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Project Code: APM_AUTO-SENSOR_2016

ADI AUTOMOTIVE SENSOR AND SENSOR INTERFACE SOLUTION

Application Description

Automobiles must become increasingly green to meet emerging regulations for improved fuel economy and reduced emissions. These requirements can only be fulfilled by improving the efficiency of the traditional internal combustion engine, achieved through improvements in combustion sensing and control, which leads to the need for higher sensor and signal conditioning accuracy and integration. There are typically more than 100 sensors in a vehicle and sensors can typically be categorized into six functions, including pressure, current, capacitance, position, speed, and temperature sensors.

System Requirement and Design Challenge

Vehicle sensors are used across multiple applications in powertrain, chassis/safety, and body systems. Improvements in fuel economy, emissions, and vehicle performance need to be simultaneously improved in powertrain systems. For sensors, this results in significant performance improvements and/or features that are challenging to achieve in areas such as dynamic range, accuracy, diagnostics, and robustness (such as EMC, ESD, and temperature).

Pressure Sensors

Many pressure sensors are required in high pressure and harsh environments to measure air or fluid pressures. Some powertrain examples include in-cylinder, transmission oil, diesel common rail, GDI fuel, diesel particulate filter (DPF), and exhaust gas recirculation (EGR) pressure. Safety applications include brake fluid and occupant detection weight or pressure. High pressure and harsh environment applications require that the sensor element (capacitive or piezoresistive) is separated from the signal conditioning IC. A piezoresistive (strain gage) solution can, for example, measure pressure ranges up to 2800 bar.

The strain gage technology is based on a resistive bridge. Four strain gages are attached to a diaphragm to form a diaphragm-type pressure transducer. The output signal is as small as 10 mV. The system errors include mechanical output, thermal output, tolerance, and gage factor errors. The total errors can reach up to 100% FSR. Hence, the conditioning circuit must be highly accurate and have low drift. Multiple variable compensations related to gain, offset, temperature, and linearity are also required.

Pressure sensors are placed mainly in harsh environments. A typical operating temperature range is −40°C to +125°C and in some cases up to 150°C. The sensors also require high EMC capability and diagnostic functions.

Current Sensors

To improve fuel economy and energy management, the position of the solenoid valves in the fuel injection system and automatic gearboxes must be precisely controlled. In addition electric motor current for power 'on demand must be monitored more accurately. High accuracy, a low offset (an offset needs <5 mV and an offset drift needs <20 μV), a high bandwidth (some cases require up to 500 kHz), a wide common-mode voltage range, (up to 6580 V), and a wide operating temperature range (up to 125°C) in a harsh environment comprise the typical design challenges.

Capacitance Sensors

Capacitance sensors have advantages such as their low system cost, different shape feasibilities, and low power consumption. They are typically applied as proximity detectors in a keyless entry system, rain detectors, humidity sensors, and fuel level/quality sensors. Capacitance sensors are sensitive to environmental changes and thus require a high resolution, accuracy, adjustable common-mode capacitance, and EMI immunity.

Position and Speed Sensors

In EPS and BLDC/PMSM motor control applications, position/speed measurement requires a fast response, good accuracy up to 5 arc minutes, robustness, and low drift. Diagnostic functions are also needed.

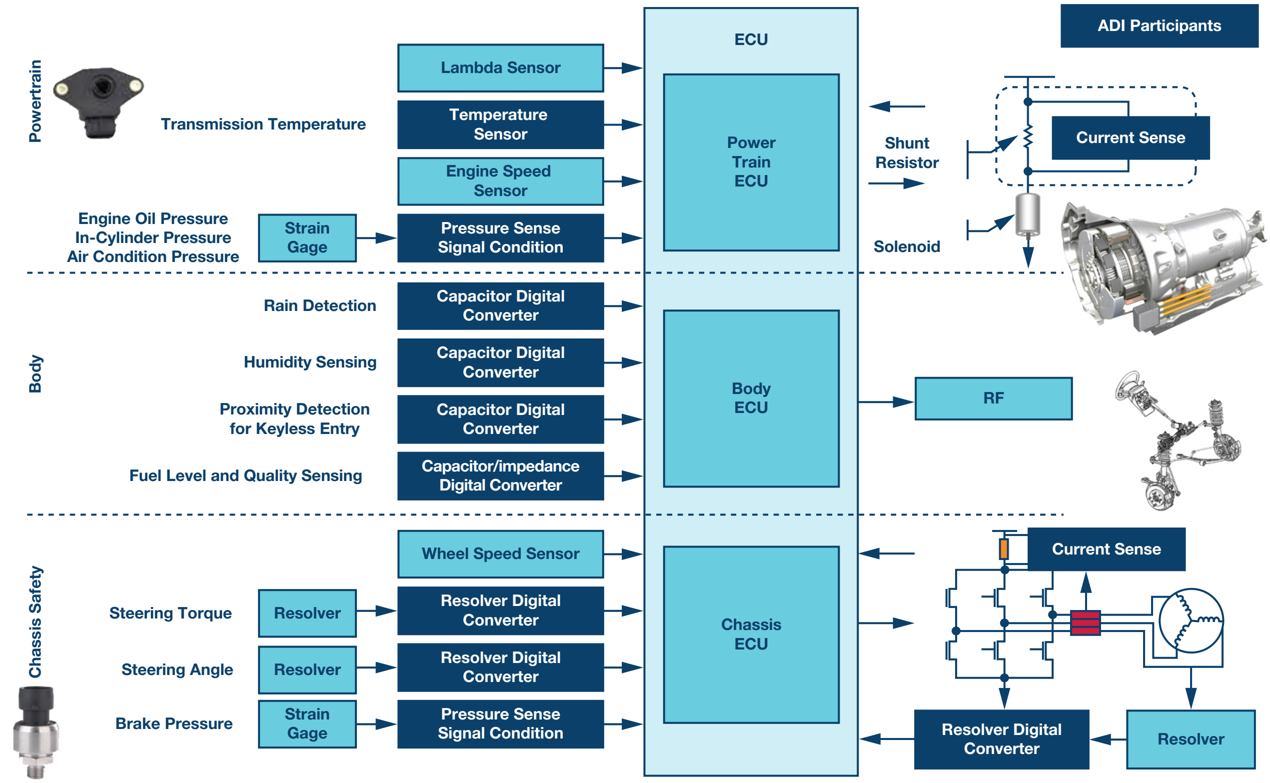
Temperature Sensor

Wide temperature ranges and high accuracies are required in some high temperature automotive applications such as transmission control. A typical temperature range is −40°C to +150°C and in some cases up to 175°C. Further, an accuracy of ±2°C or ±1°C is required.

Solutions from Analog Devices

Thanks to good, long-term relationships with worldwide leading automotive suppliers, plus the experience of high performance signal processing, high reliability, and quality product development, Analog Devices, Inc. (ADI) is the leader in sensor technology and able to provide optimized solutions to meet these challenges.

Auotmotive Sensor and Sensor Interface Signal Chain



Notes: the signal chains above are representative of an automotive sensor and sensor interface system. The technical requirements of the blocks vary, but the products listed in the table are representative of ADI's solutions that meet some of those requirements.

Pressure Sensor

ADI's strain gage signal condition ICs, ADA4557, is a single-supply bridge sensor signal conditioner specified from –40°C to +150°C in a small, 4 mm × 4 mm LFCSP package. The analog output is processed in an advanced signal-processing engine that incorporates digitally programmable gain, output offset correction, temperature compensation, and sensor nonlinearity correction.

The ADA4557 contains an internal EEPROM for programming end of line (EOL) calibration and debugging via a zero wire, serial programming interface through the output pin (OUT). The EEPROM stores the gain, output offset, temperature compensation, and nonlinearity correction coefficients that configure the device at power-up. Gain is programmable over 20 different settings from 6.3 V/V to 821.5 V/V in exponential steps. The ADA4557 also features an internal low dropout (LDO) voltage regulator that provides a regulated, low noise voltage supply for internal circuitry.

Current Sensor

ADI's current sense amplifiers support shunt-based precise current sensors on both the high and low sides. ADI provides more than 10 ICs in two different architectures, including difference and current sense amplifier types. The difference amplifier type is based on an input resistor divider. The AD8207/AD8208/AD8209 parts have the EMI filter inside, providing higher EMC performance. The AD8207 has zero-drift function (offset drift <1 μV/°C) and maximum offset is <0.5 mV. The current sense amplifier type is based on a high voltage process to withstand the high common mode voltage. They have low input bias currents and high input impedances and are suitable for meeting the high bandwidth (up to 500 kHz) and CMRR (up to 120 dB) requirements. Both architecture types have good input common-mode step response capability.

ADI also has a current threshold monitor solution for the total current monitor and overcurrent protection. The AD8214 has a very low 200 nS prop delay.

Capacitance Sensor

ADI has a special sigma-delta (Σ-Δ) architecture capacitance-to-digital converter (CDC), which is based on ADI's quality architecture. The Σ-Δ modulator uses charge balancing techniques to help customers get capacitance value more easily and more accurately.

The AD5933 is a high precision impedance converter that combines an on-board frequency generator with a 12-bit, 1 MSPS ADC. The frequency generator allows an external complex impedance to be excited with a known frequency. The on-board ADC samples the response signal from the impedance, and an on-chip DSP engine processes a discrete Fourier transform (DFT). The DFT algorithm returns a real (R) and imaginary (I) data word at each output frequency. It can be used in fuel level and quality sensors. It also can measure the mixing ratio of the gasoline and ethanol in the flex-fuel application.

Position and Speed Sensors

ADI has a wide portfolio of and long tradition in resolver-to-digital converter (RDC) technology. The AD2S1205 and AD2S1210 are able to trade tracking rates at up to 3125 RPS. Their accuracies can reach ±2.5 arc minutes. The AD2S1205 is a 12-bit RDC, and the AD2S1210's 10-/12-/14-/16-bit resolution can set by the user. The chips have differential inputs and incremental encoder outputs with programmable fault detection thresholds. They can be used in motor shaft angle and speed measurements in transmission, EPS, and HEV/EV motors.

ADI recently released anisotropic magnetoresistive (AMR) sensor ADA4571 with integrated signal conditioning amplifiers and ADC drivers. ADA4571 produces two analog outputs that indicate the angular position of the surrounding magnetic field.

It consists of two die within one package, an AMR sensor, and a fixed gain (G = 40 nominally) instrumentation amplifier, and delivers clean and amplified cosine and sine output signals related to the angle of a rotating magnetic field. The output voltage range is ratiometric to the supply voltage.

ADA4571 contains two Wheatstone bridges at a relative angle of 45° to one another. A rotating magnetic field in the x-y sensor plane delivers two sinusoidal output signals with the double frequency of the angle (α) between the sensor and magnetic field direction. Within a homogeneous field in the x-y plane, the output signals are independent of the physical placement in the z direction (air gap).

Temperature Sensor

The ADI's TMP36 is accurate to ±2°C of the full scale and linear to 0.5°C of the full scale with a temperature range of –40°C to +125°C and an analog output. The ADI's ADT7311 and ADT7312 are accurate to ±1°C of the full scale with a temperature range of –40°C to +150°C and a digital SPI output. The temperature range of the ADT7312 can increase to –40°C to +175°C with bare die package.

ADI Products

Part Number	Description	Temperature	Benefits
Pressure Signal Condition			
ADA4557W[1]	VCC 4.5 V to 5.5 V, include EEPROM, ESD HBM 6 kV, gain 6.3 to 821.5, ZWI program interface combined with analog output	–40°C to +125°C	With temperature and nonlinearity compensation, package: 16-lead LFCSP
Current Sense			
AD8202W*	Input common-mode range –8 V to +28 V, –8 V to +35 V survival, gain 20 V/V, unidirectional, bandwidth 50 kHz, offset drift 10 µV/°C, gain error, 0.3%, gain drift 20 ppm/°C ESD HBM 2 kV, CMRR typ 82 dB, worst-case 80 dB	–40°C to +125°C	Difference amplifier solenoid control, package: 8-lead SOIC, 8-lead MSOP
AD8205W*	Input common-mode range –2 V to +65 V, –5 V to +68 V survival, gain 50 V/V, bidirectional, bandwidth 50 kHz, max offset 4.5 mV, offset drift 15 µV/°C, gain error, 1.2%, gain drift 30 ppm/°C ESD HBM 2.5 kV, CMRR typ 80 dB, worst-case 76 dB	–40°C to +125°C	Difference amplifier motor control, with EMI filter, package: 8-lead SOIC
AD8206W*	Input common-mode range –2 V to +65 V, –25 V to +75 V survival, gain 20 V/V, bidirectional, bandwidth 100 kHz, max offset 4.5 mV, offset drift 15 µV/°C, gain error, 1.2%, gain drift 30 ppm/°C ESD HBM 3 kV, CMRR typ 80 dB, worst-case 76 dB	–40°C to +125°C	Difference amplifier motor control, with EMI filter, package: 8-lead SOIC
AD8207W*	Input common-mode range –4 V to +65 V, –25 V to +75 V survival, gain 20 V/V, bidirectional, bandwidth 100 kHz, max offset 0.4 mV, offset drift 1 µV/°C, gain error, 0.3%, gain drift 15 ppm/°C ESD HBM 3 kV, CMRR typ 90 dB, worst-case 80 dB	–40°C to +125°C	Difference amplifier zero drift, difference amp, with EMI filter, package: 8-lead SOIC
AD8208W*	Input common-mode range –2 V to +45 V, –24 V to +80 V survival, gain 20 V/V, unidirectional, bandwidth 80 kHz, max offset 4 mV, offset drift 20 µV/°C, gain error, 0.3%, gain drift 20 ppm/°C ESD HBM 4.5 kV, CMRR typ 80 dB	–40°C to +125°C	Difference amplifier robust, solenoid control, with EMI filter, package: 8-lead SOIC, 8-lead MSOP
AD8209W*	Input common-mode range –2 V to +45 V, –24 V to +80 V survival, gain 14 V/V, unidirectional, bandwidth 80 kHz, max offset 4 mV, offset drift 15 µV/°C, gain error, 0.3%, gain drift 20 ppm/°C ESD HBM 8 kV, CMRR typ 80 dB	–40°C to +125°C	Difference amplifier robust, solenoid control, with EMI filter, package: 8-lead MSOP
AD8216W*	Input common-mode range 0 V to 65 V, –40 V to +80 V survival, gain 3 V/V, bidirectional, bandwidth 3 MHz, max offset 3 mV, offset drift 20 µV/°C, gain error, 0.4%, gain drift 15 ppm/°C ESD HBM 5 kV, CMRR typ 90 dB, worst-case 80 dB	–40°C to +125°C	Difference amplifier fast output response, with EMI filter, package: 8-lead SOIC
AD8210W*	Input common-mode range –2 V to +65 V, –5 V to +68 V survival, gain 20 V/V, bidirectional, bandwidth 500 kHz, max offset 1.8 mV, offset drift 8 µV/°C, gain error, 0.5%, gain drift 20 ppm/°C ESD HBM 7.5 kV, CMRR typ 120 dB, worst-case 80 dB	–40°C to +125°C	Current sense amplifier, motor control, high bandwidth, high CMRR, package: 8-lead SOIC
AD8211W*	Input common-mode range –2 V to +65 V, –3 V to +68 V survival, gain 20 V/V, unidirectional, bandwidth 500 kHz, max offset 2.5 mV, offset drift 10 µV/°C, gain error, 0.4%, gain drift 13 ppm/°C ESD HBM 4 kV, CMRR typ 120 dB, worst-case 80 dB	–40°C to +125°C	Current sense amplifier solenoid control, package: 5-lead SOT-23
AD8212W*	Input common-mode range 7 V to 65 V (up to 500 V with external high voltage PNP), 7 V to 68 V survival, gain adjustable, unidirectional, bandwidth 500 kHz, max offset 3 mV, offset drift 10 µV/°C, gain error, 1%, gain drift 50 ppm/°C ESD HBM 4 kV, CMRR typ 90 dB	–40°C to +125°C	Current sense amplifier current out, 500 V with $0.03 external transistor, including 5 V regulator, package: 8-lead MSOP
AD8213W*	Input common-mode range –2 V to +65 V, –3 V to +68 V survival, gain 20 V/V, unidirectional, bandwidth 500 kHz, max offset 2.2 mV, offset drift 12 µV/°C, gain error, 0.5%, gain drift 25 ppm/°C ESD HBM 4 kV, CMRR typ 90 dB	–40°C to +125°C	Dual-channel current sense amplifier, package: 10-lead MSOP
AD8215W*	Input common-mode range –2 V to +65 V, –3 V to +68 V survival, gain 20 V/V, unidirectional, bandwidth 450 kHz, max offset 2.5 mV, offset drift 10 µV/°C, gain error, 0.3%, gain drift 15 ppm/°C ESD HBM 4 kV, CMRR typ 120 dB, worst-case 80 dB	–40°C to +125°C	Current sense amplifier solenoid control, package: 8-lead SOIC

[1] Please contact ADI or distributors if you need any further information on the ADA4557W.

Part Number	Description	Temperature	Benefits
AD8214W*	Input common-mode range 5 V to 65 V, 0 V to 68 V survival, gain adjustable, unidirectional, bandwidth 500 kHz, max offset 8 mV, offset drift 15 μV/°C, ESD HBM 2.5 kV	–40°C to +125°C	current threshold monitor 200 nS prop delay/ including 2.4 V regulator, package: 8-lead MSOP
AD8417W*	Input common-mode range –2 V to +70 V, bandwidth 250 kHz, gain 60 V/V, input impedance 1.5 MΩ	–40°C to +125°C	Bidirectional, auto-zero, current sense amplifier, package: 8-lead MSOP, 8-lead SOIC
AD8418AW*	Input common-mode range –2 V to +70 V, bandwidth 250 kHz, gain 20 V/V, input impedance 1.5 MΩ	–40°C to +125°C	Bidirectional, auto-zero, current sense amplifier, package: 8-lead SOIC
Capacitor-to-Digital Converter			
AD5933W*	Impedance converter, 12-bit 1 MSPS ADC, programmable output peak-to-peak excitation voltage to a maximum frequency of 100 kHz, I^2C interface, real (R) and imaginary (I) measurement	–40°C to +125°C	16-lead SSOP package
Resolver-to-Digital Converters			
AD2S1205 (ADW71205)	12-bit resolution, max tracking rate 1250 rps, accuracy 11 arc minutes (Y grade), accuracy 22 arc minutes (W grade)	–40°C to +125°C	44-lead LQFP package
AD2S1210W*	10-bit,12-bit,14-bit,16-bit adjustable resolution, max tracking rate 3125 rps/ 1250 rps/625 rps/156.25 rps (CLK = 10.24 MHz), accuracy typical 2.5 arc minutes	–40°C to +125°C	48-lead LQFP package
AMR Sensor			
ADA4571W*	Angular error of 0.1°, 180° angle sensor, low thermal and lifetime drift, minimum phase delay	–40°C to +150°C	8-lead SOIC package
Temperature Sensors			
TMP36	Temperature error @ ambient temperature 1°C, analog output, accuracy ±2°C of full scale	–40°C to +150°C	5-lead SOT-23 package
ADT7311W*	Accuracy ±1°C of full scale, SPI interface	–40°C to +150°C	8-lead SOIC package
ADT7312W*	Accuracy ±1°C of full scale, SPI interface	–40°C to +175°C	Bare die package

* -W suffix represents automotive grade

Design Resources

Evaluation Boards

- AD8555ARZ-EVAL
- EVAL- ADA4557
- EVAL-AD5933EBZ
- EVAL-AD2S1205SDZ
- EVAL-SDP-CB1Z
- EVAL-AD2S1210EDZ
- EVAL-CED1Z
- EVAL-ADT7X10EBZ
- EVAL-ADA4571
- EVAL-AD8417
- EVAL-AD8418A

Circuits from the Lab®

- CN-0116: High Voltage High Precision Current Sensing with Output Level Shifting Using the AD8210 Current Sense Amplifier and the AD8274 Difference Amplifier—*www.analog.com/en/cn-0116*
- CN-0217: High Accuracy Impedance Measurements Using 12-Bit Impedance Converters—*www.analog.com/en/cn-0217*
- CN-0218: 500 V Common-Mode Voltage Current Monitor—*www.analog.com/en/cn-0218*
- CN-0368: Magnetoresistive Angle and Linear Position Measurements—*www.analog.com/en/cn-0368*

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