A Through Line Microwave sensor, with Single Cell Sensitivity for Lab on Chips Applications

Kaveh Mohammad
Dept. Electrical & Computer Engineering
University of Manitoba
Kaveh_Mohammad@umanitoba.ca

Simple low cost and sensitive electronic detectors of cells and particles are important for highly integrated lab-on-chip systems. Microwave frequency detection avoids uncertainty due to potential drops across cell membranes. At frequencies of 2 GHz the detector is largely sensitive to the volume of the dielectric particle. This work presents a simple microwave frequency detector. The operation of the sensor is based on electrical path difference in an interferometric structure.

The interferometer is composed of two paths. An RF signal is split between reference path is applied to LO input of a mixer. The other path carries the sensing signal that is applied to co-planar electrodes in a microfluidic channel. Particles are suspended in media, flowing through inside of the channel. The electrodes are connected to circuitry using a 50Ω PCB transmission line and a pair of brass wire probes. To maximize signal coupling, a circulator was used to couple signals to the electrodes. The reflected signal from channel is then amplified using a Low Noise Amplifier (LNA) to improve signal to noise ratio. By applying this signal to RF input of the mixer an output signal proportional to phase shift is produced. The reference and sensing path lengths are different. Therefore, the phase can be easily nulled by adjusting the RF generator frequency. As a cell passes over the electrodes, the phase of the sensing path shifts, producing an output signal proportional to the phase shift.

Using 6 micron polystyrene spheres in DI water for calibration, the estimated uncertainty was 670 Zepto Farad in a 56 Hz bandwidth. The sensitivity is comparable to more complex resonator designs [1]. The sensitivity was also measured for media conductivity of 1mS/cm, 3mS/cm, 10mS/cm and 30mS/cm. The measurement uncertainty was found to be insensitive to media conductivity. This detection system is useful over the full range of media conductivities used for mammalian cells.

A test with mammalian cells carried out using CHO cells and a 5 electrode chip [2]. This system has been used for monitoring cells to detect changes such as early apoptosis [3]. The cells were suspended in a 1.7 mS/cm conductivity media. In this case the middle electrode is used to apply Dielectrophoretic force to cells. The DEP force is positive for live cells, but negative for apoptotic cells. So the capacitance change detected by system is a measure of cells status.

Compared with the resonator design [1], which made use a bulky resonator and phase shifter for detection, the through line design is simpler and potentially much more compact. Nulling is easier; because adjustment is done through signal generator frequency alone without the need for a phase shifter. All the components for the through line design can be obtained in surface mount packages. Therefore, the

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through line system can be easily integrated into lab-on-chip systems where the detection of subtle (ppm) dielectric changes in the fluids or the detection of single cells is important.

The future work for this design would be integrating the sensor on a chip. To do this, first a PCB version of sensor is already being designed and tested. In this step, all of the components are replaced with and SMD version with pretty close specifications. In this step the sensitivity of the sensor is supposed to increase also. Later, all of the component should be checked to be Integratable in a chip format. So as the end goal, the sensor could be fabricated as a chip for single cell detection.

REFERENCES

