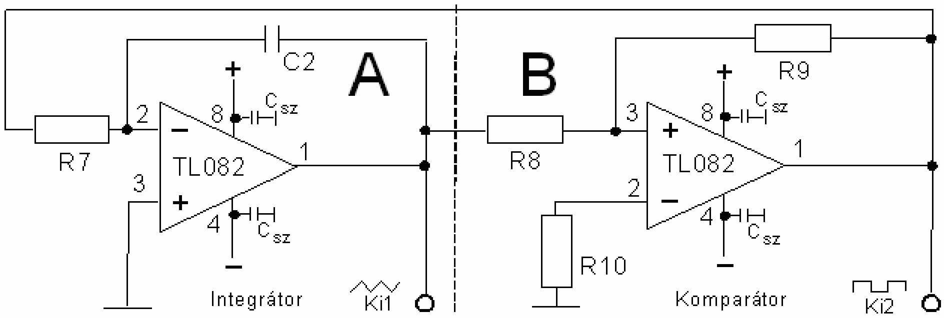

Figure 4-4. Waveform generator

4.2. Build the Waveform generator: connect the comparator output to the integrator input. Double check the power supply (±15 V)! Switch on the circuit ***only*** if the tutor has checked it.

After the successful design and building, a triangle signal can be measured on clamp “Ki1” and a square on “Ki2”. The amplitude of the latter one is determined by the saturation voltage of the op-amp. The triangle is determined by the threshold levels of the Schmitt-trigger.

4.3. Copy the typical waveforms (U_{ki1}, U_{ki2}) to the report!

5. Test

5.1. What are the basic parameters of an ideal operational amplifier?

5.2. What is the voltage between the ‘+’ and ‘–‘ pins of an ideal op-amp?

5.3. How are the input and output offset defined?

5.4. How is the saturation voltage defined? How can it be measured?

5.5. How is the voltage gain defined? How can it be measured?

5.6. What is the formula for the calculation of Au[dB] if Au is given?

5.7. How can you measure the phase shift?

5.8. How are rise- and fall-time defined?

5.9. How can you calculate the effective value of a periodic signal u(t) with period T

5.10. Draw the basic (non)-invering amplifier circuit (with AC coupling)