PreLab 5: Blood Pressure Measurement System (7 problems for 30 pts)

The goal of Lab 5 is to build and test a blood pressure measurement system. An off-the-shelf pressure cuff will be connected to a piezoresistive pressure sensor. The sensor output is amplified by the AD620 instrumentation amplifier, acquired by an Arduino, and processed in MATLAB.

• PART 1: BLOOD PRESSURE BASICS

➢ **Read the "Blood Pressure Measurement" pdf on the course website.** This pdf describes non-invasive blood pressure measurements, such as the auscultatory and oscillometric methods. The pdf is from the Fluke Biomedical website.

o Problem 1: Describe the auscultatory technique to measure blood pressure.

o Problem 2: Describe the oscillometric technique to measure blood pressure. Does it give identical information as the auscultatory technique?

• PART 2: PIEZORESISTIVE PRESSURE SENSOR

There are many kinds of pressure sensors for a wide range of applications. In this lab, we will use the MPX2050GP sensor from Freescale Semiconductor, Inc. On the outside, it looks like a circuit component with a plastic nozzle (see Fig. 1a).

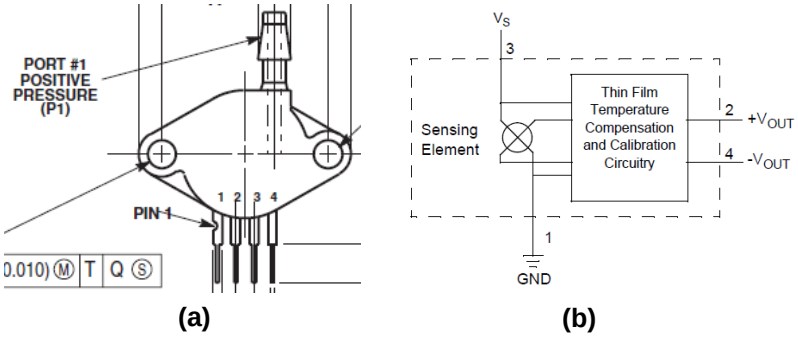


Fig. 1: (a) External appearance of the MPX2050GP pressure sensor (b) Simplified block diagram of the internal electronics of the sensor

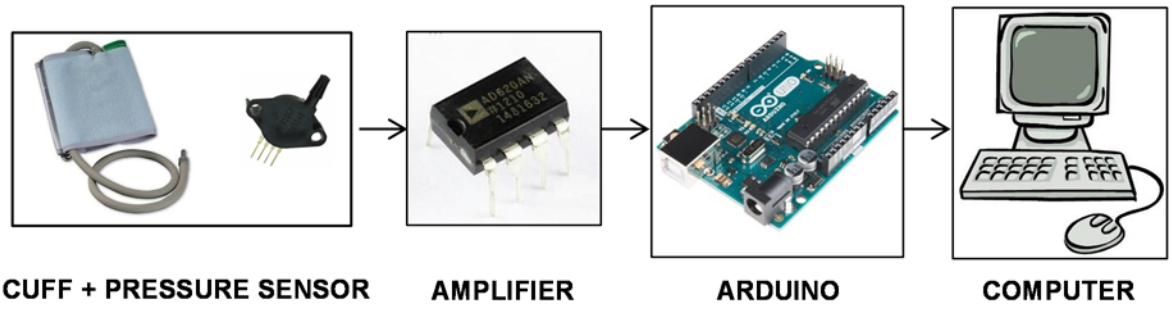
On the inside, it contains a thin silicon membrane that deforms under air pressure. The membrane contains miniaturized strain gages that convert the membrane strain into a measurable voltage. Unlike the constantan strain gages in Lab1, these micromachined silicon strain gages rely primarily on the **piezoresistive effect**. This means that the ΔR/R is primarily due to a change in the resistivity of the material (rather than elongation or contraction).

The MPX2050GP is a very convenient sensor, since it contains temperature compensation and calibration circuitry. This means the sensor output is a voltage that is directly proportional to the air pressure. All you need to do is attach a tube, apply power and ground leads, and connect the sensor chip to the instrumentation amplifier! ☺

- Problem 3: Mathematically, the sensor voltage can be simply expressed as: $\Delta V_{SENSOR} = S * P$, where S is the "responsivity" of the sensor. What is the value of S for the MPX2050GP sensor? What supply voltage V_S should you use? Hint #1: Read the MPX2050GP datasheet on the course website. Hint #2: Unfortunately, the datasheet uses the term "sensitivity" instead of "responsivity". A matter of semantics ….

PART 3: BLOOD PRESSURE MEASUREMENT SYSTEM DESIGN

The blood pressure measurement system will use a pressure cuff, the MPX2050GP sensor, the AD620 instrumentation amplifier, the Arduino for data acquisition, and MATLAB for data processing.



Suppose we want to measure pressure values up to 175 mmHg. Let the responsivity of the pressure sensor be 0.8 mV/kPa. Assume the instrumentation amplifier is powered by +10V and -10V with a voltage reference V_{REF} = 1.5V. Assume the amplifier output is limited to -9V (min) and +9V (max). The Arduino ADC operates from 0 to 5V with 10 bits.

- Problem 4: When the cuff is deflated, the cuff pressure is 0 mmHg and should produce a measured voltage of 1.5V. What is the maximum permissible value for the instrumentation amplifier gain? Hint #1: As always, start by seting up an equation for V_{MEAS}, then figure out the max permissible gain. Hint #2: It should be close to 188.

- Problem 5: Choose the best value (standard 5% resistor) for gain resistor R_G of the AD620 chip (see datasheet on course website) and also compute the actual gain based on this resistor.

- Problem 6: Now we need to process the measured voltage to obtain cuff pressure in mmHg. Derive a formula for the cuff pressure in terms of the measured voltage V_{MEAS}.

- Problem 7: Suppose the rms noise voltage of the system is 1 mV_{RMS}. What is the minimum detectable pressure change in your system? Express your answer in mmHg. Hint: It should be about 0.25 mmHg.

(End of PreLab 5)