MINIATURIZED ISFET INTERFACE FOR THE USE ON A SERIAL PC PORT

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0. Abstract

A new interface for using an ISFET (Ion Sensitive Field Effect Transistor) was developed and realized. The advantages of the new design are the small size of the printed circuit board and the low power consumption. This resulted in an electronic circuit small enough to fit in a 25 pins sub-D connector without external power supply. As the circuit is connected to the serial port of the PC, easy interfacing is guaranteed. Furthermore, no hardware calibration is necessary, all calibration can be done by software.

Keywords: ISFET amplifier, interface, serial port

1. Introduction

Because the ISFET does not give a pH dependent voltage directly, it must be part of an electronic circuit for proper operation. This electronic circuit (commonly referred to as the ISFET amplifier) takes care of setting the bias point for proper pH sensing operation.
The proposed ISFET interface consists of a low power ISFET amplifier and an A/D converter. This A/D converter can be controlled and read out by a serial PC interface.

The total power consumption of the electronics is less than 8 mA. Since the standard serial RS232 port can supply up to 10 mA, the electronics could be supplied by the computer. The size of the printed circuit board of the proto type is small enough to fit in a 25 pins sub-D connector housing.

2. The electronics

The conversion from the sensor signal to a PC signal takes three steps. First, the ISFET, which behaves like a depletion type PMOS transistor from the electronical point of view, is forced into the unsaturated mode with a constant drain current and a constant drain-source voltage. This yields a pH dependent gate-source voltage [1] where the gate is being contacted via the reference electrode and the solution. The chosen drain current is 90 µA at a drain-source voltage of 0.4 Volt.

Next, this gate-source voltage is sampled by a 12-bit analog to digital converter with a serial output. The input range of this converter is set to 0 .. 5 Volt which results in a wide allowed range of ISFET offsets, while still having a satisfying feasible pH range. For example, a pH range from 0 to 14 will cover about 14 ´ 59 mV = 0.826 Volt. So, in a 5 Volt A/D converter window, still more than 4 Volt remains for differences in the ISFET offsets. This implies that with a 12 bits sample resolution, about 10 bits are used for the pH part and the other 2 bits for the offset part. So the chosen permitted offset range reduces the resulting pH resolution. This concession still leaves an acceptable resolution of 0.02 pH per bit (5 Volt divided by 2^{12} and 59 mV/pH).

The A/D converter has a TTL level output stage (0 and 5 Volt). However, the standard serial RS232 port uses -12 and +12 Volt stages. Therefore, a third step is necessary to convert the TTL levels to standard RS232 levels.

The total dissipated current of those three blocks could be limited to 8 mA. The standard RS232 port is capable of sourcing up to 10 mA through any pin, so the power supply for the electronics could be taken from the PC by just setting a free pin to the high level. This results in a power supply of 0 (ground) to 12 Volt. Because an ISFET amplifier requires a symmetrical power supply with respect to the reference electrode, this reference electrode is shifted to half the power supply. A consequence of the reference electrode not being at the computer ground is that the system might give grounding problems when used in combination with other (electrochemical) equipment.

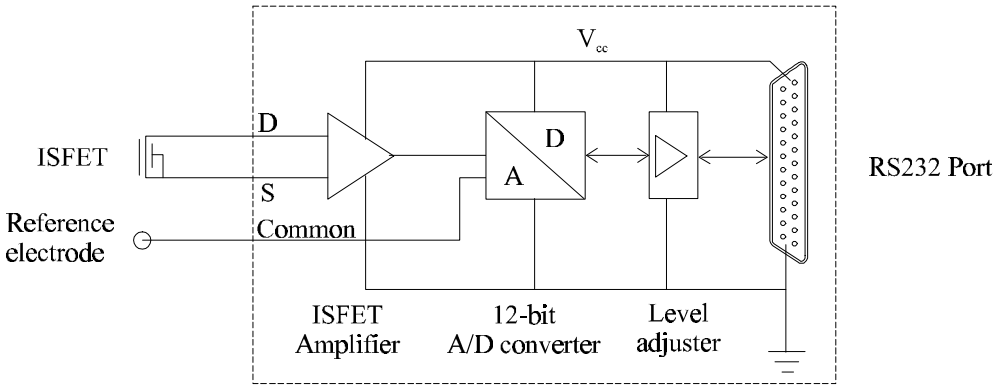

Figure 1: Schematic view of the electronic circuit

Figure 1 shows a block diagram of the whole converter. The components fitted on a single-sided printed circuit board of 3.5 × 3.5 cm (figure 2), when using SMD components this size might even be reduced.

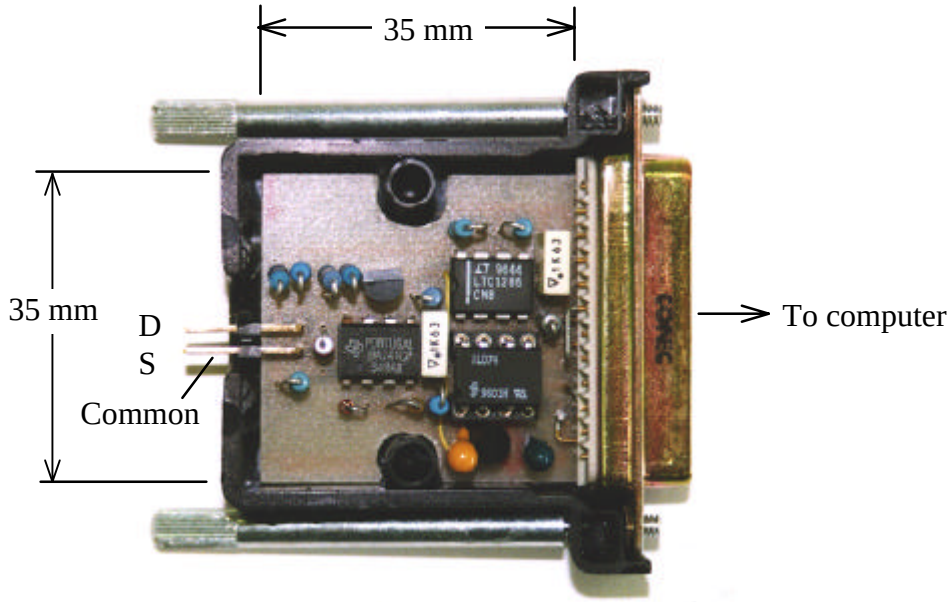

Figure 2: Top view of a completely assembled connector, S, D and Common are the connection pins for the source, drain and reference electrode respectively

Because of the low impedance characteristics of the ISFET, there are no special demands on the wiring between the probe and the converter. Using three leads of a cheap and flexible telephone wire (with almost no limits to the length) will be suitable. Notice that ISFETs should be used with the bulk short circuited to the source.

3. Software

To control and read out the interface, computer programs were written for the use under MS-DOS, MS-Windows and LabView. All programs offer an interactive calibration possibility for both one and two points calibration. These programs set the sample frequency to 10 Hz, not dependent on the used computer.

The advantage of the LabView application is that the program can be easily expanded to automated measurements set-up. For example, a drift measurement application program that stores the measured pH every minute during 24 hours can be programmed in a few minutes.

The simple MS-Windows program looks like a stand alone pH meter. All functions are accessible by menus. When the measured data need to be stored, it can be "polled" by another program like Excel using the standard MS-Windows Dynamic Data Exchange (DDE) features.

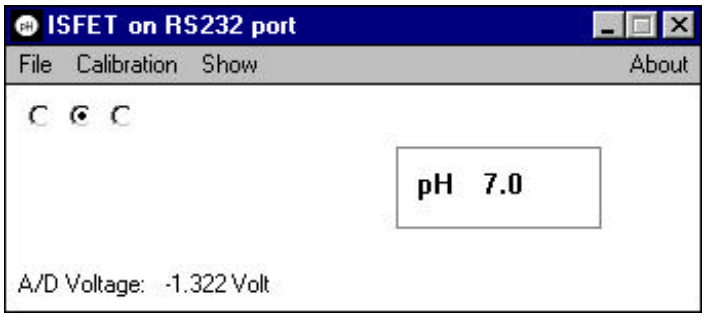

Figure 3: Screenshot of the MS-Windows program for using the converter

The screenshot, represented in figure 3, shows the MS-Windows program. Under the "Show" menu the monitoring of the A/D voltage and the calibration data can be toggled. The "Calibration" menu covers the single or two points calibration dialogs. The calibration result is automatically written to disk. When the program is started, the last saved calibration data is loaded. Using the "Settings" dialog, accessible under the "File" menu, the used COM port and the standard calibration buffers can be selected. Calibration data, being an offset and a slope, can be entered manually in this menu as well.

4. Specifications

A summary of the specifications of the ISFET to RS232 converter is given in table 1. It can be seen that neither the available resolution of the electronics (being 0.02 pH) nor the maximal allowed sample rate of the A/D converter (12.5 ksamples per second) is displayed by the software (0.1 pH and 10 samples per second respectively). This is done because in practical chemical applications these software criteria are sufficient. The overhead is used for reducing noise by software.

Table 1: Specifications of the interface

A/D Converter		
Resolution	12	bits
	1.22	mV/bit
Range	0 .. 5	Volt
Maximum sample rate	12.5	ks/s
Total system		
Size of prototype	3.5×3.5	cm
Supply current	8	mA
Resolution (at 59 mV/pH)	0.02	pH/bit
Printed circuit board	Single sided	
Software		
Operating system	MS-DOS, MS-Windows	
Displayed precision	0.1	pH
Calibration	1 or 2	Points
Sample rate	≈ 10	Hz

5. Experimental

The converter was tested using an ISFET with an Ag/AgCl reference electrode. This reference electrode was mounted on the backside of the ISFET stick in order to get a single probe pH sensor. A photograph of the system is displayed in figure 4.

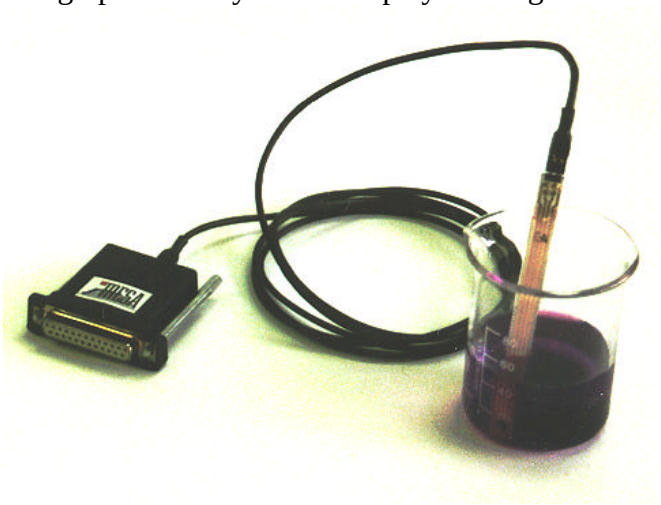

Figure 4: A complete pH measurement system

As a test, the ISFET with converter was compared to a conventional glass electrode. First, both the ISFET system and the conventional pH meter (a Radiometer PK80 with a GKH2401C glass electrode with internal reference) were calibrated using a two points measurement (pH = 4.01 and pH = 7.0). Directly after the calibration the probes were placed in a 100 mM acetic acid solution with 100 mM KNO_3 as a background electrolyte.

After applying several volumes of 1M NaOH and stirring, both measured pH's were written down. Figure 5 shows the recorded curve.

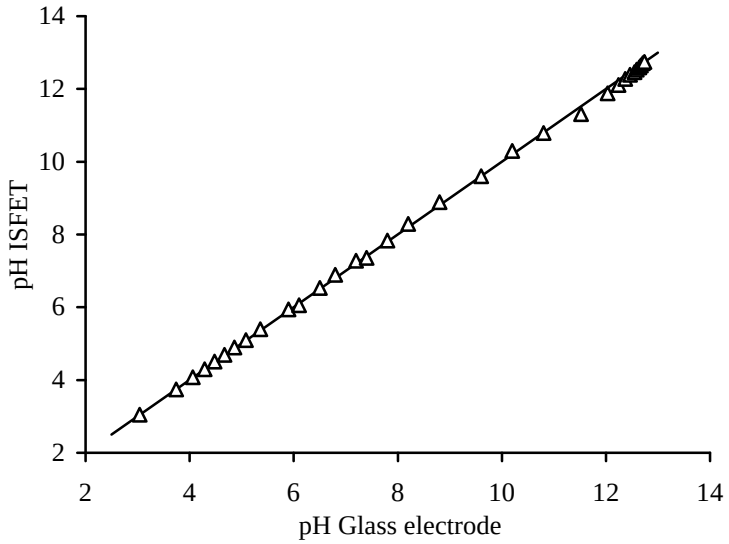

Figure 5: Comparison of a glass electrode to the ISFET system in acetic acid

It is obvious that there are no significant differences between the two pH meters. So the ISFET to RS232 converter can be used for standard pH measurement purposes.

6. Conclusions

The proposed ISFET interface offers a low-cost and small piece of hardware for sampling ISFET signals into a computer using the serial port. This interface can completely be controlled by the computer.

Besides being relatively cheap, the advantage of the device is in the field of the flexible test application building. Now the building of test applications using graphically programming techniques like LabView becomes more and more common [2], the demand rises for equipment that acquires data into the computer. The ISFET to RS232 converter appeared to be a flexible tool for acquiring pH where the calibration procedure can be implemented in software. An automated ISFET-drift measurement or titration set-up can easily be realized using graphical programming.

References

[1] P. Bergveld and A. Sibbald, in G. Svehla (ed.), Comprehensive analytical chemistry, Chapter 8, Vol. XXII, Elsevier, Amsterdam, 1988

[2] Gary W. Johnson, LabView graphical programming - Practical applications in instrumentation and control, McGraw-Hill Inc., 1994