Annex III: Heater driver technical description

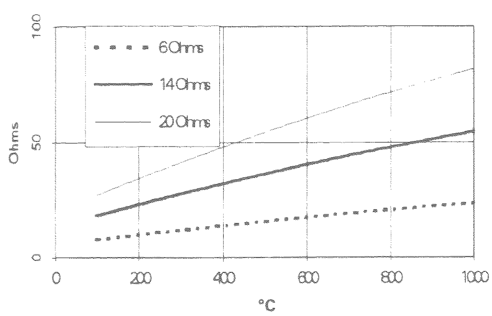


Figure 1
Heater resistance as a function of temperature

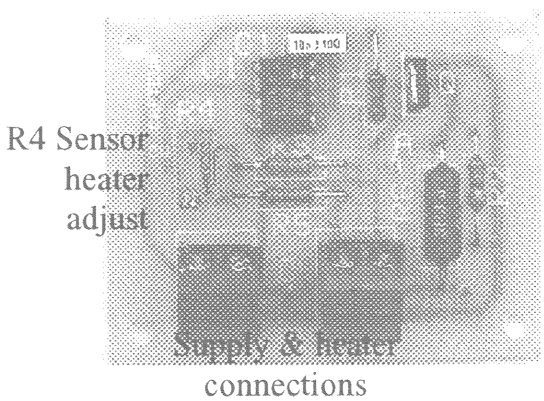


Figure 2
Heater driver PCB

It is recommended that Capteur sensors are heated using a ***heater driver*** circuit which controls the heater at constant resistance. Figure 1 shows the variation in resistance of the three heaters commonly employed by Capteur. These have resistance at room temperature of either 6Ω, 14Ω or 20Ω, and all have an approximately constant temperature coefficient of resistance which results in a doubling of the heater resistance for a temperature rise of about 400°C. The temperature of a sensor is uniquely defined by the value of the resistance adopted by the heater when it is excited by a heater driver. A constant voltage heater power supply allows less perfect compensation for ambient temperature variations than the constant resistance excitation of the heater driver. Constant current excitation is unsuitable as it tends to magnify changes in the ambient temperature, resulting in a sensor baseline which fluctuates.

Optimum stability of the output of the sensor is achieved by using Capteur Heater Driver Part Number HD/2. This can be purchased separately although it is automatically supplied when sensors are ordered with Option D = 1. The circuit board supplied by Capteur is shown in Figure 2, and the circuit diagram in Figure 3. The sensor heater forms part of a Wheatstone bridge and the current through it is controlled so as to maintain the sensor heater at constant resistance. The value of this resistance is determined by the setting of potentiometer R4 (marked 'Sensor heater adjust' in Figure 2). With the values of R3 and R5 shown in Figure 3, R4 allows the heater to be set at any value between about 10 times and twice the value of R6. Effectively, therefore, the potentiometer R4 sets the temperature of the sensor, which is controlled by op-amp U1 and FET Q1 to better than ±1°C. The supply voltage needs to be stable and about 1V above that required by the heater to achieve the correct sensor temperature.

When sensors from Capteur are purchased for evaluation purposes it is recommended that the heater is excited by heater driver HD/2, and that Capteur matches the two components to each other. This will ensure and easy start to the tests, give maximum sensor stability and make the tests largely independent of extraneous factors such as gas flow conditions over the sensor or the presence of a surrounding heat sink adjustment and the sensor will then remain at the set temperature when subjected to ambient temperature fluctuation. For 'W' Series sensors and the '1c' header option the sensor resistance can take a few hours to stabilise.

Temperature adjustment method

6. The first trial voltage to apply to the sensor heater is the numerical square root of the correct sensor heater resistance (R_{REQ}). Thus, to aim for the value of 15.5 Ω, put a voltage meter across pins B and C of the heater driver and adjust the potentiometer R_4 so that V_{BC} equals $\sqrt{15.5}$, 3.94V on the meter if only a 2 decimal place display is available.

7. Allow the circuit to settle with V_{BC} at this value, making minor adjustments to secure this value over an interval of about 2 minutes.

8. Calculate the value of the sensor heater resistance R_1 at this voltage by measuring V_{AB} and V_{BC} and employing the formula:

$$R_1 = 3.3 \times V_{BC} / V_{AB}.$$

9. Now recalculate the required voltage V_{NEW} as follows:

$$V_{NEW} = V_{BC} \times \left\{ 1 + \frac{(R_{REQ} - R_1)}{R_1} \right\}^2.$$

10. Monitor V_{BC} and adjust the heater driver potentiometer R_4 so that V_{BC} equals V_{NEW}, allowing more than one minute for the sensor to stabilise. Recalculate the resistance of the sensor heater R_2 using the equation:

$$R_2 = 3.3 \times V_{BC} / V_{AB}.$$

R_2 should be equal to R_{REQ} to better than 1%. If it is not, repeat steps 5 and 6.

11. If the sensor resistance that you now measure is different from that shown on the Capteur information sheet, firstly check the exact value of R6 by disconnecting the heater driver and power supply and measuring it with a resistance meter. If it is different from 3.3Ω use the numerical value of the resistance rather than 3.3 in the above equations and readjust the heater driver.

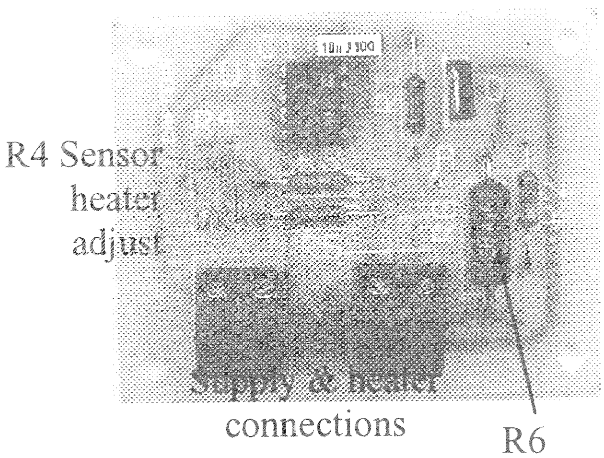


Figure 2
Heater driver PCB

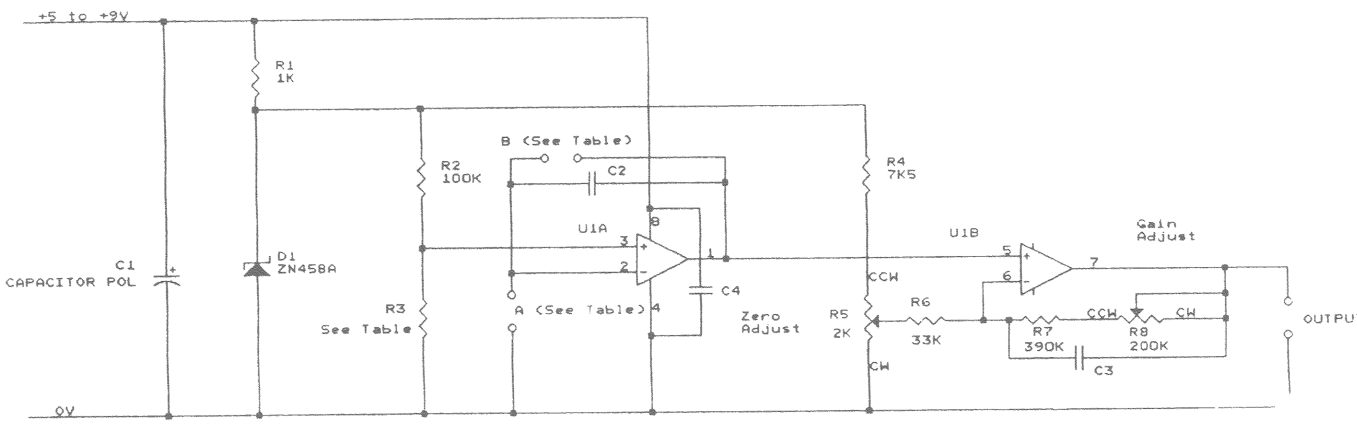
12. If there are impurities in the air around the sensor, to which it is responding, the zero resistance value measured may still not be correct. The best procedure is then to adjust the heater driver with the sensor in reference air, clean air of known humidity with other impurities less than 1 ppm.

13. Note that volatiles from adhesives, sealants and potting compounds can produce zero shifts and sometimes seriously impair sensor performance.

Annex V: A simple electronic interface for all Capteur gas sensors

The electronic circuit diagram given below illustrates an approach which can be used to convert the output resistance change of all Capteur sensors into a 'standard' voltage change. The output of the circuit is in the approximate range 0.5 to 5 volts, and it faithfully translates the sensor response function for the target gas concentration variation into a voltage output. This output can be used directly for alarm applications. It can also give the actual gas concentration by either digital (eg. use of a look up table) or analogue techniques. In the latter case the zero offset is removed and the signal then squared using fairly standard techniques in instrumentation electronics.

In the ***second stage*** of this circuit U1B has a nominal gain of 15. To obtain an output in the desired range, an input voltage change of 200 mV is required as the sensor resistance changes. This stage is provided with zero and gain adjustment potentiometers (R5 and R8).



Note: *U1 is a low voltage rail to rail op amp (eg TLC 2272CP)*

Only three resistor positions in the ***first stage*** are involved in matching all Capteur sensors to the electronics: 'A', 'B' and R3. Sensors for which the ***resistance increases*** in the target gas ***are placed in position B*** and a fixed resistor chosen to match the sensor output characteristic is put in position A. R3 is generally 10 kΩ. Sensors for which the ***resistance decreases are placed in position A***; at 'B' is located a fixed resistor (generally 39 kΩ), and a resistor selected to match the sensor is positioned at R3.

Resistor selection: resistance increasing

R1 and D1 establish a stable reference voltage of 2.45V, and through fixed resistors R2 and R3 establish a drive voltage of 222mV at the non inverting input of U1. By feedback around the operational amplifier the inverting input is maintained at the same voltage. This causes a constant current *i* to flow through the fixed resistor at A. The required 200 mV change through the passage of this current through the sensor at B develops a voltage signal, on top of the driving voltage, which is proportional to sensor resistance. The current *i* should not exceed 5μA and is given by:

$$i = \frac{200}{R_{g\,max} - R_{g\,min}}$$

where the units here and in the equations below are μA, mV and kΩ. *Rgmax* and *Rgmin* are the maximum and minimum values of the sensor resistance at the maximum and zero concentrations of the target gas. The voltage of 222mV at the non inverting input of U1 allows the value of the resistor at A to be determined:

$$'A' = 220/i\,.$$

With R3 = 10kΩ typical values of 'A' are:

Sensor range (kΩ) Rgmin to Rgmax	Resistor 'A' (kΩ)
10 to 100	100
20 to 120	110
30 to 300	300
40 to 400	390
80 to 180	110
80 to 250	180
100kto 250	160
100 to 1000 (1MΩ)	1000

Resistor selection: resistance decreasing

'A' is now the sensor and the driving voltage causes a variable current to flow through it. 'B' is a fixed resistor which is used to develop a voltage from this current. R3 needs to be adjusted in order to limit the current through the sensor. In this configuration the output voltage is as required proportional to the reciprocal of the sensor resistance. The determination of the resistor values is a two-step procedure, using the same units as previously and with *Rgmax* and *Rgmin* the maximum and minimum values of the sensor resistance, this time at the zero and maximum concentrations of the target gas respectively. The drive voltage (v) at the non inverting input of U1 for a maximum 5μA through the sensor at its minimum resistance is:

$$v = 5.R_{g\,\min}$$

R3 is then calculated as follows (bearing in mind that D1 develops 2450mV and R2 is 100kΩ):

$$R3 = \frac{100}{(2450/v - 1)}.$$

The value of the gain resistor 'B' to get the desired 200mV change is given by:

$$'B' = \frac{200}{(5 - v/R_{g\,\max})}.$$

In practise the required value of 'B' does not vary very much and a 39kΩ resistor will generally suffice to generate the required voltage of about 200 mV. Note that values of the drive voltage (v) less than 25mV should be avoided. Suitable values of R3 are tabulated below for different sensor resistance ranges:

Sensor range (kΩ) Rgmax to Rgmin	Resistor R3 (kΩ)
100 to 10	2
200 to 20	4.7
300 to 30	7.5
500 to 50	13
500 to 20	4.7

Resistance changes for different gases

The flexibility of circuits like the above make it possible to interface all the semiconductor gas sensors made by Capteur with a single PCB. Sensors are connected to the PCB at location 'A' or 'B' according to the sign of their response.

For sensors at position 'A' (resistance decreasing) only the value of R3 need generally be changed, and it depends upon the lowest value of the resistance achieved by the sensor at the maximum expected target gas concentration.For sensors connected at position 'B' the resistor at position 'A' is approximately equal to the change in the resistance of the sensor between the zero and maximum expected target gas concentrations. ***Note that*** generally for all sensors of a given type responding to a particular target gas and concentration range, only a single value of either R3 or 'A' will be required.

Screened leads should be employed to connect the sensor to the interface board.