A Local Bus for MCM-Based Microinstrumentation Systems

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Abstract

A local bus is described which is designed for use in a multi-chip-composed microinstrumentation system. The bus is able to transmit a digital code, bitstream, analog voltage, frequency, duty-cycle and also provides calibration facilities, service request and interrupt request for the smart sensors. Corresponding sensor bus interface was implemented in a 1.6μm CMOS process and successfully tested in a local sensor network.

Introduction

A microinstrumentation system, as shown schematically in Fig.1, includes all features of a complex measurement system on the smallest possible material carrier; a silicon chip. The system is composed of an universal platform which is to be populated with the required sensors, micro-actuators and a microcontroller using MCM (Multi Chip Module) techniques, to solve a particular measurement problem.

The platform provides all infrastructural functions, such as power/thermal management of the system, test facilities and an on-system sensor bus [1]. The sensor bus should be versatile enough to ensure efficient communication between all sensors and systems on the platform, however, should be simple enough to be on-chip merged within platform [2]. As an additional feature the sensor bus should be able to handle both digital and semi-digital signals, such as pulse width and frequency modulated pulse series. Moreover, self-test should be implemented over the bus by using analog excitation signals and simultaneous semi-digital or digital readout.

The basic Integrated Smart Sensor bus (ISS-bus [3]) has been upgraded for this purpose, while maintaining downward compatibility. The basic ISS serial bus includes two communication wires and allows digital data transfer using the Manchester encoding scheme and semi-digital data transfer. The enhanced version of the ISS bus is based on a single controller to coordinate the activity on the bus and includes a maskable interrupt mechanism, which makes it very suitable for implementation on the microinstrumentation platform.

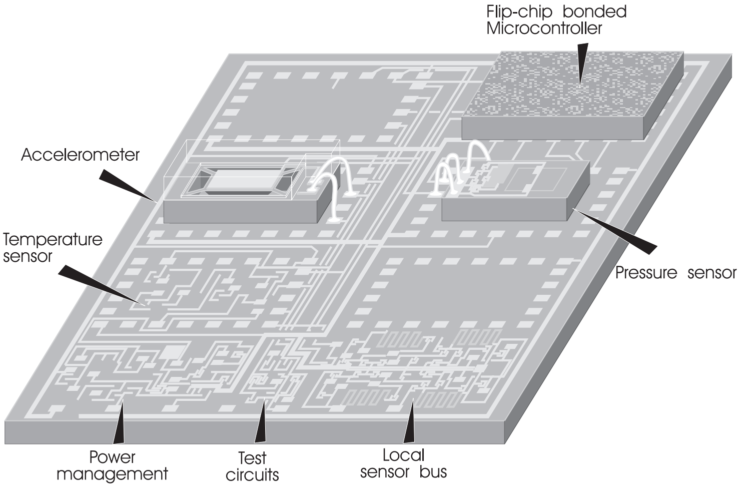

Fig.1: A microinstrumentation system.

Design and implementation

Besides the simplicity, this bus interface has two convenient features which makes it very suitable for an integrated instrumentation system, composed from several heterogeneous subsystems. Firstly, analog data can be transferred over the bus. Data generated by a sensor with limited signal processing capability usually comes in this form, so this requirement is necessary, but not present in the usual standard interfaces, which are designated to interconnect only digital subsystems (their degree of abstraction is too high).

Secondly, the use of the Manchester encoding scheme for transmission of the data at the logical level adds further flexibility. In such a scheme, the clock is embedded into the data allowing four logical level instead of having two (see Fig.2). The physical structure (physical layer) of the classic ISS bus consists of two wires, a data line and a clock line, both open drain driven. Beside these two communication lines, the subsystems have two other common power supply wires, one for the positive supply and the other for the ground. The data line allows a half-duplex communication between the modules connected to the bus [4].

In order to increase the flexibility, in the enhanced ISS bus a second data line was added, to be used for duplex transmission (e. g. in the case of an on-line sensor calibration or testing procedure). This supplementary line will be used only in the case of a duplex communication, all the rest of the protocol makes use of only the clock and primary data line.

In the case of the embedded systems, particularly for instrumentation systems, one would like to also exist some facilities for the sensor modules to announce the controller when they have available data [5], or more generally, when some particular event happened. In the developed interface this flexibility is obtained by adding an interrupt request and a service request protocol.

An interrupt request message, if it is not disabled by the configuration used for that particular module, could be sent over the bus in any moment, even if the controller was in the middle of another conversation. A service request instead is allowed only if the bus is in idle state, that is, no other communication takes place in that moment. Nevertheless, the treatments of both interrupt and service requests by the controller are unified in a single mechanism, since both represent the same abstraction: a request message from a slave module. Except for the request messages, all the other messages are initiated by the controller and are frame oriented.

The length of the frame is variable, depending on its significance. The structure of the bus interface is shown schematically in Fig.3. These functions have been realised in a 1.6 μm CMOS process. A photograph of the chip (1.5x0.7 mm^2) is shown in Fig.4.

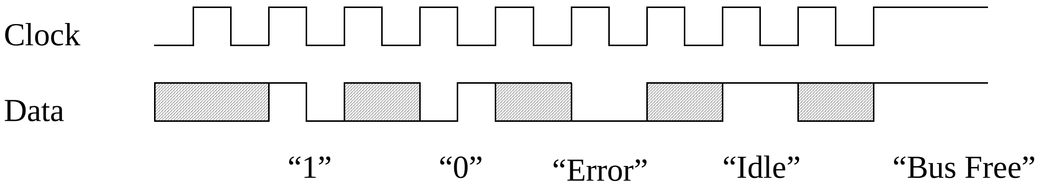

Fig.2: Manchester encoding scheme.

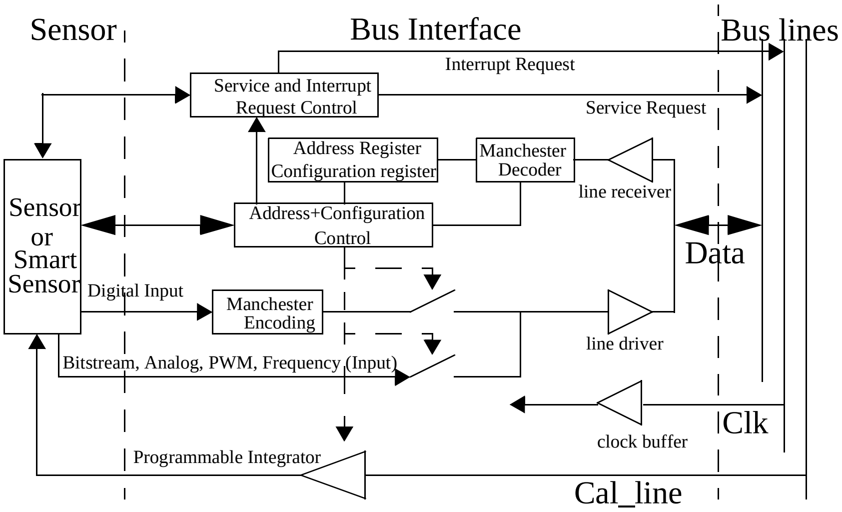

Fig.3: The block diagram of the bus interface.

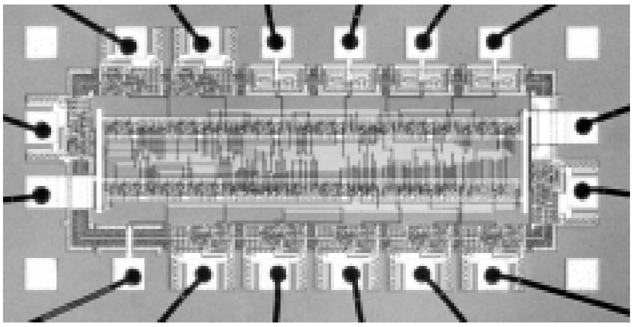

Fig.4: A microphotograph of the bus interface.

Experimental results

A typical addressing sequence transmitted serially over the data bus has been recorded and is shown in Fig.5. The frame transmitted was composed by start bit, 4 bits for the sensor address more 4 bits related with sensor internal configuration. The chip has a power consumption of 500μW (5V@100kHz) and 2mW (5V@4MHz). A network with three bus interfaces was implemented and the request block was successfully tested.

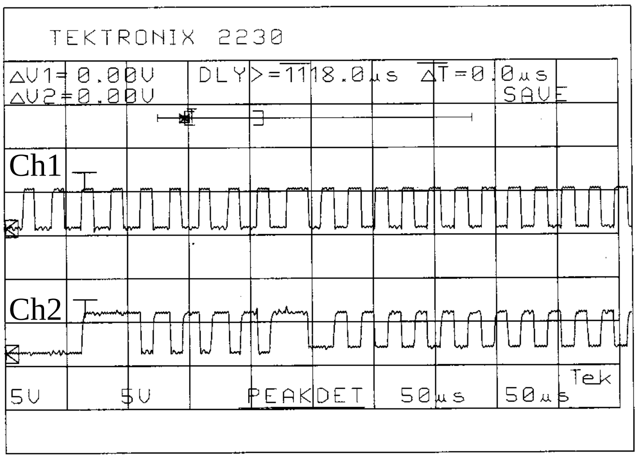

Fig.5:A plot of clock and data lines from the oscilloscope.

Conclusions

The features of the microinstrumentation bus interface are:

- Simplicity of structure; only two communication wires are used in the minimum configuration.
- Reliable data transfer by using the Manchester encoding with error detection schemes.
- Flexibility of signal type, as synchronous and asynchronous transmission of digital data is possible in combination with semi-digital signals, such as bitstreams, or even analog signals.
- Flexibility of signal handling based on a maskable interrupt mechanism.
- Sensor self-test capability over the bus using separate directional data lines.
- To be used as a separate die in microsystems and also suitable for on-chip integration with sensors.

The features of the bus claimed above have been demonstrated, which makes it suitable for implementation in a practical microinstrumentation system. An update version of the chip in a 0.7 μm CMOS process will decrease significantly the total chip area and the power consumption.

Acknowledgements

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