Experiment : MEMS – pressure sensor & ADC

1. Objectives

The objective of this experiment is to familiarize students with measurement system consisting of a MEMS (Micro Electro-Mechanical Systems) sensors (in this case pressure sensor), analog digital converter (in this case delta-sigma converter) and microcomputer system. Analog to digital conversing must be selected in such a way to read the pressure in H2O.

2. Components and instrumentation.

The measuring system consists of a pressure sensor MPX2010 (http://www.atmicroprog.com/download/metrologie/MPX2010.pdf). The sensor is powered with 3.3 V (Fig. 1). The output of the measuring bridge is connected to a 16-bit AC delta-sigma converter type ADS1110 with I2C output (http://focus.ti.com/lit/ds/symlink/ads1110.pdf). The pressure sensor, a 3.3 V stabilizer and AC converter are mounted on one PCB (Fig. 1). This board is connected to the microprocessor controller with 4 lines: The voltage 5V, Ground and two signal lines, of the I2C bus.
Fig.2 presents the schematic and PCB of the microcontroller system. It is based on the processor AT89C51ED2 (http://www.atmel.com/dyn/resources/prod_documents /doc4235.pdf) containing: 2kB RAM, 2kB EEPROM and 64 Kb flash memory. The main advantage of this controller is the possibility of in-system programming via RS232 i.e. there is no need for the programmer. In addition, the controller board contains 6 buttons and LCD display (4 lines of 20 characters).The program included reads, in a continuous manner, the pressure transducer and shows, on the display, the measured differential voltage in mV and the value of the pressure in cmH2O. Processing is carried out according to the relation:

$$\text{RESULT}\ [cmH_2O] = \text{SCALE}\ [cmH_2O/mV] * (\text{READING}\ [mV] - \text{OFFSET})$$

Moreover, the program allows the user to enter TIME_CONSTANS. The time constant greater than 1 will cause that the results appears on the display will vary according to the recursive relationship (average value -AVRV):

$$\text{AVRV.} = \text{AVRV.} - (\text{AVRV.} - \text{SAMPLE\_VALUE}) / \text{TIME\_CONSTANS}$$

3. Preparation.

Estimated time to prepare for classes is 2 to 6 hours.

3.1. Readings

Basic:
1. Lecture materials (“Sensors” and “AD Converters”)
2. Data sheets of MPX2010 and ADS1110.

3. W. Tietze, Ch. Schenk, Electronic circuits – Handbook for Design and Applications, Spriger, 2008, chapters 18.9 and 21.2
4. Walt Kester, Analog-Digital Conversion, Analog Devices 2004

3.2. Problems

1. The principle of A / D converters:
   • "Flash"
   • Compensation (successive approximation, or counting)
   • With double integration
   • Sigma Delta
2. Main processing errors AD and DA converters
3. Principle of operation of the pressure transducer used in the lab
4. Pressure units:
   • PSI (pound per square inch)
   • Pa (Pascal)
   • cmH_2O (centimeters of water)
   • at (technical atmosphere)
   • atm (atmosphere physical)
   • mm Hg (millimeters of mercury)
   • Tr (torr)
   • Br (bar)?

3.3. Detailed preparation

Based on the datasheets of MPX2010 pressure sensor and AD converter ADS1110 estimate (for various gain values of the internal amp - PGA = 1,2,4,8):
1. Maximum offset of the system (in Volts and cmH_2O),
2. Scaling factor (the sensor supply voltage is 3.3 V!)
3. AC voltage converter quantization and the corresponding accuracy of measuring the pressure in cmH2O.

Fulfill the below table with estimated results (shaded cells):

PGA	$1=2^0$	$2=2^1$	$4=2^2$	$8=2^3$
Estimated maximum offset [mV]				
Observed offset [mV]				
The estimated gain factor [cmH2O/mV]				
Real gain factor				
Estimated quantization error [µV]				
Estimated quantization error [cmH2O]				
Observed quantization error [mV]				
Observed quantization error [cmH2O]				

4. Content of report

1. Establish experimentally “offset” and “scale” of the microcontroller system to achieve correct display value of pressure in cmH2O.
2. Repeat previous point for different gain of the AD converter (values of 0,1,2,3 correspond to PGA = 1,2,4,8).
3. Establish quantization error by observing the displayed value for a very small change of the pressure.
4. Conclusions.

5. Appendixes

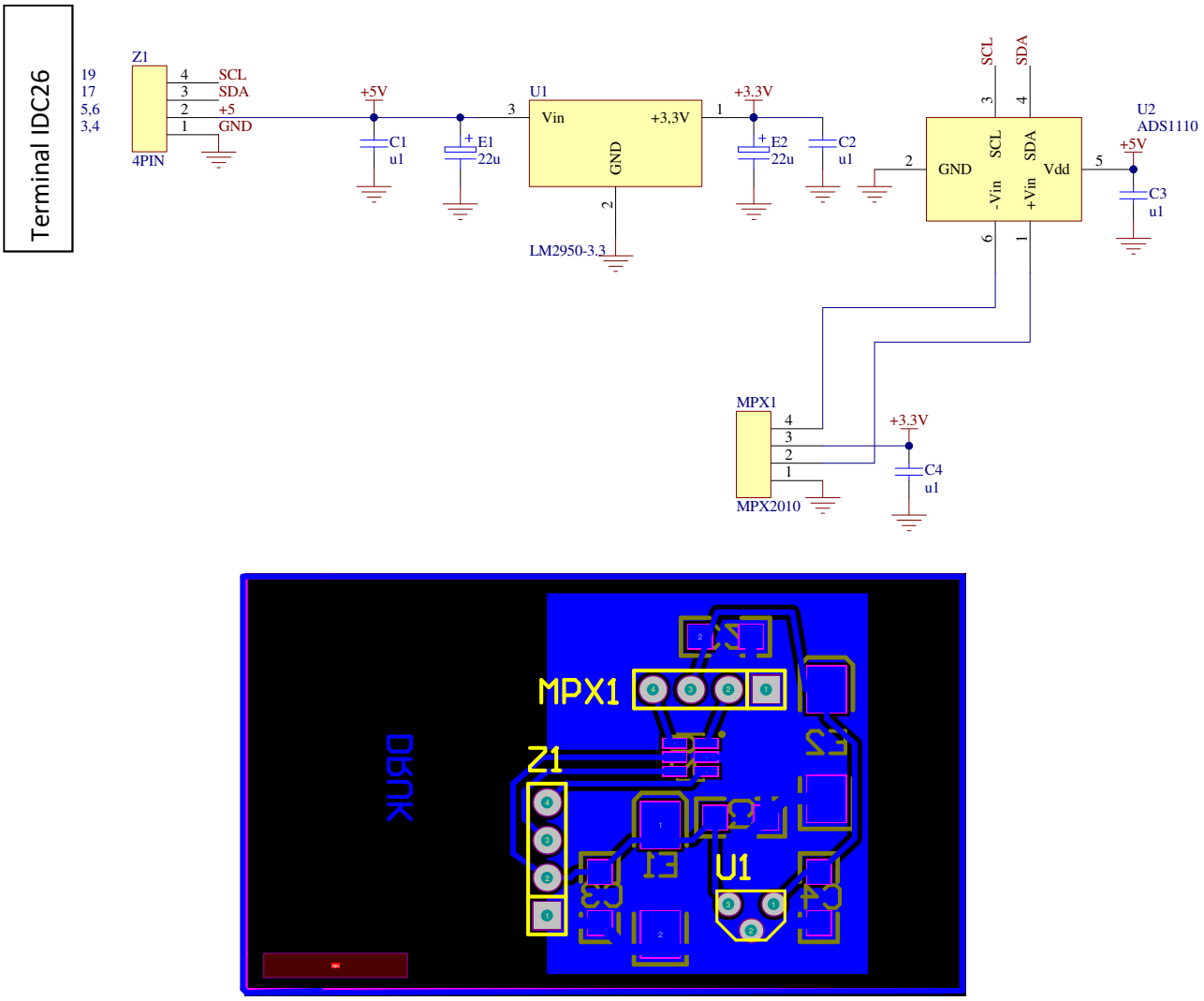

Fig.1. Pressure transducer – schematic diagram and PCB

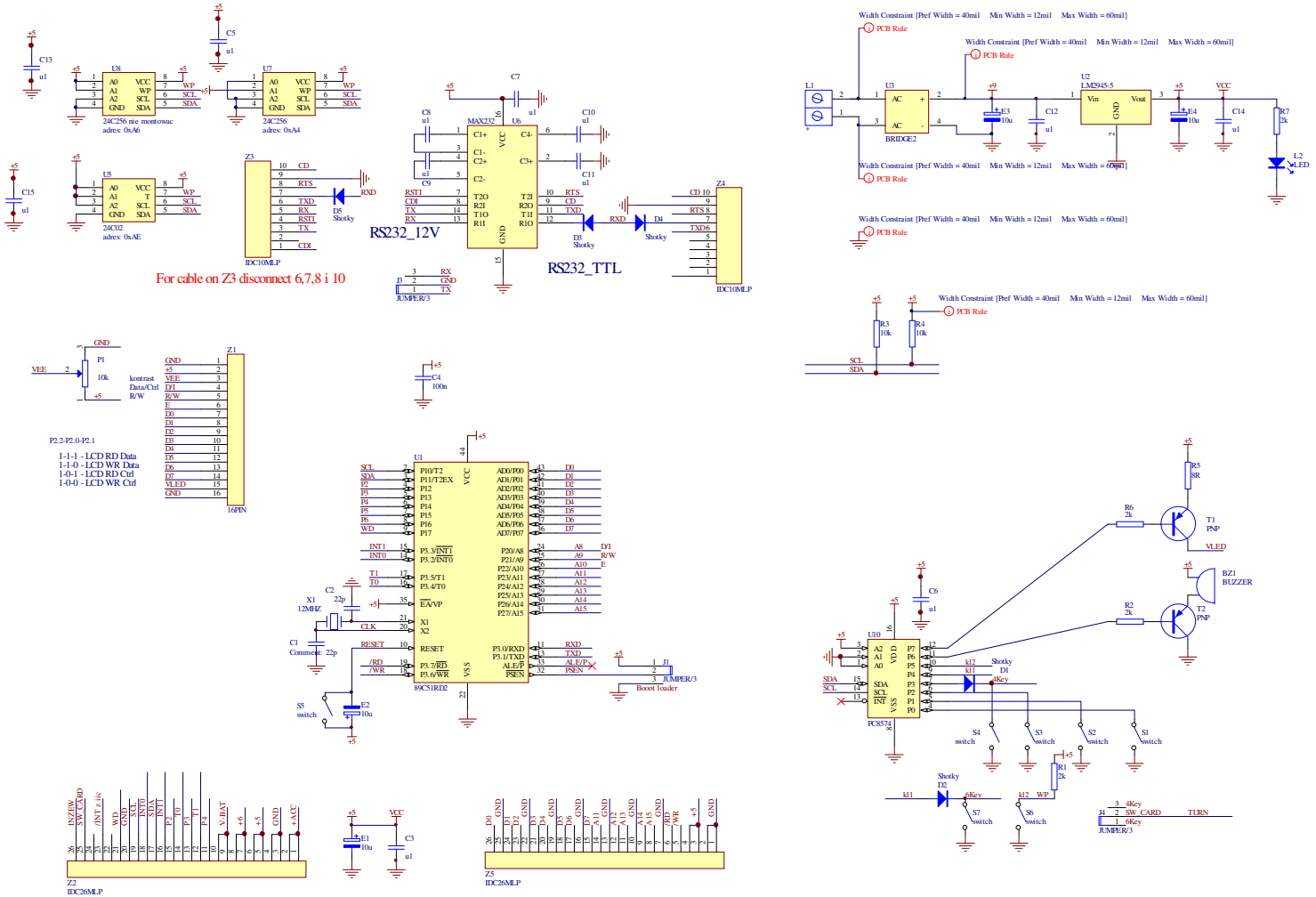

Fig.2a. Microcomputer schematic diagram

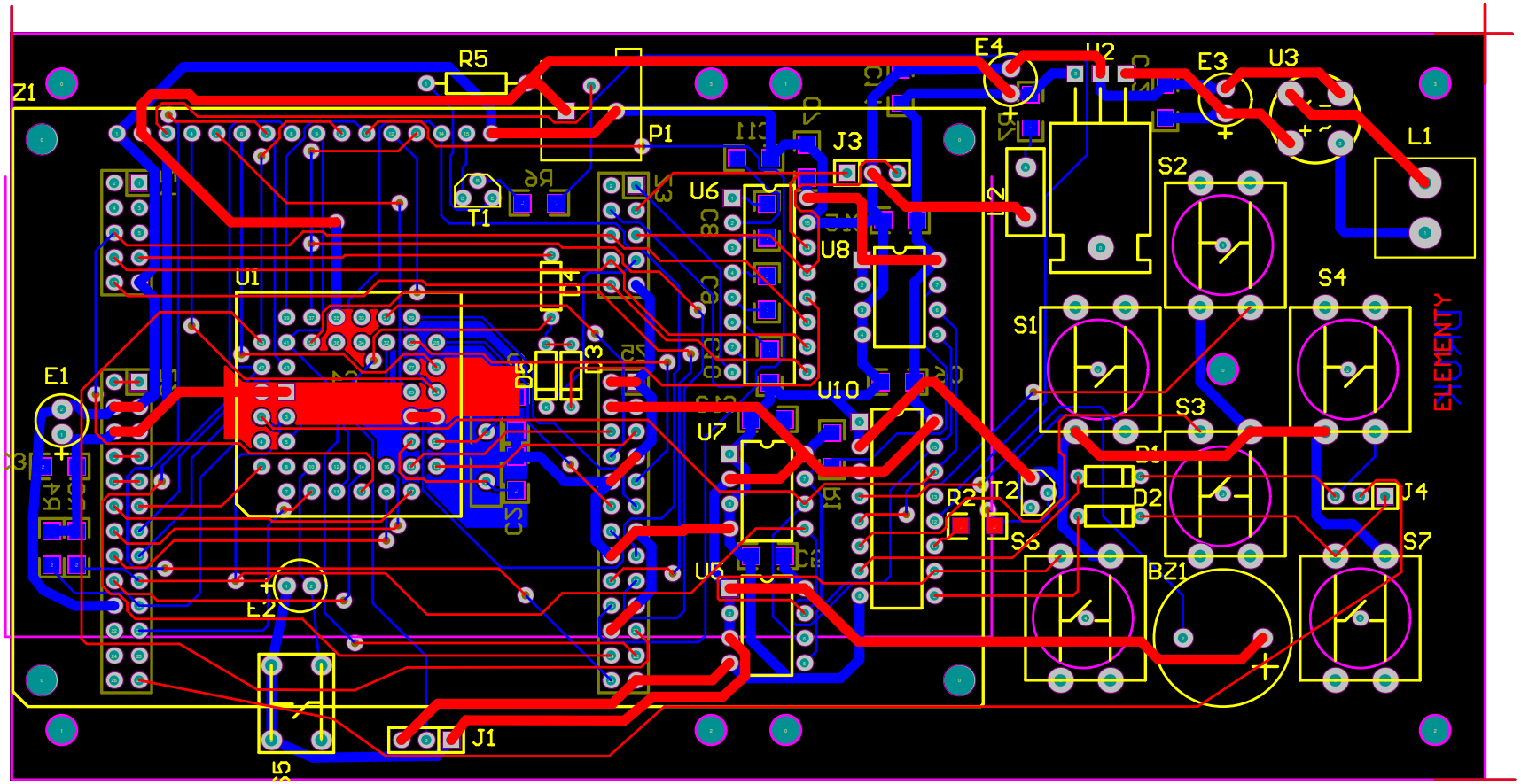

Fig.2b. PCB of microcomputer