Gas sensing using an array of polymer-coated quartz crystals strongly driven into non-linear regimes.

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TITLEPAGE

Abstract

abstract

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1 Introduction

In our pocket we carry a device which copies almost all human senses. A camera gives your phone sight, a microphone gives your phone ability to hear, and the touch screen is like our skin, allowing your phone to feel touch. The vestibular system is mimicked by a gyroscope and accelerometer combination, and thermoreceptors by thermometers. Using GPS, your phone has a sense of direction, which is arguably something half of the human population doesn't even have.

Of course our phone doesn't need the ability to discern flavors, since it is a very picky eater anyway. It only likes electrons at a small range of potentials to get its energy from. But the underlying principle of the senses of taste and smell, namely the ability to detect molecules, can have many more uses than to decide which dish is delicious or foul-tasting. Examples of uses for a nose in your phone would be to test whether you are too intoxicated to drive, to warn whenever a dangerous amount of carbon-monoxide is in the air, XXX. Outside of mobile applications there are even more uses, such as XXX.

Many devices already exist which can mimic the function of the nose. Notable technologies are gas chromatography and spectroscopy, however these devices are often clumsy and expensive [XXX]. New methods are needed to decrease the size and cost of an electronic sense of smell. A cheap electric nose which is currently popular is [XXX]. However, it is weak at discerning molecules and requires six connections per sensor, which makes it cumbersome and bulky.

XXX something about how usually we try to be linear but we increase sensitivity and onderscheidend vermogen with non-linearity.

XXX In this paper the possibility of making a cheap, small nose with a high onderscheidend vermogen XXX is researched. Something about what experiments are described in the paper

2 Theory

2.1 Piezoelectricity

2.2 Non-linear mechanics

2.3 Resonance

2.3.1 Q-factor

The Q-factor characterizes a resonators' bandwidth relative to its center resonant frequency. [1]

2.4 Crystal oscillator

3 Method & Materials

Multiple experiments were conducted with gradually increasing complexity.

3.1 Experimental set-up

The set-up consists of the electrical system to drive the crystals and measure its response, and of the system to bring the coated crystals in contact with gasses. The two systems will be described consecutively in the following sections.

3.1.1 Eletrical system

A schematic overview of the electrical system can be found in fig:oveele. A function generator sweeps the desired frequencies, which are amplified before exciting the crystal. The voltage drop over a series shunt resistor is measured using a differential amplifier. This voltage drop, which is linearly proportional to to the current that flows through the quartz crystal as described by Ohm's law, is indicative of the changing impedance of the crystal as a function of frequency. Therefor, this signal can be used to show when the crystal is on resonance.

A more detailed schematic can be found in fig:detsch. Preliminary tests showed that the peak voltage of about $V_{pp} = 10$ V is needed to have a strong

Figure 1: Schematic overview of the electrical system of the experimental set-up.

Figure 2: Detailed schematic of the electrical system of the experimental set-up.

non-linear response. The maximum current at these voltage were about $I_{pp} = 200$ mA.

3.2 Crystal analysis

The goals of the first phase are to choose a resonator and find benchmark impedance-frequency data of the chosen resonator.

Since a mechanical resonator is needed to react to the change of mass, but it is desirable to drive and analyze the system electronically, a piezoelectric resonator is used as a transformer between the electronic and mechanical signal. Piezoelectric materials exist with a Q-factor up to XXX, but they are very expensive. Ceramic resonators are cheap, but they lack stability and have low Q-factors. A good middle ground is a quartz crystal oscillator, since they have Q-factors up to 10^6, and are mass-produced because of their use in almost any electronic device on the market.

Quartz crystals come in a variety of fundamental frequencies, shapes and sizes. For this experiment a large crystal is preferred over a small crystal, since it eases polymer coating. The fundamental frequency is preferably small, since it loosens bandwidth requirements of all components in the circuit and reduces crosstalk and phase lag XXX. The most common crystal shapes are a planar shear resonator and a tuning fork. Since the tuning fork has an irregular shape, it is hard to get an even coating. The first tests resulted in a coating which filled up the gap XXX.

The circuit used in the first test is

3.3 Measurement

Since the crystal is driven by a voltage

3.4 Amplification

Initial tests show (XXX) that a peak-to-peak voltage of $V_{PP} = 30$ V is needed to see a significant anisochronic effect. When driving the crystal with a sinusoidal signal with frequency f:

$$\frac{V_{PP}}{2} \sin 2\pi f t,$$

the slope of the signal is:

$$\pi f V_{PP} \cos 2\pi f t, \tag{1}$$

where the maximum slope is $pifV_PP$. Using crystal frequency of $f = 4.606$ MHz, the minimum slew rate of the amplifier should therefore be 425 V/μs.

The output of the mixer has a peak to peak voltage of about $V_{PP} = 20$ mV. To get the desired $V_{PP} = 30$ V, an amplification of about 1500 is needed. Since the frequency is $f = 4.606$ MHz, a gain-bandwith product of

4 Results

5 Conclusion

References

[1] Michael H. Tooley. *Electronic circuits: fundamentals and applications.* Elsevier, 2006.

A Temperature-based quartz crystal relaxation oscillator