Óbuda University
Kandó Kálmán Electrical Engineering Faculty
Institute of Microelectronics and Technology

Micro- and nanotechnology (KMENT14NEC)

Laboratory program

Measurements guide

1. Study of pressure sensors

Theoretical background

The sensors to be measured are based on micro-machined Si chips. This chip contains 4 diffused resistors placed on a membrane and creating a bridge circuit. The pressure sensing is taking place with measuring the resistor values which will change when the membrane deformed by the applied pressure (piezo-resistivity).

The resistors are placed in a way, that the neighboring ones will change oppositely when a pressure is applied. Supplying the bridge with a current or a voltage source, at the output we will see a voltage proportional to the applied pressure. The measuring setup is ready to measure a relative and an absolute pressure sensor together its temperature sensor.

There are three different kind of the pressure:

- Absolute pressure value: a value related to the vacuum.
- Relative pressure value: deviation from the outer pressure.
- Differential pressure value: related to a referential value.

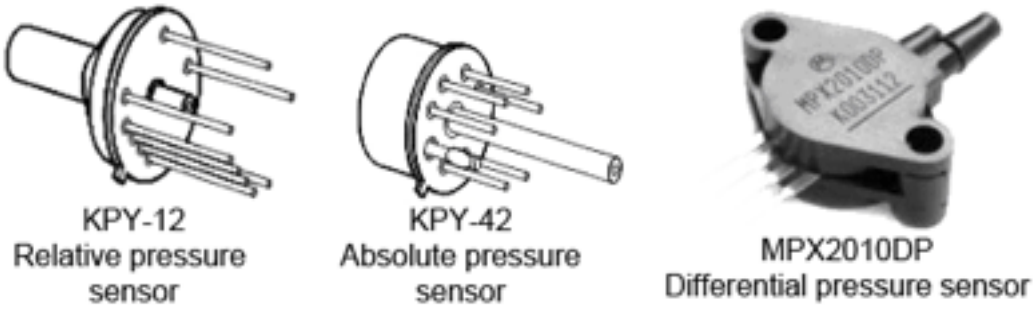

Figure 1: a) Outline of the different pressure sensors

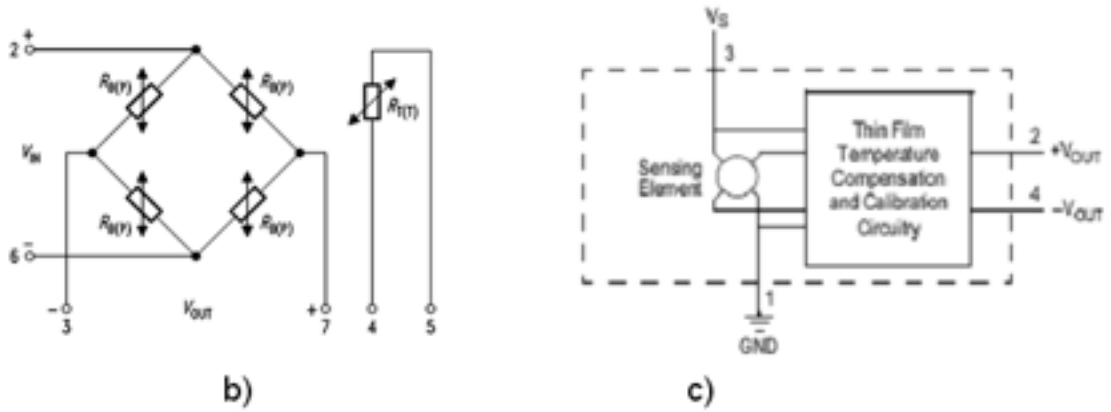

Figure 1: b) internal structure of a relative and an absolute sensor;
c) a differential sensor's internal structure

The goal of this laboratory exercise is to measure the pressure — voltage characteristics of a relative and an absolute pressure sensor (supplying by a voltage source and a current source), to study their temperature dependence, and to measure and calculate the errors of the pressure sensors.

The basic error of the pressure sensor has three components:

- Nonlinearity error (NL-error);
- Hysteresis (H-error);
- Repeat error (I-error).

Since they are independent the basic error can be expressed as:

$$A_H = \sqrt{NL^2 + H^2 + I^2}\ .$$

The pressure sensor has some additional errors in excess of the basic one. The most important one is its temperature dependence. Since the silicon specific resistance is temperature dependent the resistance values will change not only by the pressure but by the temperature, as well.

The outgoing signal of the balanced Wheatstone bridge is:

$$U_{out} = \Delta U_{out} = \frac{1}{4}\left[\frac{\Delta R_1}{R} - \frac{\Delta R_2}{R} + \frac{\Delta R_3}{R} - \frac{\Delta R_4}{R}\right] U_{in}$$

Applying a voltage supply the temperature dependance of the sensor will be the function of the $R(T)$ and $\Delta R_i(T)$.

In spite of this, applying a current supply the outgoing signal will be:

$$U_{out} = \Delta U_{out} = \frac{1}{4}\left[\frac{\Delta R_1}{R} - \frac{\Delta R_2}{R} + \frac{\Delta R_3}{R} - \frac{\Delta R_4}{R}\right] R I_{in} = \frac{\Delta R_1 - \Delta R_2 + \Delta R_3 - \Delta R_4}{4} I_{in}$$

Since the temperature dependence of the piezoresistive component is less significant than the temperature dependence of the resistance itself it is advisable to apply the sensor with a current supply.

The test setup

The test setup is shown on the Figure 2 and 3.

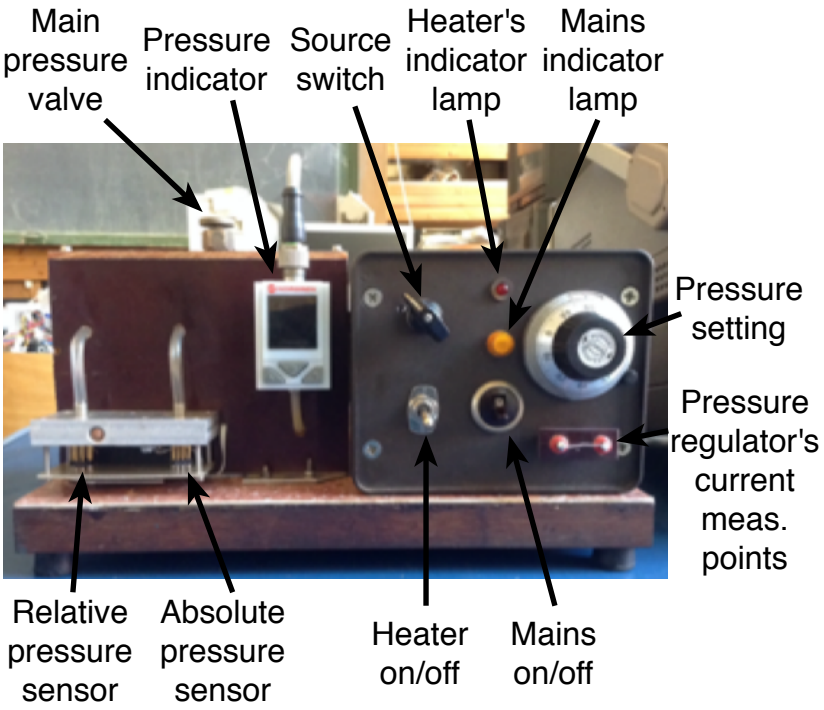

Figure 2: Test setup front side

The pressure to be measured is produced by a compressor station. Its buffer tank has about 3 bar pressure.

The compressor station will be handled by the teachers.

The pressure valve of the compression station is rather coarse, that is why the test setup is containing a pressure regulation unit. This Norgren VP12 type regulator has to be controlled by 4-20mA current. The regulator's control current can be measured by a milliampere meter connected to the marked connections on the front side of the unit (Fig. 2). If we do not use a current measurement, these connectors must be shorted. The current value can be set with the potentiometer located above the connectors. Meanwhile you can see the actual pressure value on the display.

The pressure indicator has an offset value. This should be determined at the beginning of the measurement. You can get it recording the displayed value when the pressure valve is closed still, and the controller current is in its minima. During the all measurement, this offset value must be deducted from each pressure reading.

The pressure regulator releases the excess pressure to reach the set value. You can hear it, it's ok. Comparing the analogue measure on the compressor and the above mentioned regulator, the differential pressure in the pipe could be evaluated.

The pressure sensors are located in an alumina block. This block contains a heater and a thermistor, as well. The heater switch located on the front side (Fig. 2).

On the Fig. 2 left up there is the pressure valve. Using it the pressure sensors could be switched out when the pressure regulator profile will be measured. Measuring the sensors do not forget to open it.

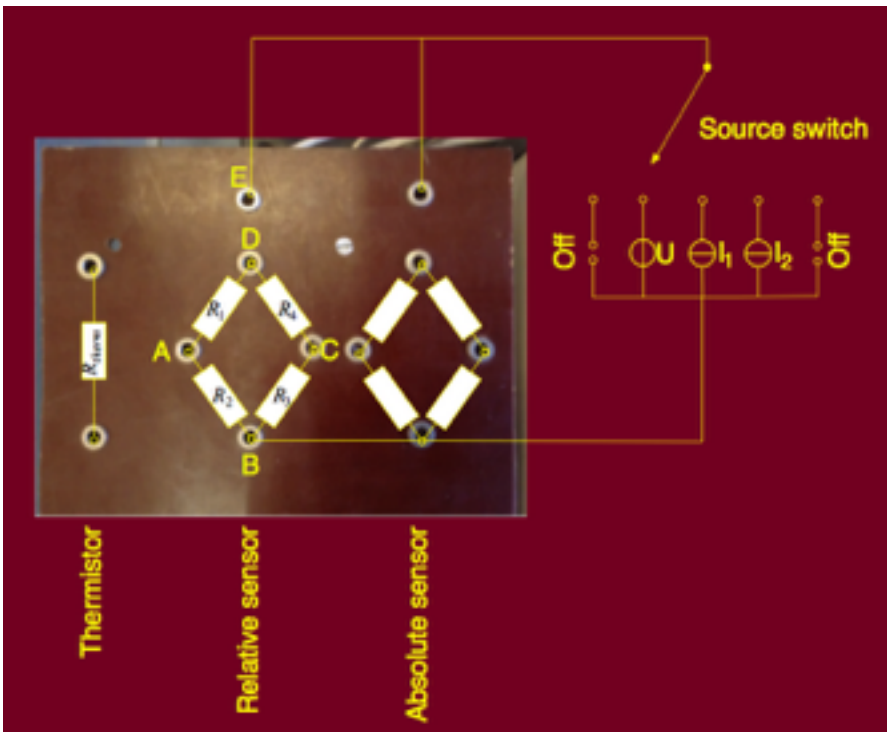

Figure 3: Test setup top side and the circuitry behind

The Fig. 3 shows the reachable measuring points and the built in circuitry of the setup. To measure the input current the milliampere-meter should be connected between D and E point for the relative sensor or between the similar (but not lettered) points for the absolute sensor. If you do not want to measure the incoming current D and E or the similar two point must be shorted with the supplied plug BUT ONLY ONE PAIR AT THE SAME TIME.

The source switch is located on the front side of the unit. It has five stages as it is shown in Fig 3.

Measurement tasks

1. Investigation of the pressure regulator

a) Obtaining the offset reading

It should be performed with closed compressor tank. The current of the pressure regulator is set to minima. If there were any pressure in the pipe wait to release it. After that you should record the displayed value. This will be the offset error. In the course of the measurements this value must be deducted every time.

b) Current — pressure characteristic of the pressure regulator

The data sheet of the pressure regulator does not contain the current — pressure curve, it states only that we need a controlling current in between 4-20mA. So we have to measure it.

Switch off the pressure valve. This will shield the sensors against the high pressures. Check the line pressure at the compressor it should be 2.6 bar. Set the current of the pressure regulator in between 2 … 18 mA by 1 mA step using the pressure setting knob and record the pressures using the digital display. (Do not forget the offset-compensation.)

The displayed pressure value will not exceed a given value reaching a given control current.

The pressure difference detectable between the analogue regulator (on the compressor) and the digital regulator will be the necessary minimal pressure which is necessary to the proper work of the regulator. This is the minimal input value to get a pressure on the outgoing side. The pressure difference is released through the internal valve of the pressure regulator.

2. Pressure — voltage characteristics

a) Resistances

At the switched of pressure valve, the resultant resistance of the sensor bridges have to be measured to identify the value of the separate resistances. Let's measure the thermistor resistance, as well.

b) Pressure characteristics

At first measure the offset value of the sensors at the closed pressure valve.

The characteristics should be obtained **with all the three sources** in the 0 … 1 bar region with 0.1 bar steps. To get the hysteresis of the curve the measurements should be taken backwards from 1 bar to 0 bar, as well. If some points are over, never goes back, continue the measurement.

Graph the output signal's pressure dependence.

Using the bidirectional data get the hysteresis of the sensor in percentage values.

3. The temperature dependence

The heater switched on and the resistance of the thermal sensor should be measured. The heater is heating the system to about 45 °C and keeping this temperature. The thermistor resistance will not change if it is reaches 45 °C.

Let’s measure the thermistor value, and determine which type is it (PTC or NTC).

Measure the pressure characteristics in the same way as it is prescribed in 2.b).

The thermal error could be evaluated using the room temperature (cca. 24-26 ˚C) and 45 ˚C temperature data as a function of the pressure. The dimension of the error is %/°C consequently we have to calculate the changes taking place at 1°C, this is related to the room temperature net signal and expressed in percentage. The room temperature can be obtained by the thermometer or asked from the colleagues doing the temperature sensor measurement.

Equipments to be used

Compressor with analogue pressure's regulator

Test setup shown in Fig. 2.

1 pc voltmeter (Hameg HM8012)

1 pc current meter (Hameg HM8012)

Review questions

- According to the pressure to be measured what kind of pressure sensor do you know?
- Why is beneficial the current supply at the pressure sensor measurement?
- Sketch the measuring bridge of the pressure sensor!

Measurement protocol

Each measuring group is asked to give in one protocol. The protocols could be preferably submitted through e-mail latest after two weeks of the measurement performed.

The protocol has to contain:

1. The title of the measurement
2. The names of the colleagues performing the task
3. The date and location of the measurement
4. A declaration stating that the task is performed by the enumerated colleagues
5. The list of applied equipments with types and identification numbers
6. The tabulated list of the measured values, the calculated values, and the requested graphs
7. In the case of calculations, the applied forms
8. Short discussion of the results for each measurement task

PLEASE do not copy previous protocols. Identical protocols will be refused.