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Integration of Odour Sensing and Odour Recreation Systems using Sensor Arrays and Canister Grid

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Abstract

This paper describes the use of MOSFET Odour Sensors and Quartz Crystal Microbalance (QCM) odour sensor array to recognize odour constituents in the vicinity of the electronic nose and proposes a design of a matrix-type odour generator. The odour regenerator is responsible for remote recreation of the odours identified and transmitted by the electronic nose.
This set-up can be integrated in the fields of telemedicine [1], entertainment, educational training etc.

1. Introduction

It is well known that, in recent years, intensive research has been carried out on odour-sensing systems (electronic nose). To understand the concept of odour perception, one needs to be acquainted with the characteristics of odour and its presence in an environment[2].

Based on the application, different types of sensors are available which can be employed in the electronic nose. Apart from the two sensors described in this paper, conducting polymers and MEMS have found applications, but mostly for specific chemicals[3]. The two sensors used in the electronic nose are the MOSFET Odour Sensors and Quartz Crystal Microbalance (QCM)[4], with the former being used for detection of low molecular weight compounds and the latter for high molecular weight compounds, thereby ensuring greater accuracy in detection. This is driven by a low power chip as described in another paper[5].

Now that electronic noses are well established devices, scientists are looking toward odour reproduction. The concept of reproduction of odours has been present from the first half of the 20th century, where in devices were used to produce a fixed set of smells, and used mainly in the field of entertainment. There has always been difficulty in the recreation of the perceived odours with accuracy and on a wider spectrum. The trouble lies in the reproduction of the odours with a high degree of fidelity as has been realized in the videos and images[6]. Many odour recreation models have been designed[6], but few are practically realisable on a real-time basis, and till date, none of those are capable of being mass-produced to be sold as consumer electronics. The proposed system can provide an efficient solution to the problems, due to the relative simplicity of its overall design.

2. Proposed Implementation

2.1 Odour Sensor Unit

The odour sensor unit works on a pro-active sensing technique which is used for quantitative and qualitative analysis of the vapour mixture inhaled by the unit. The odour sensing mechanism comprises of two different sensory arrays, the MOSFET Sensing module and the QCM, which are housed in a "measurement chamber", and a breathing mechanism comprising of vents, fans and a valve. Refer Figure 1.

2.1.1 Inhaling Vent. The breathing mechanism which is situated at the face of the sensing module incorporates the vents along with small fans, to draw the air comprising of the molecules of the odour in toward the measurement chamber. This breathing mechanism, coupled with a valve, controls the flow of the air across the sensory arrays.

2.1.2 Sensor Array. The array comprises of two types of sensors:

The first, A MOSFET Odour Sensor is implemented through an array of MOSFET sensors. The sensors are nonspecific, thus each sensor individual sensor in the array is capable of reacting with several of the molecules, rather than just one. The molecules entering the sensor module contain a charge, either positive or negative, which affects the electric field inside the MOSFET. Each of the charged particles produces a unique change in the MOSFET signal, which is then interpreted through pattern recognition in the processor module (described in the next section). The MOSFET array considers the holistic effect that the molecule has on the each of the sensors present in the array to identify the molecule's fingerprint and its concentration, because, while the changes potential in a single element of the MOSFET array wouldn't be enough to identify the molecule, the varied changes in multiple array elements produce a distinctive, identifiable pattern.

Second, the Quartz Crystal Microbalance array consists of a sliver of quartz crystal with electrodes on either side. Two electrodes at different potentials create an electric field across the crystal. Due to the piezoelectric nature of the crystal, the electric field present in the rolling axis of the crystal, results in shear motion occurring in its yaw axis, and vice versa. Thus the shear waves in the quartz are coupled to voltage between the electrodes. The mechanical displacement occurs in the direction of pitch movement, which is also referred as the electric axis. QCMs are sensitive detectors of deposited mass on their surface. The exposure surface of the QCM to the molecules of the odour, results in deposition of some mass on the surface, which thereby results in change in the resonant frequency of the QCM. Measurement of the change in resonant frequency of the QCM, and some physical knowledge can yield the mass per unit area of the substance on the QCM. Because frequency changes can be measured to very high precision, QCMs are highly sensitive; capable of measuring amounts of deposited material with an average thickness of less than a single atomic layer. Thus, they prove to be efficient detectors of odour molecules.

The two sensor systems are used in combination because the MOSFET sensors are used to detect the compounds of low molecular weight, and the QCM sensors are adopted for the detection of compounds of high molecular weight[4]. Another reason for the two sensor types is the operating temperature. MOSFETs work well in warm temperatures whereas QCMs work well in cold air.[8] In case of failure in extraction of parameters of the molecules in one array system, only parameters from the array which detects the odour are propagated to the processor. The working of the two systems in tandem provides a robust mechanism for odour detection.

2.1.3 Driver Circuitry. To derive the resultant parameters from the sensory arrays, an interface circuitry and an ADC follow the sensor arrays. The digitised data is sent to the identification module[5].

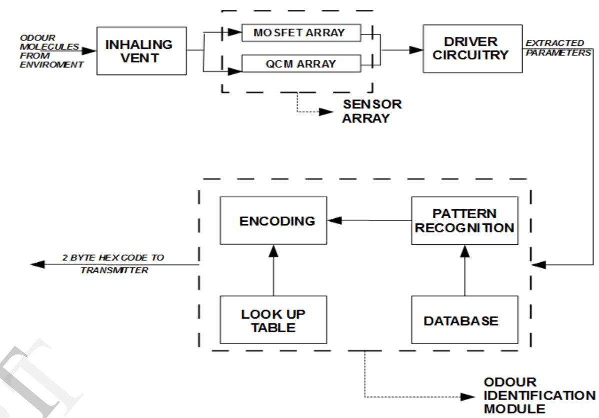

Figure 1. Odour Sensing Module

2.1.4 Odour Identification Module. The signal processing module included in this odour sensing system controls the measurement process and employs a pattern recognition algorithm. Based on the parameters extracted by the sensors, pattern recognition algorithms perform comparison and matching functions with the pre-loaded database. The database is derived experimentally from olfactometric analysis of odours. Once the compounds have been identified, the obtained information is sent forward for encoding. The odour information is encoded with the help of a look up table. The resulting data is a 2 byte code (4 digit hexadecimal), which contains the qualitative and the quantitative components of the odour that is detected. 16 bits will be used, of which 10 bits are to identify the chemical compound and 2 bits for the intensity level. The remaining 4 bits are redundant bits, leaving scope for future expansion. These encoded bytes are sent to the transmitter for transmission over a channel.

2.2 Odour Recreation Module

The odour recreation module is fed by the receiver. The responsibility of converting the encoded bit stream to human-perceivable odour lies with this component. Refer Figure 2.

2.2.1 Interpreter. The Interpretation Module comprises of a Digital Signal Processor which deciphers the characteristic odour and its intensity from the received bit stream. The decoder is referenced to a look-up table which comprises of the list of aromatic compounds loaded in the canisters. Once the compound is identified, the module generates a 4 digit number (0000 to 1023) which corresponds to a canister containing the particular volatile organic compound. An energising signal is then sent to the matrix to vaporize the compound in the matched vial. The processor controls the intensity of liberated aroma by altering the time duration of heat supplied for vaporising.

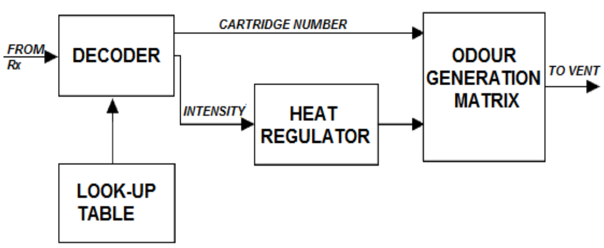

Figure 2. Odour Recreation Module

2.2.2 Odour Generation Matrix. This matrix of aromatic compounds is the key set-up for the proposed odour-recreation unit. Aromatic compounds are filled into canisters and are arranged in the form of a grid. This layout helps in indexing each compound in the database and look-up table. Though the processor has provision for indexing 1,024 compounds, space restrictions of the practical unit limit the number of canisters to a few 100. The canisters are Iron vials whose inner surfaces bear a protective Teflon coat. It is this surface which is used for vaporization of the volatile organic compound. The canisters are encapsulated in copper windings to enable Induction heating, the benefits being efficiency, speed and safety. Based on the 4-digit canister identifier generated, the processor sends a signal to energize the coils of that particular canister. This will result in the vaporization of top layer of the volatile organic compound contained.

2.2.3 Vent. It is located at the front end of the module. The vapours which are liberated from the matrix of canisters exit the module through a small fan placed near the vent. A valve is built into the pipe leading to the vent which can be used to shut off the vent when vapours do not have to be liberated.

Table 1. List of Essential Oils/Aromatic Compounds

Compound	Odour
1. Ammonia	(Very pungent)
2. Anise oil	*Saunf*
3. Balsam oil	
4. Basil oil	
5. Bay leaf oil	
6. Benzaldehyde	Almond
7. Bishop weed oil	*Ajwain*
8. Caffeine	Coffee
9. Caraway oil	
10. Cardamom seed oil	
11. Caronaldehyde	Fresh-cut Grass
12. Carvone	Spearmint
13. Chamomile	
14. Cinnamic acid	Cinnamon/honey
15. Citronella oil	
16. Clover leaf oil	
17. Coriander seed oil	
18. Cumin oil	
19. Ethanol (Dilute)	Alcohol
20. Ethyl acetate	Paint thinner
21. Ethyl Benzoate	Fruity
22. Eucalyptus oil	
23. Fennel seed oil	
24. Fenugreek oil	
25. Ginger oil	
26. Glacial acetic acid	Vinegar
27. Jasmine oil	
28. Limonene	Orange/Lemon
29. Zinc sulphide	Rotten egg
30. Methyl salicylate	Wintergreen oil
31. Mustard oil	
32. Neem oil	
33. Oregano oil	
34. Peppermint oil	
35. Rose oil	
36. Rosemary oil	
37. Sage oil	
38. Sandalwood oil	
39. Thyme oil	
40. Tsuga oil	
41. Vanillin	Vanilla
42. Vetiver oil	*Khus*
43. Yarrow oil	Bitter gourd
44. Zedoary	Camphor
45. Lactone	Red wine
46. Furaneol	Strawberry

3. Conclusion

This paper describes a system for the detection of odours using an Odour Sensor Unit, and the mechanism for subsequent reproduction of the detected odours which can be communicated over a variety of transmission channels. The encoded odour parameters may be transmitted over the telephone line, co-axial line, GSM or ZigBee[7] depending on the application. At the perceiving-end, the parameters are decoded, interpreted, and subsequently used to trigger the corresponding odours. The proposed system is also suited for specific applications such as television, as in culinary and scientific shows[9], and the field of education.

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