National Semiconductor Revolutionizes Design of Sensor Systems

Configurable Sensor AFE Products Simplify Design and Speed Time-to-Market
National’s Sensor AFE

• Introduction

– James Ashe, Vice President, Precision Signal Path Division

– Anita Ganti, Business Unit Director, Precision Systems Business Unit

– Chuck Sins, Applications Engineering Manager, Precision Systems Business Unit
Revolutionizing Design of Sensor Systems

• Sensor systems can take months to develop
  – Sensor selection
  – Component search and analysis - Systems today require many ICs
  – Estimate system performance
  – Layout and board assembly
  – Design validation
  – Prototyping

• National’s New Sensor AFE Products
  – Enable system designers to develop highly-integrated sensor systems in a fraction of the time
Agenda

1. National’s Sensor AFE Products
2. LMP90100 Multi-Channel, 24-bit Sensor AFE
3. LMP91000 Low Power Potentiostat Sensor AFE
4. WEBENCH Sensor AFE Designer / Eval System
5. Summary, Q&A
Agenda

1. National’s Sensor AFE Products
2. LMP90100 Multi-Channel, 24-bit Sensor AFE
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5. Summary, Q&A
# National’s Sensor AFE Products

## Integrated Circuit
- Configurable ICs designed for families of sensors
  - Complete analog signal path solution

## WEBENCH Designer
- WEBENCH Sensor AFE Designer
  - Fast design

## Development Platform
- Sensor AFE Development Platform
  - Rapid design validation and prototyping

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![WEBENCH Sensor AFE Designer](link)

![Sensor AFE Development Platform](link)

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Sensor AFE Integrated Circuit

- Designed for specific families of sensors and application spaces
- Configurable - can be optimized to support specific end application requirements
- Includes features and functions needed for the end applications including:
  - Sensor drive, reference selection, diagnostics, offset / gain calibration, variable sample rate
Sensor AFE WEBENCH Designer

- Select sensors
  - WEBENCH tool includes typical sensors (RTDs, thermocouples, pressure sensors, load cells, gas sensors)
- Configure sensor signal path parameters
- Sensor drive, reference, gain, sample rate, alarms
- Estimate device performance
- Program diagnostics (open, short, signal level)
- Save configuration data
Sensor AFE Development System

- **Attach**: Sensors
- **Load**: Configuration data
- **Evaluate**: Signal path performance
- **Optimize**: Design
- **Complete**: Your sensor system design
Agenda

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5. Summary, Q&A
LMP90100 Application Diagram
Pressure Sensor and Temperature RTD

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LMP90100 Configurability
## LMP90100 Configurability

<table>
<thead>
<tr>
<th>Input</th>
<th>Signal Path</th>
<th>Sample Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB1</td>
<td>IB2</td>
<td>VIN0, VIN1, VIN2, VIN3, VIN4, VIN5, VIN6, VIN7</td>
</tr>
<tr>
<td></td>
<td>RANGE SETTING</td>
<td>FLEXIBLE MUX</td>
</tr>
<tr>
<td></td>
<td>SENSOR DIAGNOSTICS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VREF MUX</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MUX</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VREF1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VIO</td>
<td></td>
</tr>
</tbody>
</table>

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LMP90100 Configurability

Sample Rate

Input

Signal Path

Gain 1x to 128x

FLEXIBLE MUX

VREF MUX

INTERNAL CLOCK

MUX

BACKGROUND CALIBRATION

24-bit ΔΣ MODULATOR

DIGITAL FILTER

SERIAL INTERFACE

SCLK
SDI
SDO
CSB

POF

GND
VREF1
CLKXIN
D6
D0

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## LMP90100 Product Overview

<table>
<thead>
<tr>
<th>Features</th>
<th>Specifications</th>
<th>Sensors</th>
<th>Competitive Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multi – Channel, Low Power 24-bit Sigma Delta ADC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• True Continuous Background Calibration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Effectively eliminates gain and offset drift over time and temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Background Sensor Diagnostics Monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Fully Programmable to Optimize for Power and Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• WEBENCH Designer and Development Platform</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Shortens design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Provides estimated performance for all signal path solutions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 2 Matched Programmable Current Sources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 50-60Hz Line Rejection</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# LMP90100 Product Overview

## Features

- Guaranteed Performance down to 3V
- Programmable Gain from 1x to 128x
- Output Data Rate: 1.68SPS to 214.65SPS
- ENOB: 16 to 21.5 bits
- Current Consumption 0.4mA to 1.7mA
- Standby Power 9uW

## Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Data Rate</td>
<td>1.68SPS to 214.65SPS</td>
</tr>
<tr>
<td>ENOB</td>
<td>16 to 21.5 bits</td>
</tr>
<tr>
<td>Current Consumption</td>
<td>0.4mA to 1.7mA</td>
</tr>
<tr>
<td>Standby Power</td>
<td>9uW</td>
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</table>

- **Temperature Sensors**
  - Resistance Temperature Detectors (RTDs)
  - Thermocouples
  - Thermistors
  - Analog Temperature Sensors

- **Bridge Sensors**
  - Pressure
  - Load
  - Force

- **Voltage Inputs**
## System Configuration versus Major Competitors

(Calibration, Diagnostics, Settling Time, Input Flexibility)

<table>
<thead>
<tr>
<th>Feature</th>
<th>National</th>
<th>Competitor A</th>
<th>Competitor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Continuous Background Calibration</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Background Sensor Diagnostics</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Floating Input and Overload Protection</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Flexible Input Mux Routing</td>
<td>Yes</td>
<td>Device Dependant</td>
<td>No</td>
</tr>
<tr>
<td>Single Cycle Settling time</td>
<td>Yes</td>
<td>Device Dependant</td>
<td>No</td>
</tr>
</tbody>
</table>
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LMP91000 Configurability

Bias Drive

3-Lead Electrochemical Cell

CE
RE
WE

Signal Measurement

VREF
VDD

A1
VARIABLE BIAS
VREF DIVIDER

Control

I2C INTERFACE AND CONTROL REGISTERS

SCL
SDA
MENB
DGND
VOUT

C1
C2
AGND

R_{Load}

RTIA
LMP91000 Configurability

Bias Drive | Signal Measurement | Control
---|---|---

3-Lead Electrochemical Cell

- CE
- RE
- WE

A1

VARIABLE BIAS

VREF DIVIDER

I2C INTERFACE AND CONTROL REGISTERS

TEMP SENSOR

RLoad

RTIA

C1

C2

AGND

VOUT

SCL

SDA

MENB

DGND

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LMP91000 Product Overview

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<th>Features</th>
<th>Specifications</th>
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</tr>
</thead>
<tbody>
<tr>
<td>• Programmable cell bias and TIA gain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Supports multiple sensors with a single IC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Integrated Module Design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Enables smaller board geometries reducing assembly and logistics cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Improves EMI immunity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• WEBENCH Designer and Development Platform</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Shortens design time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Multiple operational modes permit power optimization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Integrated temperature sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• I²C interface enables signal path optimization and sensor diagnostics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# LMP91000 Product Overview

<table>
<thead>
<tr>
<th>Features</th>
<th>Specifications</th>
<th>Sensors</th>
<th>Competitive Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Power (&lt;10uA)</td>
<td>• TIA Gain ranges (KΩ) : 2.75, 3.5, 7, 14, 35, 120, 350, external resistor</td>
<td>• Reference Electrode Bias Current: 900pA (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cell conditioning currents: up to 10mA</td>
<td>• Cell conditioning currents: up to 10mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Output Drive Current: &gt; 750 uA</td>
<td>• Output Drive Current: &gt; 750 uA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Internal Temp Acc: +/- 3°C</td>
<td>• Internal Temp Acc: +/- 3°C</td>
<td></td>
</tr>
</tbody>
</table>
## LMP91000 Product Overview

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</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td></td>
<td>Nitric oxide</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Chloride</td>
<td></td>
<td>Ammonia</td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td></td>
<td>Nitrogen Dioxide</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td>Ozone</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulphide</td>
<td></td>
<td>Chlorine</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Cyanide</td>
<td></td>
<td>Ethylene Oxide</td>
<td></td>
</tr>
<tr>
<td>Sulphur Dioxide</td>
<td></td>
<td>Phosphines</td>
<td></td>
</tr>
</tbody>
</table>
LMP91000 Product Overview

Features

Specifications

Sensors

Competitive Position

National Solution

Multiple Discrete Solution (several boards)
# LMP91000 Product Overview

## Features

<table>
<thead>
<tr>
<th>Area</th>
<th>National</th>
<th>Discrete Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single solution addresses multiple gases</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Small footprint</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>One solution across multiple types of sensors</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>One solution across varying gas concentration</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Integral Temperature Sensor</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Quick Design /Prototype evaluation</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>System Reliability</td>
<td>Improved</td>
<td>-</td>
</tr>
<tr>
<td>Low Power Consumption</td>
<td>✓</td>
<td>X*</td>
</tr>
<tr>
<td>Superior EMI Protection</td>
<td>✓</td>
<td>X*</td>
</tr>
</tbody>
</table>

* Requires special op amps
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### WEBENCH Example - LMP90100

#### Startup

#### Types of Sensors

#### Choose Sensor

#### Sensor AFE Configured

**Definition:** A sensor whose resistance changes with pressures.

**Advantages:**

<table>
<thead>
<tr>
<th>Select</th>
<th>Part Number</th>
<th>Part ID</th>
<th>Manufacture</th>
<th>Thermal ID</th>
<th>Budget Price</th>
<th>Default Disty</th>
<th>Quantity In Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select</td>
<td>5312P</td>
<td>0</td>
<td>Freescale Semi</td>
<td>100</td>
<td>3.5</td>
<td>Digkey</td>
<td>100</td>
</tr>
<tr>
<td>Select</td>
<td>5312P</td>
<td>0</td>
<td>Freescale Semi</td>
<td>100</td>
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<td>100</td>
<td>3.5</td>
<td>Digkey</td>
<td>100</td>
</tr>
</tbody>
</table>

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WEBENCH Example - LMP90100
WEBENCH Example - LMP90100

Configurable Control Registers

<table>
<thead>
<tr>
<th>Sensor</th>
<th>CBL</th>
<th>VINP</th>
<th>VINH</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Configuration Options

<table>
<thead>
<tr>
<th>Configuration Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Channel Performance</td>
</tr>
<tr>
<td>Save Configuration Data</td>
</tr>
</tbody>
</table>

WEBENCH® Sensor AFE Design

LMP90100
- Chip Configurable
- Channel Configurable
- Fixed

Performance

- Name: Noise
- Value: 5.016
- Name: ENOB
- Value: 19.0
- Name: NFR
- Value: 155
- Name: Power
- Value: 4.035 mW
- Name: Device Error
- Value: N/A

Estimated Device Performance

Optimizers

- Output bitrate (ODR)

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• System Includes
  • Evaluation board with Sensor AFE IC – interfaces to sensors
  • SPI04 Data Capture Board - USB Interface to PC
  • Design Software (same as WEBENCH Sensor Designer AFE)
  • Ability to download channel configuration data to sensor AFE IC
  • Performance Analysis
LMP90100 Bench Evaluation

Development Hardware

Histogram Analysis

Oscilloscope Mode

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LMP90100 Bench Evaluation

Complete Design

Sensors
Development Hardware
Design / Configure Software

Your sensor system design

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Sensor AFE Products Summary

Integrated Circuit

- Configurable Sensor AFE ICs designed for specific sensors
  - Complete analog signal path solution

WEBENCH Designer

- WEBENCH Sensor AFE Designer
  - Fast design

Development Platform

- Sensor AFE Development Platform
  - Rapid design validation and prototyping
LMP90100, LMP91000 Sensor AFEs and the WEBENCH Sensor AFE Designer and Development Tools is Available at http://www.national.com/sensorAFE

Q & A