Electrochemical Sensors Application Note 2
Design of Electronics for Electrochemical Gas Sensors

INTRODUCTION

This application note gives guidance on the design of electronic circuits for use with SGX Sensortech electrochemical gas sensors. There are 4 types of circuits required for the range of sensors:

i. For sensors which have 3 electrodes, (the majority of sensors for detecting toxic gases and EC410 Oxygen sensor), the circuit required is known as a potentiostatic circuit. This circuit can either have the sensing and reference electrodes at the same potential (non-biased) or the sensing and reference held at different voltages (a biased sensor) .These circuits are described in section 1.
ii. For the dual CO & H2S sensor, which has 4 electrodes, a modified 2 channel potentiostatic circuit is used. This is described in section 2.
iii. For the 2 electrode toxic sensors (e.g. SureCO) a simpler circuit is required. This is described in section 3.
iv. For the SGX-4OX and SGX-7OX oxygen sensors the standard circuit for lead based oxygen sensors is required. This is described in section 4.

The information is provided for general advice and care should be taken to adapt the circuits to the particular requirements of the application. By following the recommendations of this application note the user should be able to achieve excellent performance with SGX electrochemical gas sensors.

SECTION 1: CIRCUIT FOR 3 ELECTRODE TOXIC SENSORS AND THE EC410

Figure 1 shows the outline block diagram of a typical gas detection system using an electrochemical gas sensor.

The **electrochemical gas sensor** requires a **bias circuit** known as a **potentiostat** to maintain the correct bias potential between the sensing and reference electrodes as stated on the individual sensor datasheet. In many cases this will be 0 V but some devices require either a positive or negative bias potential.

The gas sensor produces an output current proportional to the gas concentration. A **current to voltage converter**, also known as a **trans-impedance amplifier**, is required to convert the small currents from the electrochemical cell into a useful voltage for measurement.

The **analog to digital converter (ADC)** samples the output of the trans-impedance amplifier and produces a digital reading of the voltage level. This is used by the **microprocessor** to calculate the actual gas concentration.

The microprocessor may drive a number of **outputs** depending on the applications. These could include an **LCD display**, a **4 – 20 mA interface**, a number of **alarms** or other outputs as needed.

At some point in the system there will need to be a **zero setting** and a **gain setting** adjustment. This could be implemented in hardware at the trans-impedance amplifier, or in software within the microprocessor.

The inherent linearity of the electrochemical sensor means that for a simple application where only an analogue output is required, it is possible to dispense with the ADC and microprocessor. The voltage output of the trans-impedance amplifier can be used to provide an analog reading of gas concentration directly. More critical applications may need to compensate for ambient temperature and/or pressure.

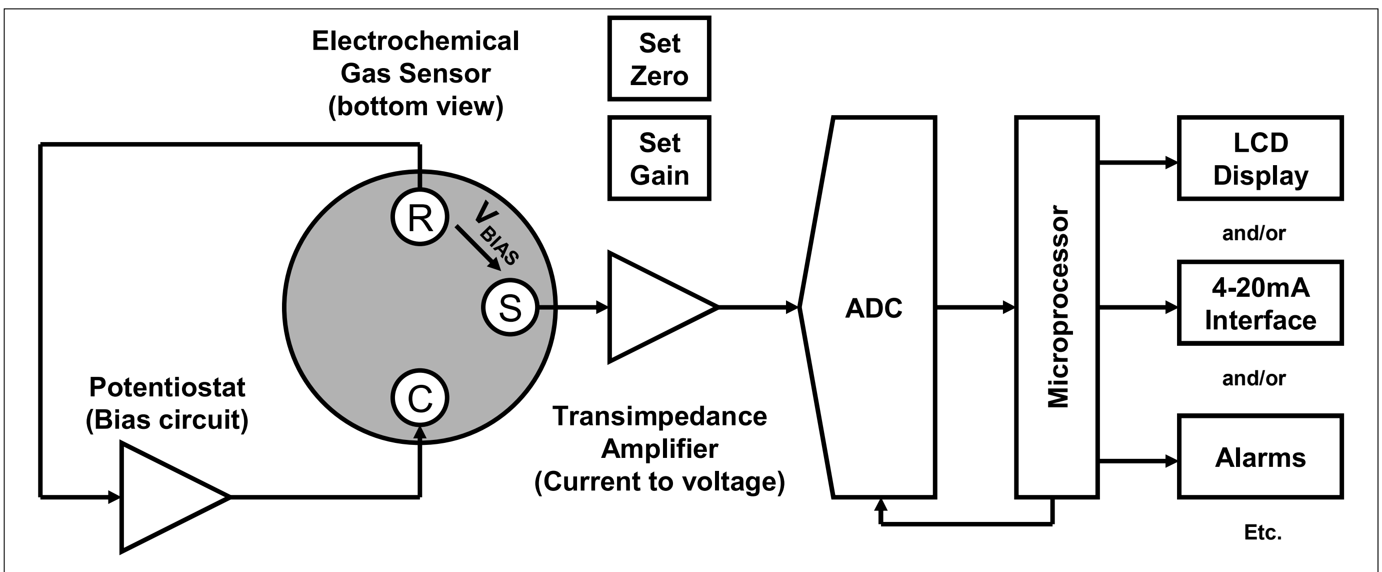

Figure 1 – Block Diagram of Typical Gas Detection System using an Electrochemical Gas Sensor

R: Reference Electrode
C: Counter Electrode
S: Sensing Electrode (sometimes called the 'Working' electrode)

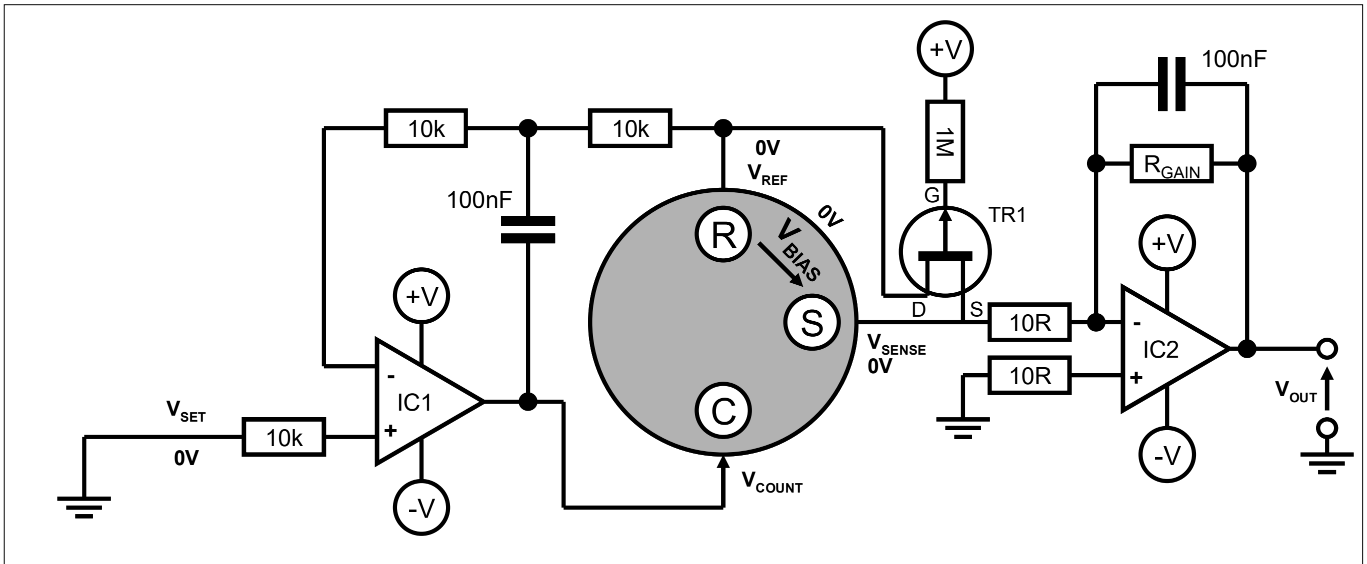

Figure 2 – Unbiased Sensor Circuit with Split Power Rails

UNBIASED SENSOR CIRCUIT (Figure 2)

Introduction to Biasing

The purpose of the sensor bias circuit (potentiostat) is to maintain the potential of the sensing electrode at a constant level with respect to the reference electrode. This is done by adjusting the voltage of a third ‘counter’ electrode.

The required bias level ($V_{SENSE} – V_{REF}$) varies according to sensor type and can be found on the relevant datasheet. It is summarised here for reference:

Sensor	Applied bias ($V_{SENSE} – V_{REF}$)	V_{OUT} Polarity
EC4-1-ClO2	0 V	Negative
EC4-50-ClO2	0 V	Negative
EC4-200-Cl2	0 V	Negative
EC4-500-CO	0 V	Positive
EC4-2000-CO	0 V	Positive
EC4-10-ETO	+300 mV	Positive
EC4-1000-H2	0 V	Positive
EC4-100-H2S	0 V	Positive
EC4-1000-H2S	0 V	Positive
EC4-250-NO	+300 mV	Positive
EC4-2000-NO	+300 mV	Positive
EC4-20-NO2	0 V	Negative
EC4-20-SO2	0 V	Positive
EC4-2000-SO2	0 V	Positive
EC410 (O2)	-600 mV	Negative
SGX-4CO	0 V	Positive
SGX-4H2S	0 V	Positive
SGX-4DT	0 V	Positive
SGX-4NH3	0 V	Positive
SGX-4OX	0 V	Positive
SGX-4NO2	0 V	Negative
SGX-7CO	0 V	Positive
SGX-7H2S	0 V	Positive
SGX-7NH3	0 V	Positive
SGX-7OX	0 V	Positive
SGX-SureCO	0 V	Positive

Table 1 – Bias Potential for SGX Sensors

Potentiostat Circuit

Figure 2 shows a typical potentiostat circuit using a positive and negative supply voltage. This configuration is simplest to explain but it can easily be adapted for single supply operation and this is described later.

Operational amplifier IC1 monitors the potential of the reference electrode, V_{REF} and applies an appropriate potential V_{COUNT} to the counter electrode to keep V_{REF} equal to V_{SET}. This potential will change as the gas concentration changes because it is supplying current into the counter electrode to balance the output current from the sensing electrode.

The majority of electrochemical sensors are ‘unbiased’ and so V_{SET} = 0 V. The potential of the sensing electrode is also held at 0V by the biasing effect of the output circuit so the result is zero bias between the V_{SENSE} and V_{REF}.

Maintaining Zero Bias during Power Down

TR1, a P-channel FET, maintains the zero bias between sensing and reference electrodes when the supply voltage is turned off. A low voltage on the gate causes the FET to conduct so that $V_{REF} = V_{SENSE}$. Holding this 0 V bias during power down enables the sensor to stabilise very quickly when the power is turned on again.

When the circuit power is reconnected, a high voltage on the gate of TR1 will cause the FET to stop conducting so that the op-amp can control the bias. TR1 should be chosen to have a positive gate-source cut-off voltage $V_{GS(OFF)}$ which is lower then the supply voltage. Transistors such as the J177 (leaded) or MMBFJ177 (surface mount) are often used. If a shorting FET is not used, the sensor may take a few hours to re-stabilise after turn-on.