Measure Pressure and Flow

Install the EMANT300 USB DAQ and Stepper Motor Training Kit

1. Connect up the EMANT300 USB DAQ and Pressure and Air pump Adaptor as shown.

2. Before plugging in the USB cable to the PC, please follow the steps in the Installation Guide to install the necessary software drivers. Skip the step involving the Light Application Adaptor. You will need to run this driver installation the first time the EMANT300 USB DAQ is connected to a PC. This step is automatically done when you subsequently connect the EMANT300 USB DAQ to the same PC.
Run the LabVIEW Program

1. Run the LabVIEW program **Pressure and Air Pump.VI**
2. We are using a differential pressure sensor. As the pressure sensor will have some offset, you may have to zero this offset when the sensor is not connected to any pressure source. If the pump is running, turn it off.

**Boyles Law**

3. The first measurement is to verify the relationship between the volume (V) and the pressure (P) of air. Connect the 50ml syringe for this measurement as shown with the plunger at 50ml. Set the Pressure unit to kPa.

4. At 50ml, the differential pressure should be 0. If not zero it. Next note the pressures at different volumes by varying the plunger position. Boyles Law state that PV = constant if the gas is behaving as an Ideal Gas. Verify this by plotting P vs V. Note that P should be absolute therefore you should add the atmospheric pressure 101.6 kPa to your pressure readings.
Hydrostatic Pressure

5. Connect up as shown to measure hydrostatic pressure. For this measurement set the Pressure unit to cm H₂O

6. Fill up the container with water and observe the readings on the gauge. It will measure the depth of water to the edge of the tube.
Flow

7. Connect the air pump to the orifice attachment as shown. Set the pressure unit to mm Hg. Click on the Show Flowrate button. Vary the pump speed by changing the duty cycle. Observe the change in air flow. If you connect the outlet to a tube to a container of water, the airflow will displace an equivalent amount of water. The volume of water displaced is equal to the on time of the pump multiply by the airflow rate. (Note that the syringe is acting as a receiver to smooth out the pulsating airflow of the pump).

To operate the pump, the Run/Hold switch should be set to Run.
How it works

Pressure is defined as a force per unit area and the U tube manometer is traditionally used to measure it. Manometers can measure absolute, gauge, and differential pressure. In a sense all pressure measurements are differential and the difference between the three types of measurement is the reference used.

In absolute pressure measurement, the reference is absolute vacuum. One application is the barometer which measures air pressure. High air pressure generally bring good weather and centers of storm are areas of relatively low air pressure.

To measure gauge pressure, the reference is the standard atmospheric pressure. The standard atmospheric pressure defined at sea-level at 0°C is 101.325 kPa (kilo Pascal absolute).

Some Alternative Units of Pressure
- 1 bar - 100 kPa
- 1 mm Hg – 0.133 kPa
- 1 inch Hg – 3.386 kPa
- 1 psi – 0.145038 kPa

Blood pressure measurement is a gauge pressure measurement.

Differential pressure measurement can be used to measure flow rate. When airflow is interrupted by a venturi or orifice, the measured pressure differential is related to the flow rate.

Pressure Sensor

In our application the pressure used is the MPX2202DP Pressure Sensor from Freescale Semiconductors. The MPX2202DP is a silicon piezoresistive pressure sensor that provides a highly accurate and linear voltage output - directly proportional to the applied pressure. The sensor is a single monolithic silicon diaphragm with the strain gauge and a thin-film resistor network integrated on-chip. The chip is laser trimmed for precise span and offset calibration and temperature compensation.

Features
- Temperature Compensated Over 0°C to +85°C
- ±0.25% Linearity (MPX2200D)
- Differential Configuration
The differential voltage output of the sensor is directly proportional to the differential pressure applied. The absolute sensor has a built-in reference vacuum. The output voltage will decrease as vacuum, relative to ambient, is drawn on the pressure (P1) side. The output voltage of the differential or gauge sensor increases with increasing pressure applied to the pressure (P1) side relative to the vacuum (P2) side.

With a 10V excitation, it measures from 0 TO 200 kPa (0 TO 29 psi) giving a 40 mV full scale span. The output is ratiometric when excited by voltages lower than 10V.

In our example, we are using the absolute sensor and the sensor is excited at $V_{\text{EXC}}=2.5V$. As the current required at the bridge is much higher than what is available from REFOUT, a simple buffer amplifier is required.

Since the excitation voltage is 2.5V, the full span output is scaled to 10mV. When the input of the EMANT300 is set to this range, the module can measure better than 1uV due to its programmable gain amplifier and the resolution of the ADC.

Thus the pressure in kPa with respect to the voltage output $V_o$ (seen at the differential input AIN4, AIN3) is given by

$$\rho = V_o \times 20000$$

**Hydrostatic Pressure**

The pressure at a given depth of water is due the weight of the water acting on a unit area at that depth plus any pressure acting on the surface of the water.
If you measure the gauge pressure (pressure with respect to atmospheric pressure), the pressure due to water alone at a given depth is given

\[ P = \rho gh \]

where

- \( P \) is the hydrostatic pressure
- \( \rho \) is the water density
- \( g \) is gravitational acceleration
- \( h \) is the height of water above

Given that the conversion factor from kPa to cm \( H_2O \) is 10.2, therefore the depth of water in cm is

\[ h_{cm} = 10.2 \times P \]

**Flow**

An effective way to measure the flow rate through a pipe is to place some type of restriction within the pipe and to measure the pressure difference between the low velocity, high-pressure upstream section, and the high-velocity, low-pressure downstream section. One common method is the use of an orifice plate

The volumetric flowrate (\( Q \)) is given by:

\[ Q = C A_2 \sqrt{\frac{2(p_1 - p_2)}{\rho \left[ 1 - \left( A_2 / A_1 \right)^2 \right]}} \]

where

- \( A_1 \) = Area of pipe upstream from restriction
- \( A_2 \) = Flow area of pipe at restriction
- \( p_1 \) = pressure upstream from restriction
- \( p_2 \) = pressure at restriction
- \( \rho \) = density of fluid
- \( C \) = correction factor for energy losses

The orifice diameter of the flow adaptor used is 0.8mm

**Air Pump**

Using Pulse-width modulation (PWM), the air pump's motor power supply is turned on and off at a fixed frequency. By changing the duty cycle, we control the speed of the fan. The larger the duty cycle, the faster the fan spins. Typical frequencies range from 20Hz to 160Hz.
The advantages of PWM include a very simple drive circuit, good startup characteristics, and minimal heat dissipation in the switching transistor. The disadvantages involve increased stress on the motor and the inability to use on board speed or alarm sensors.

However we cannot drive the motor directly from the EMANT300 Digital or PWM Output because the current needed to drive the motor is greater than the 20mA allowed by Digital or PWM Output.

Therefore we used the ULN2003 to drive the DC motor. The ULN2003 is a high voltage, high current darlington array each containing seven open collector darlington pairs with common emitters. Each open collector darlington is rated at 500 mA. Suppression diodes are included for inductive load driving. The ULN2003 has 5V TTL, CMOS inputs and allows it to be connected directly to the EMANT300 Digital and PWM outputs. The 5 ohm resistor is placed in series to the motor to reduce the 5V supply voltage to the 1.5V required by the motor.
First the program connects to the EMANT300 USB DAQ and sets the input range of the analog input to +/-0.01V. The sampling rate is set to 10 samples/sec. It then configures the EMANT300 to use the PWM output rather than the counter.

The offset voltage is read from the configuration file `pressure.ini` using the subvi `Read Pressure Cal Data.vi`

If the zero button is pressed, the configuration file `pressure.ini` is written the new offset voltage using the `Write Pressure Cal Data.vi`
The following Vis read the pressure voltage, remove the offset voltage and calculate the pressure in kPa.

This case statement converts the kPa pressure units into mmHg and cmH$_2$O.

The PWM output is changed here. Both the period and the duty cycle can be changed.

Flow is calculated using the subvi `flow rate.vi`. If the Show Flowrate button is pressed, the digital indicator `flowrate ml/sec` is visible.

For flow, as the measured pressure is relatively low, so we averaged over 10 readings to reduce the noise fluctuation.

Finally upon exit, the program closes the connection to the EMANT300 USB DAQ.
Calibration

Calibration refers to the process of determining the relation between the output (or response) of a measuring instrument and the value of the input quantity or attribute, a measurement standard. In non-specialized use, calibration is often regarded as including the process of adjusting the output or indication on a measurement instrument to agree with value of the applied standard, within a specified accuracy.

To calibrate the flow sensor, we will use it to measure the known air capacity within a 50ml syringe. Connect the flow adaptor to the syringe as shown.

Run the LabVIEW Program

1. Run the LabVIEW program Calibrate Flow Sensor.VI
2. Zero the offset if necessary.
3. The plunger of the syringe should be at 60ml mark. Move the plunger at a constant speed to the end.
4. The capture graph will display the pressure profile and the calculated capacity will be displayed.

```
Calculated Capacity ml
0
```

5. A calibration factor will also be displayed.

```
Calculated Cal Factor
0
```

6. If you insert the calibration factor into the flow sensor equation, subsequent measurements will show the correct result. You can check this by starting the plunger at the 50ml and 40ml marks.

```
Calibration Factor
1
```