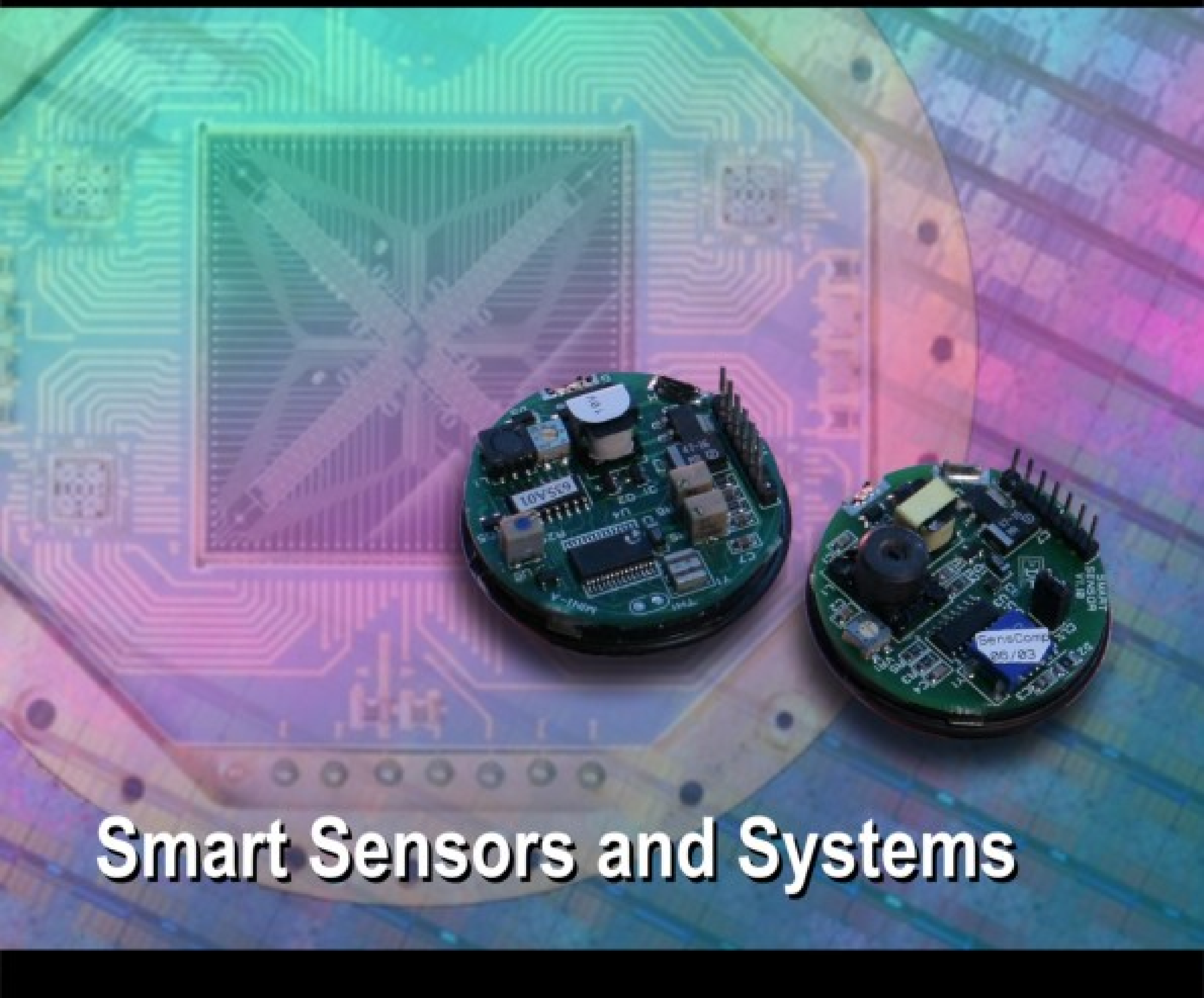
ISSN 1726-5479

SENSORS & TRANSDUCERS

3/09 vol. 102



Smart Sensors and Systems

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 102, Issue 3
March 2009

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and CD-ROM.

Sensors & Transducers Journal

Contents

Volume 102
Issue 3
March 2009

www.sensorsportal.com

ISSN 1726-5479

Research Articles

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

International Frequency Sensor Association (IFSA).

Sensors & Transducers Journal, Vol. 102, Issue 3, March 2009, pp. 115-120

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

RBIC-Lite – a Family of Signal Conditioning ICs of ZMD

Krauss GUDRUN, Krauss MATHIAS
ZMD America, Inc. 201 Old Country Road, Melville, NY, 11747, USA
Tel.: 631 549 2666, fax: 631 549 2882
E-mail: gkrauss@zmda.com, mkrauss@zmda.com

Received: 18 February 2009 /Accepted: 24 March 2009 /Published: 31 March 2009

Abstract: A family of low-cost signal conditioners for bridge type sensors is described, which has state–the-art features like chopper stabilized analog front end, high resolution A to D conversion, digital calibration math based with EEPROM stored coefficients and a variety of digital and analog outputs. Besides that, useful features like power safe mode, internal regulator and diagnostic functions are also available. The paper focuses in particular on end-of-line calibration which is supported by ZMD's proprietary one wire protocol. *Copyright © 2009 IFSA.*

Keywords: Sensor signal conditioner, End-of-line calibration, Bridgetype sensor conditioning

1. Introduction

The increasing need to measure the analog world and connect it with digital signal processing results in a rapid development of the sensor technology. The transformation of the analog electrical sensor raw signal into a standardized digital/analog output signal with the tasks of signal amplification, error correction and removal of unwanted environmental influences (for example, temperature dependence), are summarized as sensor signal conditioning. With the ability of integrating analog and digital functions on a chip, this functionality suggests the development of a standard sensor signal conditioner (SSC), especially for conditioning of Wheatstone bridge sensors. This sensor type is widely used for pressure measurement, force measurement as well as magneto-resistive bridges in the linear and angular position measurement. The differential output signal and the ratiometricity, i.e. the strict proportionality of signal and supply voltage, connected with this sensor principle, offer ideal conditions for a very robust but precise signal processing in relation to disturbances of any kind. A substantial advantage of ZMD's standard SSC is the method of the calibration procedure as one of the cost-determining factors in the sensor module production. The conventional calibration method with potentiometers and laser-trimmed correction resistors is characterizes by a complex, usually iterative calibration process, insufficient calibration accuracy (only gain and offset) as well as insufficient stability. The "END OF LINE" calibration, implemented in ZMD SSC for several product generations, eliminates multiple iterations.

Ideally, a universal SSC IC, offering all feasible features to interface with the wide variety of resistive bridge sensors and supporting a variety of different analog and digital standard outputs is one reasonable approach for a standard product. To address this, ZMD has developed the ZMD31050 RB$^{IC™}$ to cover the many different applications.

While very attractive to many custom transducer manufacturers, such solutions do not apply to requirements aligned with a single application requiring:

- Low power
- High degree of miniaturization
- Optimized cost

The following product outline describes the RB$^{IC™}$ family of "Lite" products developed by ZMD based upon the modular concept of the ZMD31050 that addresses these requirements. The core blocks and the associated features of the Lite IC family are explained in detail (Fig. 1).

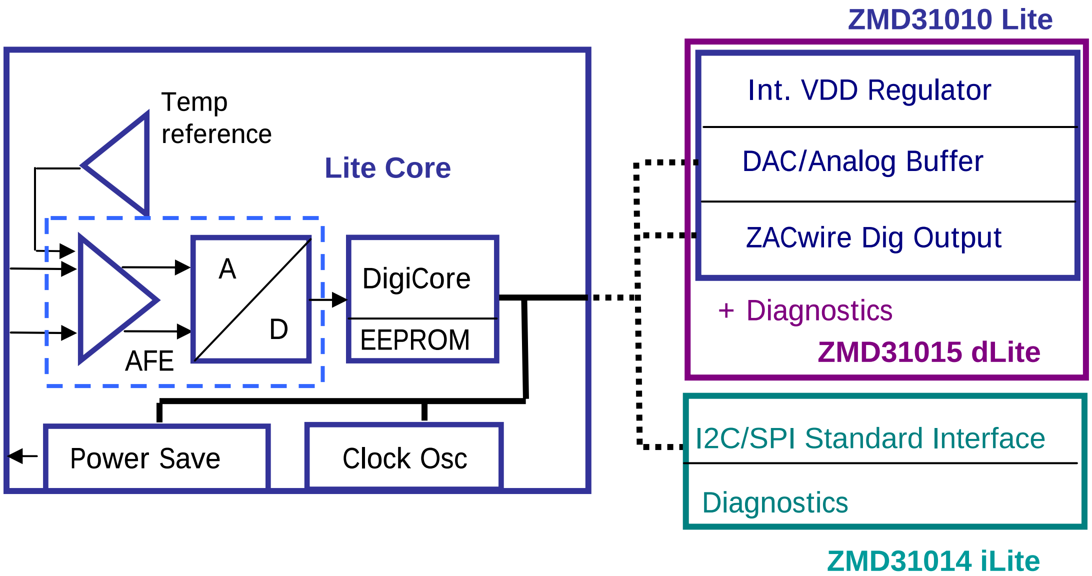


Fig. 1. Block diagram with core blocks and optional blocks.

2. Analog Front End (AFE)

The analog front end is characterized by the following blocks:
- Chopper stabilize pre-amplifier
- Second-order Charge Balancing A/D Converter
- Input multiplexer with Auto-zero function.

To reach the required output resolution of 10 to 12 bits to, the AFE must be configured in its pre-amplification (GAIN parameter) and by an adjustable zero point shift (ZERO parameter) roughly to the actual output voltage range of the sensor (see Fig. 2).

In greater time steps the temperature signal and the offset (Autozero) are sampled by the AFE.

The simplification of the AFE of the Lite product family compared to the universal SSC consists in the following:
- Applicable only for bridges with voltage excitation;
- Optimized, two-stage pre-amplifier with only 2 to 6 configurable GAIN values and without analog pre-compensation of higher bridge offset voltages;
- The 14 bit A/D converter compensates the resolution loss due to the less exact adjustment of the AFE to the sensor signal range.

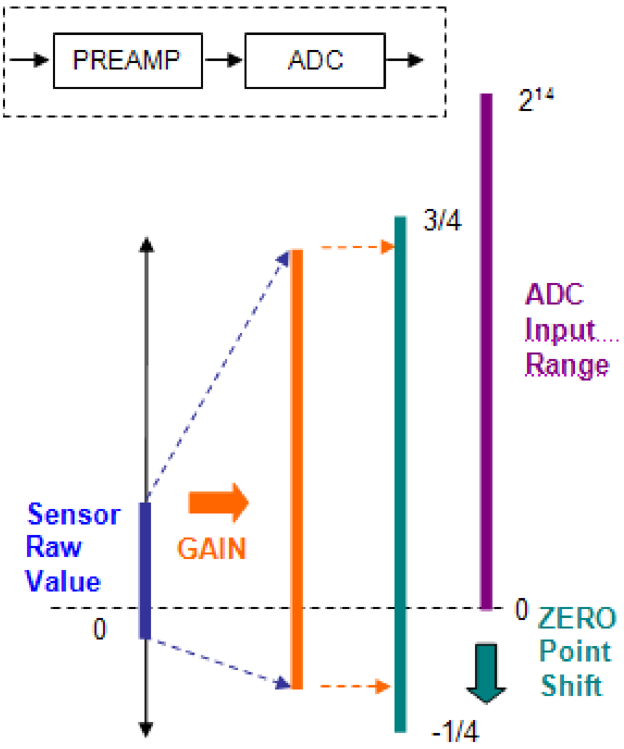


Fig. 2. AFE Configuration.

3. Digitally Core

In principle, a micro controller can provide functions like clock control of the analog circuitry, the correction calculation and the implementation of the serial communication interface. Considering less complex calculations, further chip size reduction can be achieved by using a state machine concept as is realized in the ZMD Lite product family. The retention of 16 bits processing and data width of the EEPROM coefficients together with the 14 bit A/D conversion guarantees the required computational accuracy and overflow security in the fixed-point arithmetic. Basing on a polynomial approach the implemented mathematics calculates the corrected output signals using the stored calibration coefficients and the already auto-zero compensated ADC raw values of the bridge signal and the temperature signal. For low power applications, which require only a few measurements per second, the so-called update mode is available. Between the single measurements, the IC is in standby mode and the bridge is deactivated.

4. Back End

The I^2C and SPI protocols are the most common digital interfaces for the sensor signal readout. The ZMD31014 supports at the output only these two protocols. Giving up the analog output an average current consumption can be achieved as low as some 10µA in the update mode. The digital interface serves also the so-called "END OF LINE" calibration, which prevents that possible changes of sensor parameters during the module manufacturing process due to mechanical or thermal stress can influence the calibration. There appears a time window of some ms after power ON, in which the IC must receive a certain command in order to enter the communication mode. Otherwise the IC continues in the normal operation mode.

5. Diagnostic Functions

Detectable error states with the Lite product family include sensor errors (loss or short-circuit of bridge connections), data errors in the EEPROM of the SSC IC (check sum error) and power and ground loss as well.

Additional to the diagnostic functions part traceability of failed units is required for today's quality standards. This is supported by space for customer data reserved in the EEPROM. An EEPROM LOCK function with the ZMD31014 prevents from changing of the EEPROM data after distribution of a sensor module.

6. One Shot "End of Line" Calibration

A very cost-sensitive part of the sensor module mass production is the calibration procedure, in which different pressure and temperature values (especially time intensive) must be applied to each module several times. To reach a flexible and effective calibration process, the following has to be made sure:

- Calibration without iterative steps
- Raw data collection in arbitrary order
- Raw data collection, determination of the correction coefficients and programming as separable processes
- The quality of the calibration result must be independent of whether the values were intended for pressure and temperature by accurate reproduction of the operating points or by accurate back measurement in the respective operating point.

An example for the calibration procedure will be explained for the sensor characteristics represented in Fig. 3.

In this case all 7 of the coefficients possible with the ZMD31014 are used for the bridge correction. After acquiring the raw data in 7 calibration points the 7 coefficients can be computed. In order to minimize the random measurement and rounding errors those points should lie close to the respective limits as well as in the center of pressure and temperature range.

$$RB = O * (1+ TCO1 * ZT + TCO2 * ZT^2) + G * (1+ TCG1 * ZT + TCG2 * ZT^2) * ZB + SOT * ZB^2, \quad (1)$$

where G is the Gain correction factor ("digitally zoom " up to x64); O is the Offset correction; SOT is the second order term for the correction of the nonlinearity by a polynomial of second order; TCO1 and TCO2 are terms for the compensation of the Offset TC (first and second order); TCG1 and TCG2 are terms for the compensation of the Gain TC (first and second order).

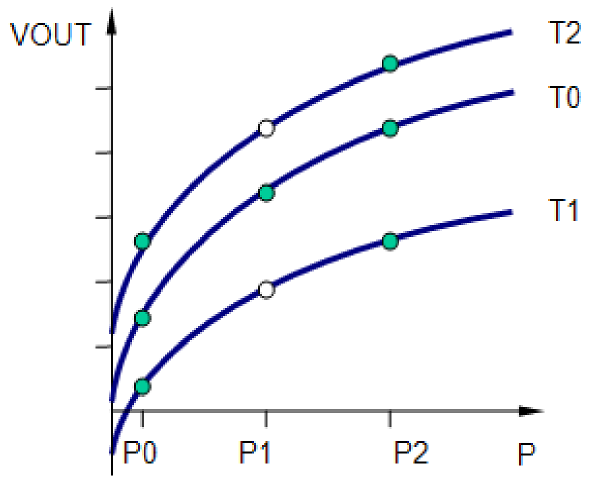


Fig.3. Measuring Point Order.

The errors at the calibration points become zero, though, the error in the ranges between them will be the smaller, the better equation (1) describes the real, physically caused sensor behavior. The solution of the polynomial equation set, in particular if the operating points are not strictly fixed (back-measured values), can be calculated by a nonlinear optimization method (curve fitting). For that reason in the ZMD development software offered for the Lite products the Excel Solver is merged into the DLL for the step of the coefficient calculation. With the process steps of digital raw data acquiring, coefficient calculation by curve fitting and programming of all coefficients (One Shot), the Lite product family fulfills all conditions for an effective calibration procedure mentioned above.

7. Summary

With the addition of the ZMD31014 iLite™ signal conditioner with digital I^2C or SPI interface, ZMD addresses high functionality, low power and low cost as required in certain high volume applications. The Rbic "Lite" SSC name is synonymous in this family of products, with iLite being the latest part in this series Following our slogan "In a World of Complexity, Simplicity is Key", overkill features have not been implemented in these products. Functionality, which extends the field of application without high auxiliary costs, is clearly the consideration in the concept behind the ZMD31014 RB^{IC} iLite™. Optimization for low power and easy micro-controller interface are its key attributes.


IEEE
Celebrating 125 Years
of Engineering the Future
IEEE SENSORS 2009 CONFERENCE
SENSORS 2009
NEW ZEALAND
OCTOBER 25-28, 2009 • CHRISTCHURCH, NEW ZEALAND
Announcement and
CALL FOR PAPERS
IEEE Sensors Conference 2009 is intended to provide a common forum for researchers, scientists, engineers and practitioners throughout the world to present their latest research findings, ideas, developments and applications in the area of sensors and sensing technology. IEEE Sensors Conference 2009 will include keynote addresses by eminent scientists as well as special, regular and poster sessions.
TOPICS:
Phenomena, Modeling and Evaluation
Biosensors
Mechanical Sensors
Sensor/Actuator Systems
Applications
Chemical and Gas Sensors
Optical Sensors
Physical Sensors
Sensor Networks
Special "Focus" Sessions
Authors are invited to submit a 2-page abstract in one or more of the areas identified above.
DATES:
Special Session Proposals Deadline: JAN 30, 2009
Abstract Submission Deadline: MAR 31, 2009
Author Notification: MAY 31, 2009
Final Full Paper Submission (4 Pages): JUL 11, 2009
Presenting Author Conference Registration: JUL 11, 2009
Early Registration: On or Before JUL 31, 2009
Advance Registration: AUG 1, 2009 to SEP 15, 2009
For additional Conference information please visit the website at:
IEEE-SENSORS2009.org
GENERAL CHAIR:
Subhas Mukhopadhyay, Massey University
TECHNICAL PROGRAMME CHAIR:
Paddy French, Delft University of Technology
SPONSORED BY:
IEEE SENSORS Council

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 6-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information