Chapter 2

Experimental Setup: The Data Acquisition System
Chapter 2: Experimental Setup: The Data Acquisition System

2.0 Introduction

The developments in sensor technology and pattern recognition methods lead to much improvement in the odour detection system. Researchers are working around the globe on different aspect of this detection system. The prototype of an odour detection system requires a data acquisition system as well as a monitoring unit along with the setup of an array of gas sensors. Researchers are working on different setup for odour detection depending on the application. In this chapter, a literature review of different setup of the odour detection system used by different researcher is presented. The design and development of an experimental setup for real time data acquisition of different odours using an array of gas sensors is described here. Different methods for the performance enhancement of the detector system have been also reviewed. The detail design description of a heater controlling circuit of Metal Oxide Semiconductor (MOS) gas sensors is presented in this chapter. The heater controlling circuit was designed with an intention to modulate the sensor surface temperature as temperature modulation has been considered as one of the method for enhancement of the gas sensor performance.

2.1 Literature Review

The sensor technology for artificial olfaction had begun in 1982 with the invention of the first gas multisensor array [1]. The commercial odour detectors known as E-nose, uses currently only four technologies - 1) a change in resistance (shown by MOS and CP sensors), 2) a change of potential (shown by MOSFET), 3) a change of resonance frequency (shown by Piezoelectric crystals) [2], 4) Other sensor technology like fibre optic. All these sensor technologies are based on the principle that whenever volatile compounds flow over the sensor surface, a series of chemical or physical changes occurs which can be detected easily.

The first generation of electronic nose (E-nose) was based on sensor array of different types of sensors. The first generation E-nose sensor unit in 1998 used an
Chapter 2: Experimental Setup: The Data Acquisition System

HP 200LX Palmtop Computer for device control and data acquisition. The second generation E Nose has been miniaturized to occupy less than 1000cm$^3$ with a mass of 800g, excluding the computer. This generation of E-nose focuses on optimization of the responses of the array of sensors. Third generation E-Nose used the same basic sensing unit as the second generation but also includes interface unit for communication to display and data storage. The sensor array is placed in an anodized aluminum chassis [3].

Today many E-nose systems are commercially available that can be used in various applications like food processing, quality control, safety and military applications etc. Some of the most widely used E-nose with manufacturer, model, and technology used is shown in the Table 2.1. E-Nose has been used for quality

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Models produced</th>
<th>Technology basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airsense Analytics</td>
<td>i-Pen, PEN2, PEN3</td>
<td>MOS sensors</td>
</tr>
<tr>
<td>Alpha MOS</td>
<td>FOX 2000, 3000, 4000</td>
<td>MOS sensors</td>
</tr>
<tr>
<td>Applied Sensor</td>
<td>Air quality module</td>
<td>MOS sensors</td>
</tr>
<tr>
<td>ChemSensing</td>
<td>ChemSensing Sensor array</td>
<td>Colorimetric optical</td>
</tr>
<tr>
<td>CogniScent Inc.</td>
<td>ScenTrak</td>
<td>Dye polymer sensors</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Cybernose</td>
<td>Receptor-based array</td>
</tr>
<tr>
<td>Gerstel GmbH Co.</td>
<td>QSC</td>
<td>MOS sensors</td>
</tr>
<tr>
<td>Illumina Inc.</td>
<td>oNose</td>
<td>Fluorescence optical</td>
</tr>
<tr>
<td>Osmetech Plc</td>
<td>Aromascan A32S</td>
<td>Conducting polymers</td>
</tr>
<tr>
<td>Smiths Group plc</td>
<td>Cyranose 320</td>
<td>Carbon black-polymers</td>
</tr>
<tr>
<td>Sysca AG</td>
<td>Artinose</td>
<td>MOS sensors</td>
</tr>
<tr>
<td>Alpha MOS</td>
<td>RQ Box, Prometheus</td>
<td>MOS, EC, PID, MS</td>
</tr>
<tr>
<td>Electronic Sensor Technology</td>
<td>ZNose 4200, 4300, 7100</td>
<td>SAW, GC</td>
</tr>
</tbody>
</table>
Chapter 2: Experimental Setup: The Data Acquisition System

assessment of food and beverages. In [4], Pinheiro et al. used a commercially available E-nose (A32S Aroma Scan) based on 32 organic conducting polymer based gas sensor, for wine aroma monitoring produced during fermentation. They observed that without pre-treatment the sample, the E-nose could only detect the production of ethanol. However using a selective enrichment step the E-nose able to detect the compounds even in presence of Ethanol. In [5], Ragazzo-Sanchez et al. used the commercially available FOX 4000 (AlphaMOS) E-nose consisting of 18 MOS gas sensors, to differentiate between different beverages. They interfaced the system with computer through RS232 port and monitored the data by program designed in Labview. In [6], Brezmes et al. used a concentration chamber for headspace preparation of fruits and a measurement chamber of 8 tin oxide gas sensors to monitor the fruit ripening process and later used ANN to classify them. In [7], Dutta et al. used a sensor chamber of four MOS gas sensors to determine the quality of tea sample. Tea headspace was prepared in a different chamber and a diaphragm pump was used to drag the headspace to the sensor chamber. In [8], Bhattacharya et al. used 8 MOS gas sensors from FIGARO controlled by peripheral computer interconnect (PCI) based data acquisition (DAQ) system, and able to predict the optimum time required for fermentation in tea industry.

In [9], Bemabbie et al. used 8 quartz crystal based gas sensor for early detection of furinary tract cancer. In [10], Gardner et al. carried our experiments with 6 MOS gas sensors for analyzing breath samples for respiratory tract infection. In [11], Brudzewski et al. experimented with a differential E-nose having two similar arrays of 12 MOS gas sensors for the detection of explosive chemical. The differential E-nose system had good recognition performance of explosive chemicals.

In the literature it was found that different researchers developed E-nose system based upon the type of application. Researchers have worked on both commercially available E-nose setups as well as indigenously built setups. In the
Chapter 2: Experimental Setup: The Data Acquisition System

subsequent section, the design and development of an experimental setup based on MOS gas sensors for data acquisition of different chemical odours is presented.

2.2 Design of odour data acquisition system

The odour detection system popularly known as E-Nose consists of a sensor array, an odour delivery system, data acquisition for acquiring the sensor signal and a processing module for pattern classification. So the hardware unit of the system comprises of the large sensor array with its temperature control circuit and custom electronics designed for acquiring the sensor response [12-13].

2.2.1 Sensor array

Gas sensor array is the main component of the odour detection system. The gas sensor array may be of module type comprising of an array of individual sensors or several indigenous gas sensor may be used for the construction of the array. Instead of highly selective gas sensor for specific gas detection, an array of less selective gas sensors produce unique response pattern for different odours. This response pattern which can be considered as the fingerprint of the gas is used by a pattern recognition (PARC) engine for odour detection.

2.2.1.1 MOS gas sensor

Although different types of gas sensors are commercially available, MOS gas sensors are widely used by researcher because it has several advantages such as low cost and high sensitivity. Generally, metal oxides are of two types: non-transition and transition. The non transition (e.g. Al₂O₃) contains compounds with only one oxidation state and much more energy is required to form other oxidation states, while the transition (e.g., Fe₂O₃) contains more oxidation states. Therefore, transition-metal oxides can be used as sensing materials, compared to the non-transition ones [14]. Metal oxide semiconductors are when exposed to
Chapter 2: Experimental Setup: The Data Acquisition System

target odour it goes through two steps 1) redox reactions, during which $O$ distributed on the surface of the materials would react with target odour, leading to an ionic variation on the sensing surface; and 2) this variation is transduced into an electrical resistance variation of the sensors [14-16].

The main task in this research is the development and optimization of a portable odour detection system using MOS gas sensors. MOS gas sensors were chosen because these type sensors are cross selective, high sensitive, widely available and used by researchers and are low in cost. An experimental setup has been developed using several commercially available MOS gas sensors. An array with nine individual MOS gas sensors of different types as given in Table 2.2 was developed. The TGS series gas sensors are manufactured by Figaro sensors, Japan while the MQ series gas sensors are manufactured by Winsen, China.

Table 2.2  MOS gas sensors and target gas

<table>
<thead>
<tr>
<th>Sensor number</th>
<th>Sensor Model</th>
<th>Target gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TGS830</td>
<td>Halocarbon gas- R-22, R-134a</td>
</tr>
<tr>
<td>2</td>
<td>TGS826</td>
<td>Ammonia</td>
</tr>
<tr>
<td>3</td>
<td>TGS821</td>
<td>Alcohol, Solvent vapors</td>
</tr>
<tr>
<td>4</td>
<td>TGS2600</td>
<td>Gaseous air contaminants such as hydrogen and carbon monoxide</td>
</tr>
<tr>
<td>5</td>
<td>TGS2610</td>
<td>Butane, Propane</td>
</tr>
<tr>
<td>6</td>
<td>TGS2620</td>
<td>Alcohol, Solvent vapors</td>
</tr>
<tr>
<td>7</td>
<td>TGS2611</td>
<td>Methane, Natural gas</td>
</tr>
<tr>
<td>8</td>
<td>TGS825</td>
<td>hydrogen sulfide</td>
</tr>
<tr>
<td>9</td>
<td>MQ6</td>
<td>LPG, iso-butane, propane, LNG</td>
</tr>
</tbody>
</table>
2.2.1.2 Measuring circuit

MOS gas sensor is sensitive to a particular odour at a high temperature. The MOS gas sensors have a built in heating element which needs to be heated up to a certain temperature for operation. In presence of an odour the conductivity of the sensor changes and a measuring circuit is required to convert the change in conductivity to a change in voltage signal. Figure 2.1 shows the basic measuring circuit of TGS800 and TGS2000 series sensors, respectively.

The TGS800 series and MQ-6 gas sensor is a 6 terminal sensor while TGS2000 series are 4 terminal sensors. A maximum of 5 volt heating voltage can be applied to heating element for raising the sensor surface temperature. Upon exposure to the target gas, the sensor surface undergoes a variation of conductance. The conductance variation can be measured by using a standard potential divider circuit. The sensor surface forms one arm of the potential divider circuit while a fixed resistor forms the other arm of the potential divider circuit. A fixed circuit voltage is applied across the potential divider circuit for measurement. The potential divider circuit transforms the surface conductance variations to voltage variations for data acquisition.

Figure 2.1 Measuring circuit a) for TGS800 and MQ series sensor and b) for TGS2000 series sensor [17]
2.2.1.3 Sensor chamber and odour delivery

In this research, we have used nine MOS gas sensors for gas sensing. A printed circuit board (PCB) was designed in Diptrace software (Novarm Inc.) and developed for mounting the sensors. The PCB was mounted inside a plastic chamber. It was here in the chamber that a liquid volatile organic chemical was injected and headspace generated was sensed by the sensors. A small fan was mounted on the lid of the chamber for quickly evaporating the liquid chemical inside the chamber.

![Sensor array chamber](image)

Figure 2.2 Sensor array chamber a) sensor mounting PCB b) complete sensor chamber with sensors mounted

After an odour data has been acquired, the sensors and the chamber are required to be cleaned. For this purpose the chamber was mounted with necessary air tubes, solenoid valves and air pumps outside of the sensor chamber to clean the chamber by purging out the odors during the cleaning cycle. The schematic diagram of flow of odour and clean air is shown in Figure 2.3. During cleaning cycle the solenoid valves are kept open so that fresh air could be pumped inside the chamber and used gas disposed off to the environment.
Chapter 2: Experimental Setup: The Data Acquisition System

Figure 2.3  Schematic diagram of sensor chamber and other components

2.3 Sensor temperature control

The commercially available metal oxide semiconductor (MOS) gas sensors are chosen for an odour detector system as they have high repeatability, sensitivity and are inexpensive. But, they exhibit some drawbacks like cross-sensitivity, drift, ageing, poisoning etc along with poor selectivity and are prone to response drift. In practical applications various different measurement strategies like temperature modulation and signal processing algorithms have been adopted to overcome such effects [18-20].

MOS sensors combine a gas sensing surface with a heating element because sensitivity and selectivity of gas sensing materials are temperature dependent. The amount of oxygen charges adsorbed on the oxide surface depends on temperature. Again the rate of oxidation reaction increases with temperature as all adsorption, desorption, and diffusion processes are also found to be temperature-dependent [21]. The sensor response in presence of an analyte gas verses surface temperature is found to possess a bell shape becoming maximum at a certain temperature [21-24].
Chapter 2: Experimental Setup: The Data Acquisition System

Figure 2.4 Variation of gas sensor response with temperature

The sensor temperature is dependent on the voltage applied across the heater wire. Since direct measurement of the sensor surface temperature is difficult, the sensor operating temperature is expressed in terms of the heater voltage. The sensor surface temperature in air is a function of the heater voltage. Generally, a voltage of 5 volt when applied to the heater coil varies the sensor operating temperature between 300°C to 400°C which has been estimated by direct measurements of tin oxide sensor conductance in a small oven equipped with a thermocouple as presented in [23]. A constant temperature of the sensing surface can be maintained by applying a constant DC voltage across the resistive heater built into the device. If the temperature of the semiconductor surface is controlled properly, the reaction rates for different volatile components may vary as a function of surface temperature [21]. For each volatile component there would be a heater voltage for which it shows maximum conductance–temperature characteristics [7]. Modulating the operating temperature may lead to response patterns of the gas sensor array which are characteristic of the specific analyte gas applied to it.

Recent works demonstrated that modulating the operating temperature of a MOS gas sensor can achieve a high degree of selectivity [21],[25-26]. Temperature modulation of the semiconductor gas sensor using periodic heating voltage has been reported to have several advantages [26-27]. Firstly a cyclic
temperature variation can give a unique response for each gas as rate of reaction of the different analytic gases are different at different temperature. Secondly low temperature may lead to the accumulation of incompletely oxidized contaminant, which may get removed during cyclic oscillating voltage. Third, thermal cycling can lead to improvements in sensitivity because for each gas there is a heater voltage for which it shows maximum conductance-temperature characteristics.

The gas sensor heater has relatively large power consumption and hence it needs specialized circuit to deliver the power to the heater. A transistor emitter follower circuit controlled by a base voltage can be used to drive the gas sensor heater. However there will be power loss in the emitter follower transistor configuration which does not fully turn on the driving transistor and results in additional power loss in the transistor. A mixed mode temperature control circuit for gas sensors has been described in [28]. The system is basically an emitter follower based driver with an on board microcontroller for controlling. In this research a Pulse Width Modulation (PWM) based temperature control circuit of gas sensor array was considered. The requirement of the system is to design a circuit for temperature modulation without dissipating much extra power.

PWM is considered as a technique for applying power to a load in a very efficient manner without much loss of power. A microcontroller can be used to control the duty cycle of a PWM output that drives the average power to the heater. The microcontroller can be used to vary the PWM duty cycle according to a pre programmed waveform. In the following section, the design of the heating waveform generation and driving circuit based on pulse width modulation is presented. The PWM techniques have the advantage that in it the driving transistor is fully saturated as against emitter follower configuration resulting in minimum power loss in the driving transistor.
Chapter 2: Experimental Setup: The Data Acquisition System

2.3.1 Heating waveform generator

A PIC microcontroller 18F448 from Microchip Corporation has been programmed to generate 10 different modulating waveforms like DC, rectangular, sinusoidal, saw-tooth, sigmoid, exponential, triangular, decreasing saw-tooth, decreasing sigmoid and decreasing exponential waveform having amplitude of 5v and a period of 50 second. The waveforms are 8 bit encoded by the microcontroller. The 8 bit parallel digital data is available at an output port of the microcontroller. The parallel digital signal is then converted to analog signal in the range of 0 to 5 volts by a digital to analog (DAC) circuit. The DAC used for the conversion is DAC 506 manufactured by Maxim. The DAC 506 has 4 channel output, 8 bit parallel input and 2 selection lines for selecting the output channel. The analog output signal from the DAC is then applied to the input of PWM generator and driver circuit which drives the heater of the gas sensor array. The scheme of heating waveform generation and PWM driving is shown in Figure 2.5. In the next section the circuit details and working principle of the PWM waveform generation and driving circuit is presented.

![Scheme of heating waveform generation and PWM driving](image_url)

Figure 2.5 Scheme of heating waveform generation and PWM driving
2.3.2 PWM waveform generation and driving circuit

The PWM signal generation and driving circuit is based on 555 timer circuit. The detail circuit diagram of the PWM heater driver circuit is shown in Figure 2.6. The transistor Q1 in the circuit charges the timing capacitor C1 using constant current. This produces a saw-tooth waveform at point P1 as shown in Figure 2.7 (A). The frequency of the saw-tooth waveform determines the frequency of the subsequent PWM signal.

![Detailed circuit diagram of the PWM heater driver](image)

**Figure 2.6** Detailed circuit diagram of the PWM heater driver

In order to reduce the harmonic effects of the PWM signal on sensor response, the saw-tooth frequency is kept low at 10 Hz. The saw-tooth waveform at point P1 has a dc offset and rises to 2/3rd Vcc. The dc offset of the saw-tooth waveform is removed and maximum amplitude is limited at 5 volt by an op-amp (U3:A) operated as a differential amplifier. The resulting output voltage at point P2 is shown in Figure 2.7 (B). This signal subsequently goes to inverting terminal of another op-amp operated as a comparator. The other input to the comparator is
Chapter 2: Experimental Setup: The Data Acquisition System

connected to the DAC waveform signal generated by the microcontroller. Now if we assume the DAC output voltage is around 1 volt. This would produce a low voltage at the output of the comparator for the duration of the saw-tooth waveform having voltage greater than 1 volt. Figure 2.7 (C) depicts the resulting waveform at the comparator output (point P4) which is applied to the input of transistor Q2. The transistor Q2 is configured as an inverter and the resulting waveform at the output of the transistor at point P5 is depicted in Figure 2.7 (D). The signal at point P5 finally controls the power MOSFET Q3 which drives the sensor heater. The MOSFET Q3 is a p-channel MOSFET and therefore it will be on at low going duration of the waveform at P5. Figure 2.7 (E) depicts the final voltage waveform appearing across the sensor heater (point P6). The fabricated PWM waveform generation and driver circuit is shown in Figure 2.8.

![Figure 2.7 Different waveform patterns at different points of the PWM heater driver circuit](image)
Chapter 2: Experimental Setup: The Data Acquisition System

2.3.3 Test results of PWM generation circuit

The maximum heating voltage across the MOS sensor heater is required to be within 5 volt for safety of the MOS gas sensors. A margin of 0.35 volt (depending on full load current) higher voltage is applied to the input of the power MOSFET in order to compensate the voltage drop across the MOSFET. The input voltage (at drain) of the power MOSFET is set at 5.35 volt regulated by a switching regulator power module. Figure 2.9 shows the various waveforms of the circuit measured using Digital Storage Oscilloscope (DSO) at different points of the PWM driver circuit. In Figure 2.9 (B) the upper trace shows the saw-
Chapter 2: Experimental Setup: The Data Acquisition System

Figure 2.9 Oscilloscope measured waveforms at various points P1, P2, P4, P5 and P6 of the PWM heater driver circuit

tooth waveform generated by the 555 timer IC at point P1. The lower trace in Figure 2.9 (B) is the saw-tooth waveform obtained at point P2 after the differential amplifier stage. It is seen that the waveform values ranges from 0 to 5 Volts. In Figure 2.9 (C) the upper trace shows the PWM waveform produced at point P4 along with the trace of the saw-tooth waveform at point P2 when a small voltage is applied at point P3. In Figure 2.9 (D) the lower trace shows the inverted waveform at point P5 after the transistor inverter stage. The final PWM waveform applied across the MOS gas sensors is shown by the upper trace in Figure 2.9 (D) whose maximum magnitude is 5 volt.
2.4 Target odour application

Researchers across the globe have worked on various end application of the E-nose like odour detection of tea samples, wine and alcohol, perfume etc. This research aims at portable odour detection system for laboratory chemicals. A total of 16 different chemicals as listed in Table 2.3 have been used in this current research. An accurate concentration of volatile organic compounds (voc) in air can be prepared using the method presented in [29]. In this research gas sensor responses were acquired for various concentrations of the voc’s.

Table 2.3 Laboratory chemicals used for target odour

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>Chemical</th>
<th>Density (g/cm³)</th>
<th>Molecular Weight (g/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-Butanol</td>
<td>0.810</td>
<td>74.12</td>
</tr>
<tr>
<td>2</td>
<td>Acetone</td>
<td>0.791</td>
<td>58.08</td>
</tr>
<tr>
<td>3</td>
<td>Acetic acid</td>
<td>1.050</td>
<td>60.05</td>
</tr>
<tr>
<td>4</td>
<td>Di methyl sulfoxide</td>
<td>1.100</td>
<td>78.13</td>
</tr>
<tr>
<td>5</td>
<td>Ethanol</td>
<td>0.789</td>
<td>46.07</td>
</tr>
<tr>
<td>6</td>
<td>Petroleum benzine</td>
<td>0.653</td>
<td>82.2</td>
</tr>
<tr>
<td>7</td>
<td>Pyridine</td>
<td>0.982</td>
<td>79.10</td>
</tr>
<tr>
<td>8</td>
<td>Formaldehyde</td>
<td>0.815</td>
<td>30.03</td>
</tr>
<tr>
<td>9</td>
<td>Xylene</td>
<td>0.864</td>
<td>106.16</td>
</tr>
<tr>
<td>10</td>
<td>Toluene</td>
<td>0.867</td>
<td>92.14</td>
</tr>
<tr>
<td>11</td>
<td>Isoamyl alcohol</td>
<td>0.810</td>
<td>88.15</td>
</tr>
<tr>
<td>12</td>
<td>Methanol</td>
<td>0.792</td>
<td>32.04</td>
</tr>
<tr>
<td>13</td>
<td>Isopropyl alcohol</td>
<td>0.786</td>
<td>60.10</td>
</tr>
<tr>
<td>14</td>
<td>N-Propanol</td>
<td>0.803</td>
<td>60.10</td>
</tr>
<tr>
<td>15</td>
<td>Ethyl ether</td>
<td>0.7134</td>
<td>74.12</td>
</tr>
<tr>
<td>16</td>
<td>Benzene</td>
<td>0.8765</td>
<td>78.11</td>
</tr>
</tbody>
</table>
2.5 Data Acquisition and control system

The most important part of an odour detection system is a data acquisition system (DAS). The use of a microcontroller as a processor for a DAS has become popular because of its speed, energy efficiency, low cost and low weight [30]-[32], which leads to the broad use of it in Data Acquisition System. DAS is a system which is used for acquisition of signals of physical parameters continuously for a certain period of time and keeps a record of those acquired values for future use. A typical DAS has a primary control and data processor, memory and a clock for time stamping the acquired data. A number of sensor attachments are also necessary depending on the applications. As most of the internal processors are digital in nature, the analog signals are often converted to digital format before being used for processing [30]. For analysis, display and recording, the processor is further connected with computer or Laptop. The complexity of a DAS system tends to increase with the increase in the number of physical properties to be measured, resolution of Analog to Digital Conversion (ADC) and accuracy and speed of the measurement required. The universal serial bus (USB) based interface with computer is most favorable because of its high data transmission rate and ease of connectivity with computer. Hence the design of USB based multi channel DAQ system can give a high speed performance at an economical price [33-35]. In the following section the design of USB based DAS system is presented.

2.5.1 Microcontroller based Data Acquisition System

In our design, an USB based DAS system was designed using PIC18LF4553 microcontroller which is ideal for low power application. It has 13 analog input channels with 12-bit resolution ADC and has three serial ports: USB, serial peripheral interface (SPI) and an asynchronous serial port [32]. The detail scheme of the proposed design of the DAS system is shown in the Figure 2.10. The
Chapter 2: Experimental Setup: The Data Acquisition System

details of the hardware, the firmware and the software parts for the real time DAS is described below.

Figure 2.10 Scheme of the Data Acquisition System

The DAS system is basically based upon two main components – the PIC microcontroller and the USB serial converter IC. The analog signal of the sensor is fed to the inputs of the microcontroller ADC input port which converts the signal to serial digital signal. The serial data is then read by a USB-serial interface IC and is interfaced with the computer through USB port. The USB-serial interface circuit is viewed in the computer environment as virtual serial port. Hence sensor data is available in the computer through virtual serial port interface.

2.5.1.1 Microcontroller

The data acquisition system has been developed using PIC 18LF4553, which is a 8-bit mid range 40 pin microcontroller which can be powered from the PC through USB cable. The microcontroller has 13 analog input channels with 12 bit
Chapter 2: Experimental Setup: The Data Acquisition System

The Data Acquisition System uses a resolution ADC. The ADC incorporates programmable acquisition time, which allows a channel to be selected and a conversion to be initiated without waiting for a sampling period and thus reducing code overhead. As the ADC is of 12 bit resolution and reference voltage applied to the ADC is 5 volt hence it has an accuracy of 1.22 mV.

Some of its special features are [32]

1. 32 Kbytes of Flash program
2. 13 number of ADC channels
3. 5 bidirectional ports
4. One standard CCP module and one Enhanced CCP module implementation
5. Streaming Parallel Port

Members of the PIC18F4553 family are available as both standard and low-voltage devices. Standard devices with Enhanced Flash memory, designated with an “F” in the part number function over an operating voltage range of 4.2 V to 5.5 V. Whereas Low-voltage parts, designated by “LF” function over an extended voltage range of 2.0V to 5.5V. PIC 18LF4553 family devices can be programmed using either the high-voltage In-Circuit Serial Programming (ICSP) method or the low-voltage ICSP method.

2.5.1.2 USB-Serial Interface

The data so converted is now required to be transferred to PC for further processing. It can be done through serial communication interface available in the microcontroller. However modern computer and laptops does not possess the old serial port interface. Hence the USB to serial interface IC FT232R has been used in the design of the DAQ as most of the modern laptop and computer possess USB interface. The IC FT232R is compatible with USB 2.0 speed standard [34]-[37]. On the computer side the IC, FT232R emulates a virtual serial port. On the DAQ
Chapter 2: Experimental Setup: The Data Acquisition System

side the data is transferred to the Universal asynchronous receiver transmitter (UART) of FT232R. The use of FT232R facilitates the advantage of USB portability and eliminates the need to write complex code for USB communication as the communication code is to be written only for (UART) [34]. Figure 2.11 shows the circuit diagram of the DAQ system along with the sensor connections.

Figure 2.11  Circuit diagram of the designed Data Acquisition System along with sensor
2.5.1.3 Firmware for DAS microcontroller

The use of FT232R facilitates the advantage of USB portability and eliminates the need to write complex code for USB communication as the communication code is to be written only for UART. The PIC program is written in C language and compiled in mikroC (MikroElectronika) to generate the Hex file. The hex file so generated is transferred to the PIC 18LF4553 microcontroller through ICSP based programmer.

Figure 2.12 Flowchart of the firmware

The UART baud rate has been set at 115200 to maximize the data transfer rate. The communication through UART is asynchronous. The computer application program initiates the data acquisition process. The computer application requests the microcontroller for data by sending a command character through the UART. Upon receiving the command character by the microcontroller, it reads the analog input sensor data and formats the digitized data in a string “command%2d%4d%4d%4d%4d%4d%4d%4d%4d
Chapter 2: Experimental Setup: The Data Acquisition System

%4d%5dXX”, which is of length 60 characters long. In the string each “%4d” denotes the data of an analog channel represented by 4 characters, “%5d” represents the summed data of all the channels, “%2d” represents a two character command code and “XX” represents the newline and carriage return. The microcontroller also sends the heating waveform voltage as one of the channel data. A simple but effective error detection method has also been implemented in the DAQ, to detect any corrupt data that may occur in the string during serial transmission. In the method all the integer values of the channel data are added to form a 5 character integer. The 5 character integer is also sent as a part of the string. At the receiving end, the computer application performs the summation of the integer values of all the channels and matches it with the summed integer value which was sent in the string. If both the integer values do not match then data corruption is assumed to occur and the string is discarded and another string is read. The flow chart of the program so developed is shown in Figure 2.12.

2.5.2 Computer application software for DAS control

A computer application program is required for computer based acquisition, real-time graphical display and storage of the data for later processing. A suitable computer application software for DAS was developed in LabView. LabView from National Instruments Inc. consists of interactive tools and configuration utilities for Virtual Instrument Software design. LabView provides a standard library for interfacing between the hardware and developed environments in computer. The LabView program performs the task of serial reception of the data from the DAS, display the received data on real time graph and then store them. The Application program accesses the USB device as a standard serial port device of the computer [37]. The program of LabView consists of a front panel and a block diagram. The front panel of LabView program represents the user interface of the program. It consists of controls, switches, displays etc. The actual functionality of a LabView program is implemented in the block diagram. Various function nodes, structures blocks etc. are graphically interconnected in
Chapter 2: Experimental Setup: The Data Acquisition System

the block diagram to implement the functionality. Figure 2.13 shows the designed front panel of LabView based application software for DAS with real time plots of data during data acquisition.

Figure 2.13 Front Panel of LabView for the designed DAS

Figure 2.14 Overall block diagram of the application software for DAS
Chapter 2: Experimental Setup: The Data Acquisition System

Figure 2.15  Block diagram for error checking during serial transmission

Figure 2.16  Block diagram for parsing channel data from data string
Chapter 2: Experimental Setup: The Data Acquisition System

The front panel of the LabView comprises of various controls -

- Settings: To set the serial port for DAS and Sampling rate
- Hardware test: To test the hardware for functionality of various components
- Data logging: To initiate the start of data logging and stopping
- Cleaning: To initiate the cleaning of gas sensors and chamber by purging with clean air

The block diagram of the computer application software is shown in Figure 2.14, 2.15 and 2.16. Figure 2.14 shows the overall block diagram of the application software. Figure 2.15 shows the block diagram code of error checking during serial transmission. Figure 2.16 shows the block diagram code of channel data parsing from data string sent by the microcontroller. A photograph of the complete hardware setup of odour data acquisition system is shown in Figure 2.17.

![Figure 2.17 Photograph of the complete hardware setup](image)
Chapter 2: Experimental Setup: The Data Acquisition System

2.6 Conclusion

This chapter presented the development of a portable system for odour data acquisition. A literature review of E-nose systems employed for various applications by researchers has been presented. The detail design and development of an odour data acquisition system have been discussed. A circuit for heating waveform generation and PWM signal generation and driving was discussed and test results presented. The design of a PIC microcontroller based DAS system was presented. This chapter also presented the detail design of a LabView GUI based computer application program for data acquisition and control of the DAS system.

References


Chapter 2: Experimental Setup: The Data Acquisition System


Chapter 2: Experimental Setup: The Data Acquisition System


Chapter 2: Experimental Setup: The Data Acquisition System


Chapter 2: Experimental Setup: The Data Acquisition System


Chapter 2: Experimental Setup: The Data Acquisition System


