A Zinc Oxide(ZnO) Gas Sensor Approach To Measure Oxidizing Gases

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Abstract. Selective detection of gases such as Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Carbon Dioxide (CO_2), and various other volatile organic gases is necessary for air quality monitoring. The project focussed on Zinc Oxide (ZnO) as a gas-sensor and the targeted gas was Nitrogen Oxide, an oxidising gas. The conductivity of a ZnO gas sensor increases when the sensor is exposed to an oxidising gas. The aim of this experiment was to modify an existing device with the introduction of the Wheatstone bridge circuit. The magnitude of the output voltage resulting from the PSpice simulation environment lies between 0 V and 3 V and is sufficient to run a microcontroller. Simulation result complement theory.

THEORY

Metal Oxide Gas Sensor(MOGS) when exposed to gaseous chemicals may respond in such a way that their resistivity changes with concentration of the gas. ZnO is an n-type MOSG that works on chemo-resistance principle and NO_2 is an oxidising gas. When ZnO is exposed to NO_2 the following chemical reaction takes place.

$$NO_{2\,(gas)} + e^-_{(surface)} \rightarrow NO^-_{2\,(adsorbed)} \qquad (1)$$

$$NO_{2\,(gas)} + O^-_{2\,(adsorbed)} + 2e^-_{(surface)} \rightarrow NO^-_{2\,(adsorbed)} + 2O^-_{(adsorbed)} \qquad (2)$$

Electrons are taken away from the surface leading to increased resistance of the ZnO MOSG.
For this project, the gas sensor was introduced in a Wheatstone bridge which was designed to balance with no gas present.

The Wheatstone bridge equation(Eq.(3)) was captured in excel to allow comparison between simulated and theoretical results.

$$V_{out} = \left(\frac{1}{1+\frac{R_2}{R_1}} - \frac{1}{1+\frac{R_3}{R_4}}\right) V_{in} \qquad (3)$$

DESIGN AND SIMULATION USING P-SPICE

The circuit in Figure 1 was captured in P-spice with ZnO placed as shown. Experimental result showed that at 350 °C, the resistance of the sensor increased from about 347 Ω in the presence of air to 625 Ω in the presence of the targeted gas. In the simulation environment, RVAL in the circuit of Figure 1 was set to vary from 347 Ω to 625 Ω in steps of 5 Ω.

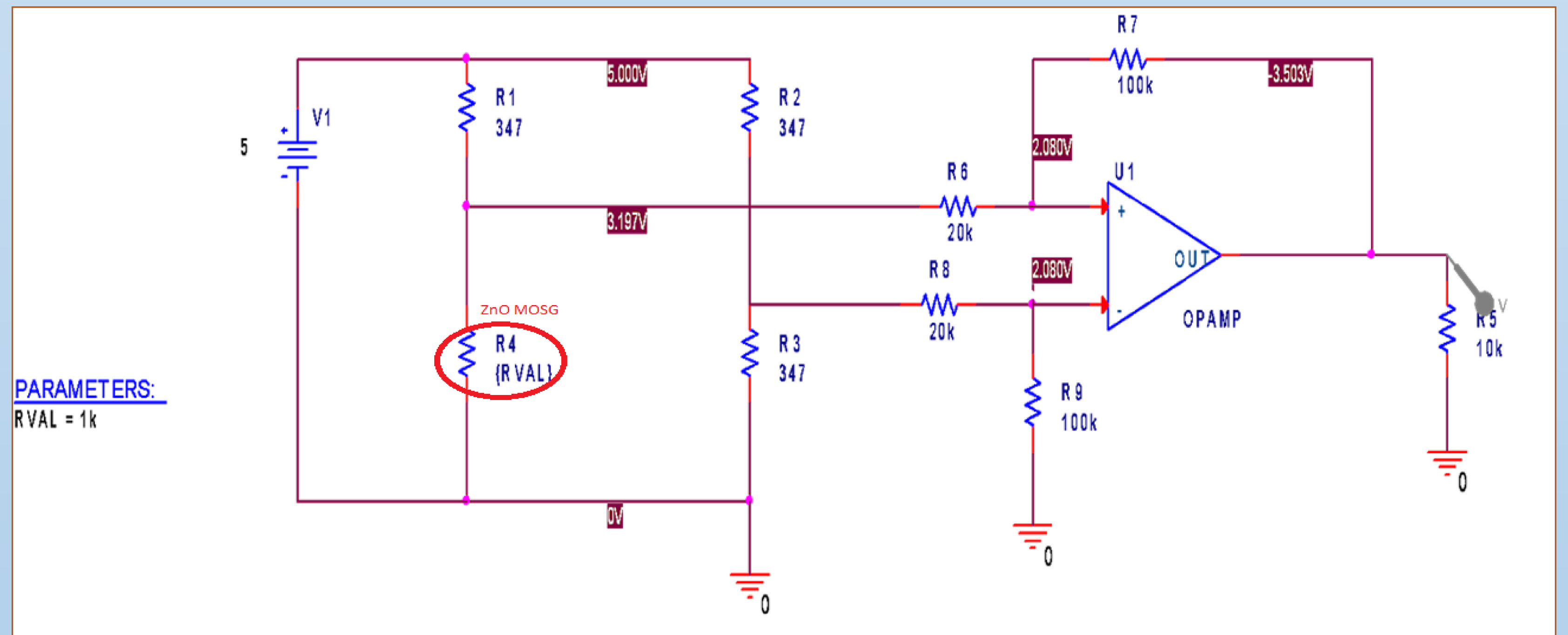

Figure 1 The schematic diagram in p-spice showing how the circuit was connected.

RESULTS

Theory and simulation results shows that as the resistance increases from 347 Ω to 625 Ω the output voltage increases negatively from 0 V to -3.5 V.

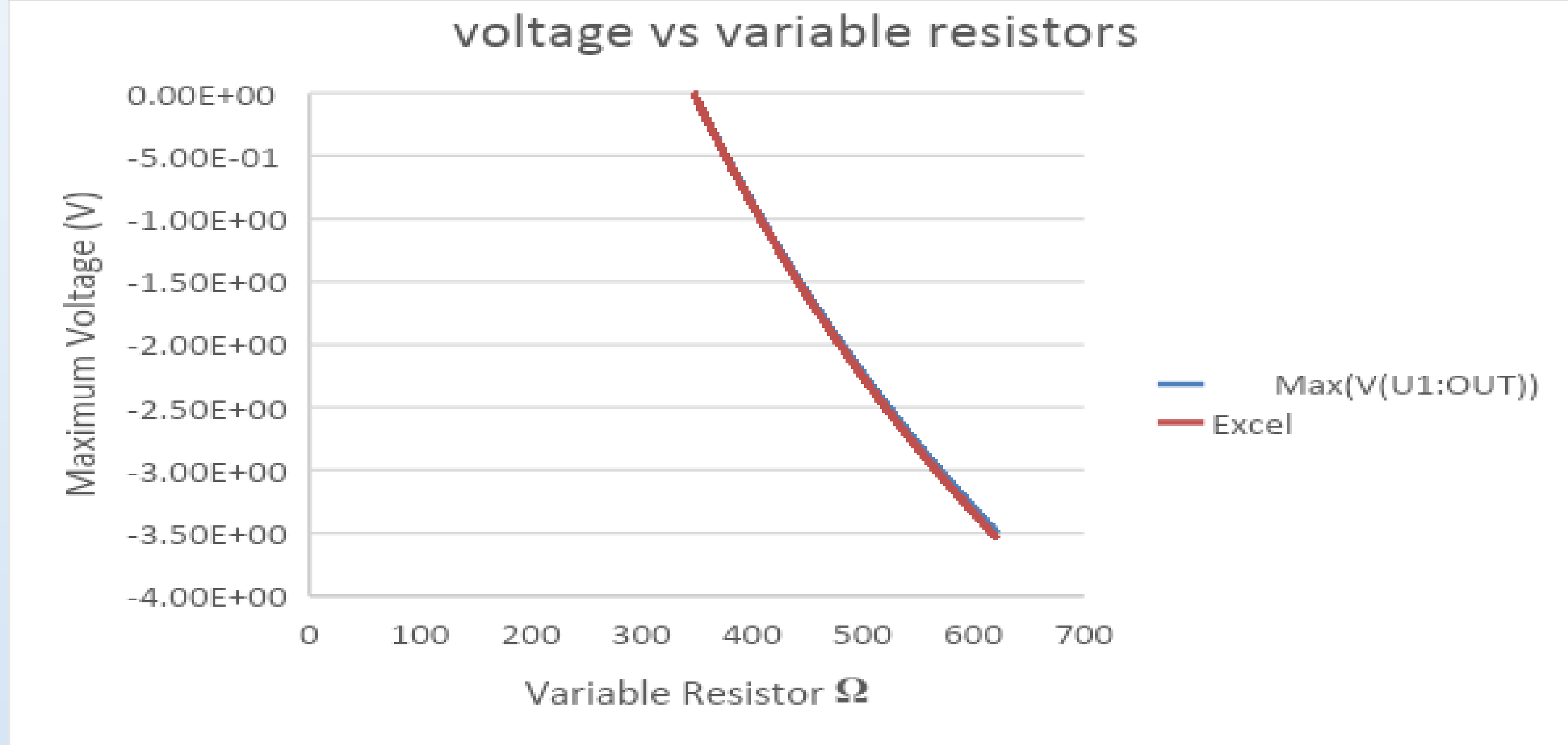

Figure 2 Simulation result for voltage versus ZnO MOSG resistance

DISCUSSION

Theoretical and simulation results were in agreement. Both curves show a negative increase of voltage as the gas enters the chamber. The voltage magnitude lies between 0 V and -3.5 V and is sufficient as an input to a microcontroller. The microcontroller can be conditioned to give an alarm indicative of an oxidising gas, whenever it detect a negatively increasing voltage.

CONCLUSION AND RECOMMENDATIONS

An oxidising gas when it included in a Wheatstone bridge circuit results in a negatively increasing voltage. The simulation was done for an oxidising gas. A colleague worked with a reducing gas. It is recommended that with ZnO MOGS in a Wheatstone bridge connected to an operational amplifier in tandem with a microcontroller would enhance its selectivity of oxidizing or reducing gases.

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