Universal Sensor Interface Circuits Performance Evaluation for Multi Sensor Systems

Siti Nur Syuhadah Baharudin, Asral Bahari Jambek and Rizalafande Che Ismail
School of Microelectronic Engineering, University Malaysia Perlis

Abstract— This paper compares the existing implementation of universal sensor interface circuits for smart sensor systems. For this type of system, since every sensor will produce different types of output, a sensor interface that can support various types of sensors is needed. To be effective, the architecture should be low power and with a small area. Most importantly, it should be able to read various types of sensor input, especially capacitive and resistive. In this paper, five different types of sensor interface circuits are discussed and the differences inherent in each architecture are highlighted. The performance of each circuit in terms of speed, power and area also compared.

Index Terms— Sensor system, Power, Universal Sensor interface.

1 Introduction

In modern technologies, smart sensor systems will be important in future applications such as in the fields of biomedicine, industry and agriculture. For example, in the biomedical field, sensor systems are used to detect temperature, glucose and blood pressure without the use of wires. This can reduce the installation costs and allow the devices to be easily positioned at any desired points. There are many challenges when designing sensor systems such as interfacing the circuit with various types of sensors and minimizing the power consumption. Typical sensor interface circuits can only support one specific application at a time. However, current applications require a combination of different sensors in single devices [2]. Therefore, a sensor interface circuit that can receive input from various sensors is needed [2]. To solve this problem, multi sensor interfaces or universal sensor interfaces have been introduced. This circuit can reduce the design cost where it can intelligently read and process different sensor application [3].

This paper highlights several architectures for multi sensor interface circuits that have been proposed in the literature. The architectures will be discussed and compared to identify the best sensor interface architecture implementation. This paper is organized as follows. Section 2 discusses the existing methods used to implement universal sensor interface circuits. Section 3 discusses their performance comparison in terms of speed, area and power. Finally, Section 4 concludes the paper.

2 Sensor Interface Circuit

The author in [3] proposed the circuit as shown in Figure 1.The circuit consists of six main modules. They are the analogue signal router, the interface circuit, the analogue multiplexer, the digital to analogue converters (DACs), the programmable gain-stage, and a sample and hold stage. The architecture uses an analogue signal router to interface with various sensors. This router allows various sensor inputs to be connected before separating them into either a voltage, capacitive or resistive sensor. Then, the signal goes to the programmable gain stage, followed by a sample and hold stage before passing to the output.
Paper [4] utilizes analogue multiplexer and bridge circuits to reduce the overall cost as shown in Figure 2. The analogue multiplexer receives various signal inputs and channels the output to either the capacitive or resistive bridge. The output from the bridge will be passed to a shared pre-amplifier and signal conditioning circuit. The conditioned signal will be converted to a digital signal by the sample and hold, and analogue to the digital converter (ADC) circuit. Based on the architecture on Figure 3 [5], the authors focused on making their design simple by combining the resistive and capacitive inputs with the use of a capacitive sensor that uses a resistive reference and vice versa.

The authors implemented the exclusive OR (XOR) logic gate to produce digital pulse with a duty cycle proportional to the sensed capacitance or resistance without using any ADC. Next, the digital signal is fed into a decimator. Based on the architecture on Figure 4 [6], the design consists of an interface circuit, an ADC, a local configuration module and timing circuits. The circuit operates when the sensor element senses one or more physical quantities such as temperature, motion, or gasses. The interface circuit consists of an analogue multiplexer, a programmable gain and a sample and hold stage and outputs the result to the ADC. The measured data is then stored before transmitting it wirelessly to the receiver. Compared to previous circuits, this design only accepts input from capacitive sensors.

Figure 5 shows the architecture as discussed in [7]. The circuit consists of a multiplexer, reconfigurable signal conditioning, a voltage-to-frequency converter, and a microcontroller. The sensors' inputs are connected directly to the multiplexer before output he signal to the reconfigurable signal conditioning. From here, the signal is then converted using a voltage-to-frequency converter (VFC). The VFC removes the need to use an ADC to digitize the conditioned signal. As discussed in [7],

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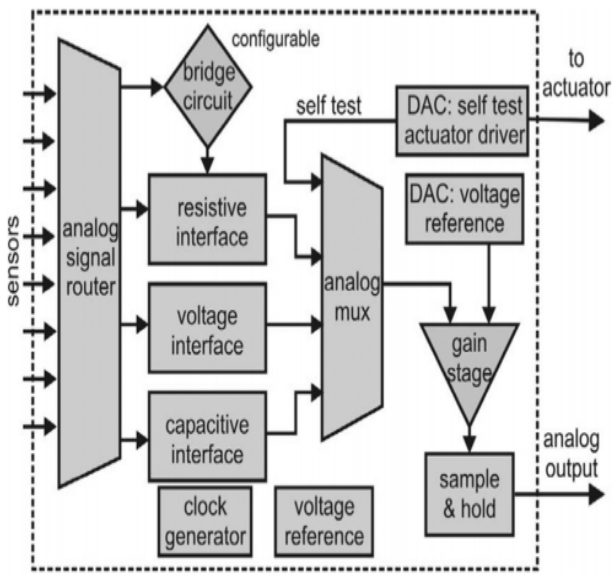

Fig. 1. Architecture [3]

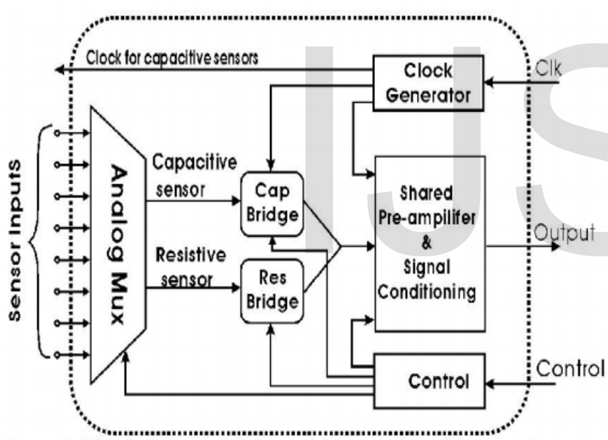

Fig. 2. Architecture [4]

The VFC has better noise immunity, wide dynamic range, and good accuracy. The output from the VFC is then fed into the microcontroller. This design has the advantage of lower cost but with the disadvantage of a slower conversion time [10].

3 Result and Discussion

Based on the existing literature, we can conclude that for universal sensor interfaces, there are three main modules to be considered. These modules are signal selection units, signal condition units and signal conversion units.

In most architectures discussed in Section 2, the signal selection unit is performed using a multiplexer. Papers [3], [4], [6] and [7] utilize a multiplexer to select the signal. In paper [5], the signal selection is unique in that it uses sensing capacitance or resistance to produce a digital signal where the duty cycle output is proportional to the sensing capacitance or resistance value.

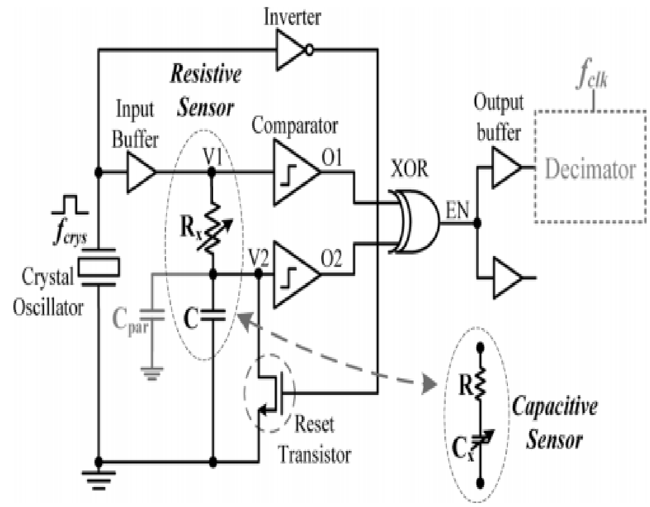

Fig. 3. Architecture [5]

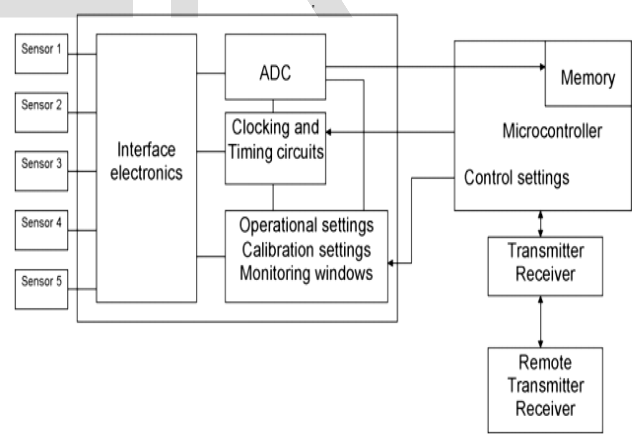

Fig. 4. Architecture [6]

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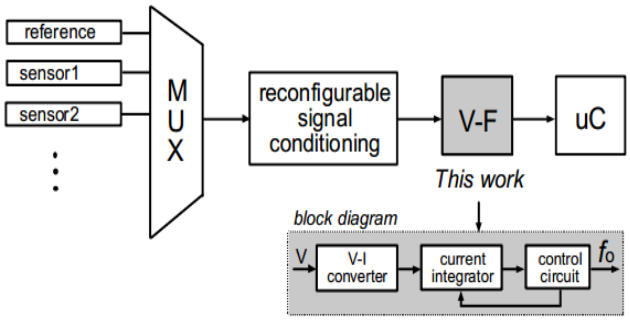

Fig. 5. Architecture [7]

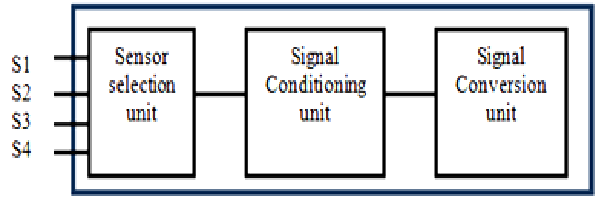

Fig. 6. Typical Universal Sensor Interface Circuit Module

Once the signal has been selected from various sensor inputs, it will be passed to the signal conditional module. The purpose of this interface is to convert low level sensor outputs to useful electronic signals. Compared to other circuit architectures, the design in [7] implements a reconfigurable signal conditioning to take into account the variety of the input types.

The signal conversion module plays an important role in universal sensor interface circuits since it provides useful input to any digital signal processing module. From the discussed papers, various methods are used to convert the signal such as using ADCs. However, paper [5] and [7] perform a different type of conversion. In [5], instead of using an ADC, the circuit converts the analogue signal to a digital pulse that has a duty cycle proportional to the input voltage signal. In [7], the author utilizes voltage-to-frequency signal conversion before it is read by the microcontroller using the internal timer as shown in Figure 5.

While signal conversion can be performed using different methods, each method has different advantages and disadvantages. Table 1 compares the advantages and disadvantages of this circuit. From Table 1, the usage of the voltage-to-frequency conversation circuit as the signal conversation circuit is attractive since this circuit is more versatile compared to other approaches. This circuit has low complexity and low design cost, and it can match the performance of many commercial A/D converters.

Table 2 compares the overall performance of the circuits in [3] to [7]. The table compares the size, power, input type, process technology and circuit features. Since each circuit is designed using different technology, comparing their performance is not a straight forward matter. Based on the table, architecture [3] provides a wider range of input sensors whereas architecture [6] only accepts input from capacitive inputs. Compare to architecture [4], [5] and [7], that use of 0.18µm CMOS, architectures [5] and [7] shows the smallest area. However, in terms of power consumption, the architecture in [7] dissipates the largest power consumption compared to the other architectures.

4 Conclusion

In this paper, the five existing universal sensor interface architectures have been discussed and compared. Based on the comparison, a universal sensor interface requires three main modules. They are a signal selection unit, a signal conditioning unit and a signal conversion unit. Since different signals perform differently, such as the signal condition module needs to be designed to accommodate different types of signal condtion module needs to be designed to accommodate different types of signal characteristic, for the signal conversion module, an ADC, VFC and digital pulse width duty cycle can be used.

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TABLE 1
COMPARISON PROS AND CONS REGARDING SIGNAL CONVERSATION

	Pros	**Cons**
ADC	Low power, low hardware complexity and good robust-ness	Introduce extra noise
Pulse	Low power	
VFC	Low cost	Low conversation time

TABLE 2
COMPARISON OF UNIVERSAL SENSOR INTERFACE (USI)

Arch	**Size (mm)**	**Power (µW)**	**Mul-ti In-put**	**Signal Type**	**Condi-tioning circuit**	**CMOS Process (µm)**	**ADC**
[3]	4.84	50	Yes	C,R, V,I	Yes	0.5	Yes
[4].	0.40	209	Yes	C,R	Yes	0.18	Yes
[5].	0.011	60	Yes	C,R	Yes	0.13	No
[6].	9.28	120	Yes	C	Yes	0.5	Yes
[7].	*0.018	*500	Yes	C,R	Yes	0.18	No