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**NOTE**

# Digital readout manometer using an optical mouse

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**Abstract**
The manometer remains a useful pressure measuring instrument in the laboratory and in industry despite it being discovered centuries ago. One of the major limitations of this instrument lies with its inability to produce digital readouts for automated data acquisition. In this work, we demonstrate this ability via the incorporation of an optical mouse to sense liquid level movement. The approach is very easy to implement and inexpensive. It is also shown to be able to provide digital pressure measurements with good accuracy and repeatability.

## 1. Introduction

Despite being one of the earliest pressure measuring instruments around, the manometer is still in wide usage today due to its inherent accuracy and simplicity of operation. It is also a robust instrument that possesses no moving parts and requires no calibration. Some recent reports of application using this simple instrument include the measurement of soap solution surface tension [1], pleural pressure [2] and air permeability of asphalt [3].

Efforts to improve the performance of manometers have mainly centred on enhancing pressure measurement sensitivity. Some reported undertakings in this endeavour include the use of optical interferometry to determine liquid level displacement [4, 5], and air bubble in lieu of liquid level monitoring [6]. While these developments are beneficial, they do not address the major limitation in using conventional manometers; i.e., the inability of the instrument to produce digital readouts for automated data acquisition. A somewhat dated work reported the incorporation of a motor-driven translating cum optical level sensing mechanism [7] into a basic U-tube manometer for this purpose. Although functional, this approach is rather cumbersome to implement.

In 1999, Agilent Technologies unveiled the first optical mouse that was immune to the problems of wear and dirt accumulation. Due to the economics of large volume production, the cost of an optical mouse is extremely low. Currently, it is possible to acquire a reasonably good

  

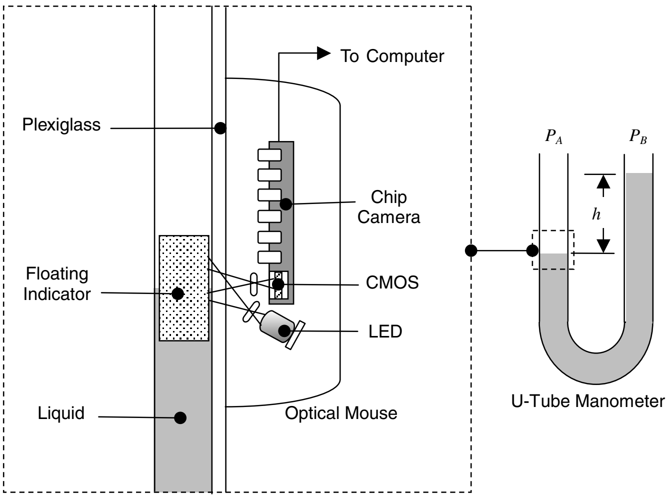


**Figure 1.** Schematic description of the setup to obtain digital readouts for automated data acquisition from a simple U-tube manometer using an optical mouse.

quality unit below US$20. The optical mouse was arguably first demonstrated to be a viable scientific sensor by Ng [8]. Since then, it has been used in a myriad of sensing applications that include region-of-interest tracking in microscopy [9], viscoelastic material deformation [10], oscillation [11, 12], flexion and lateral bending of the lumbar spine [13], indoor mobile robot odometry [14] as well as component movement in invasive surgical training tools [15].

Here, we report efforts to incorporate the optical mouse into a U-tube manometer in order to produce digital pressure readouts for automated data acquisition.

## 2. Technique description

In the setup shown in figure 1, differential air pressures—$P_A$ and $P_B$—that are applied at the arms of the U-tube manometer cause a difference in height of the liquid levels $h$ according to the relation

$$P_A - P_B = \gamma h \tag{1}$$

where $\gamma$ is the specific gravity of the liquid in the manometer. A floating indicator is placed in one arm of manometer such that it moves with the liquid level. The optical mouse is located such that it is able to sense the movement of this floating indicator. The electrical signals from the optical mouse signals are sent to a computer through the USB port for processing. Each displacement unit $x$ measured using the optical mouse should correspond to $h = 2x$ in determining the differential pressure in equation (1).

It is necessary to calibrate the optical mouse displacement units to actual displacement units using the setup described in figure 2 before using the adapted manometer. Here, the floating indicator is placed on a translator stage that has 10 $\mu$m resolution. A translator stage is basically a device that is able to provide accurate linear movement. It is commercially available and found in almost any physics laboratory. For specific amounts of movement with the translator stage, the corresponding measurements with the optical mouse were recorded.

In the experiment to test the performance of the U-tube manometer incorporated with optical mouse sensing, the liquid used was water, with one arm of the manometer air column

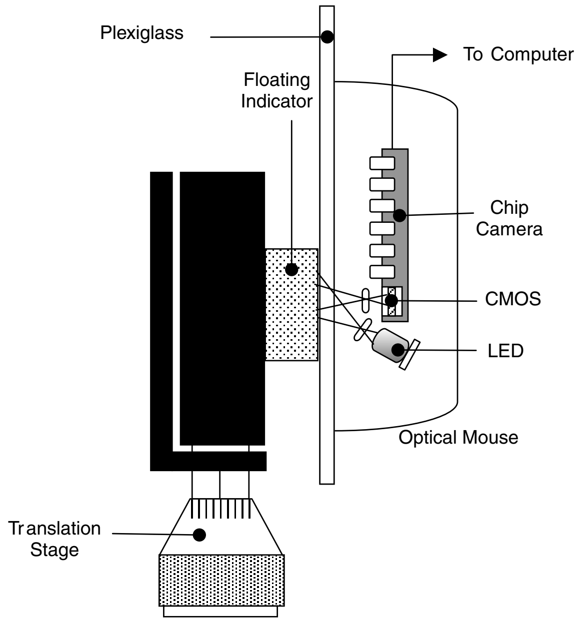


**Figure 2.** Schematic description of the setup to calibrate the translation sensitivity of the optical mouse.

open to the atmosphere while the other was connected to a syringe that supplied variable amounts of positive air pressure. Pressure readings with this modified manometer were compared with readings from an electronic pressure gauge (Digitron model 2002P with 2 bar operating range).

## 3. Results and discussion

A picture of the setup used is given in figure 3 which indicates simultaneous measurement of pressure using the setup and the electronic pressure gauge. The sensing of movement by the optical mouse can be tracked using simple algorithms [16].

The result of the calibration procedure, which gives a plot of the translator displacement against the measured displacement using the optical mouse, is shown in figure 4. From the slope of the plot, it was found that one unit of the displacement with the optical mouse corresponded to a displacement of 0.972 mm with the floating indicator. The solid line in the graph depicts the best fit linear regression of the plot. That a correlation coefficient value of 0.994 was obtained in this calibration procedure demonstrates a high linearity in which displacement measurements are possible with the optical mouse.

A typical comparative result of the pressure measurement experiment is presented in the plot of figure 5. The solid line in the graph denotes perfect correlation between both sets of data. The correlation coefficient was calculated to be 0.998, indicating a very high positive correlation between both sets of data. The pressure measurement procedure was repeated a few times and in each instance, similar results were obtained. This showed that the measurement scheme was repeatable.

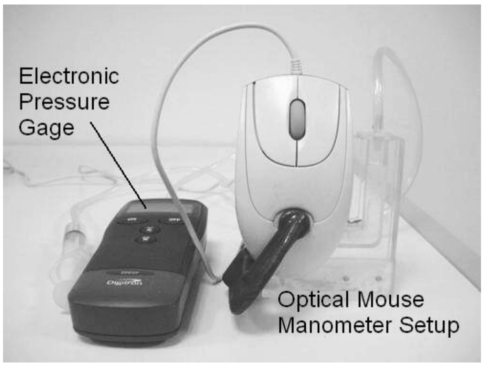


**Figure 3.** Pictorial description of simultaneous pressure measurement with the optical mouse manometer setup, and electronic pressure gauge.

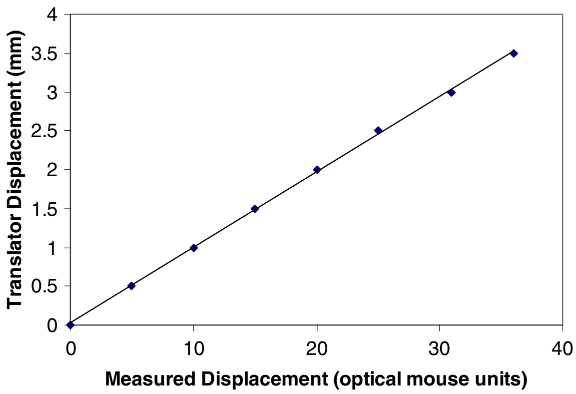


**Figure 4.** Calibrated plot of translator displacement against optical mouse displacement sensing units. The solid line indicates a best fit of the data points.

Based on the results of the calibration procedure, the pressure measurement sensitivity achievable with the U-tube manometer incorporated with optical mouse sensing in the experiment should be 1.94 Pa. This may be further improved via the use of liquids with lower specific gravity or by adopting a tilted manometer configuration.

In order to make the instrument more elegant, an attempt was made to determine if the liquid level in the manometer could be sensed without the floating indicator. We unfortunately discovered that the liquid level did not provide sufficient image contrast to cause readings on the optical mouse. It was also found that the floating indicator needed to be of the right buoyancy in order for the manometer to function properly. In our case, we used a polystyrene piece with a small aluminium piece adhered to it for added weight. We believe other alternatives should work just as well with a little prior experimentation.

It is worth highlighting that the incorporation of an optical mouse to a manometer with a circular tube housing the liquid column may present problems. This is because the optical mouse relies on imaging to sense movement of the float. A tube with circular cross section may result in image distortion or spurious reflection problems from the LED light. This, in turn, will limit displacement sensing by the optical mouse.

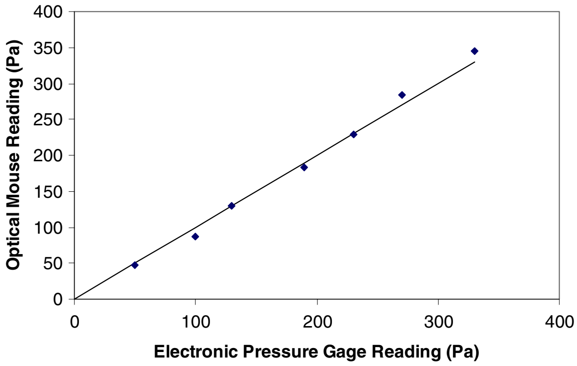


**Figure 5.** Typical plot of pressure determined using the optical mouse incorporated with a U-tube manometer against pressure determined using an electronic pressure gauge. The solid line indicates perfect correlation.

It is important to note that the manometer verification experiment was conducted using static pressure. When trying to implement the experiment with dynamic pressure, it is imperative to consider the response of the optical mouse. Previously, it was found that standard optical mice should be able to respond reasonably well if the frequency was limited to 5 Hz and the actual movement amplitude limited to 0.2 mm [11]. This then should form a general guideline when trying to monitor for dynamic pressure. Despite the limitation on dynamic pressure measurement usage, we envisage a wide scope where the digital readout scheme with optical mouse described here is applicable.

## 4. Conclusion

We demonstrate that the optical mouse can be used as tool to obtain digital readouts for automated data acquisition from a simple U-tube manometer. The approach is inexpensive and easy to implement. The measurements were also highly linear and repeatable. Based on the manometer configuration and model of optical mouse used in this work, the pressure measurement sensitivity achieved was 1.94 Pa.

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