Gas sensing using an array readout of non-linearly driven oscillators

Mars Geuze *

January 18, 2015

TITLEPAGE

Abstract

abstract

Contents

*Advisor: Warner Venstra

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 prototype of a

2 Theory

2.1 Piezoelectricity

2.2 Non-linear mechanics

2.3 Resonance

2.3.1 Q-factor

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

2.4 Crystal oscillator

3 method

Multiple experiments were conducted with gradually increasing complexity.

3.1 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

3.2 Measurement

Since the crystal is driven by a voltage

3.3 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