Sensing Applications

Pressure Sensors, Load Cells, and Force Sensors

Pressure, load, and force sensors typically combine a wheatstone bridge resistor configuration with a mechanical structure. As the mechanical structure is stressed, the bridge output changes in proportion to the pressure, load, or force applied to the sensor. A small number of analog configurations support most of these applications.

Load Cell

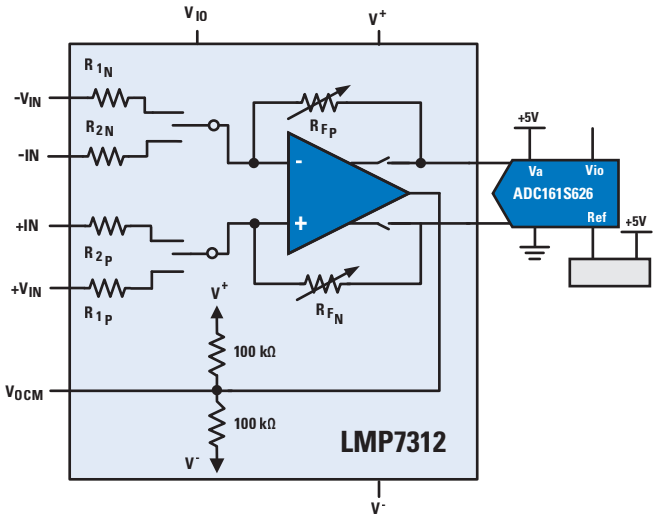
Typical Parameters:

- Accuracy ranges between ±0.02% to ±0.5% of the total span
- Sensitivity in the 1.5 mV/V to 3 mV/V range with bridge impedances between 300Ω and 400Ω
- Sensor drive in the 5V to 15V range, making low-noise power an important part of the design

Applications

- Pharmaceutical
- Food and beverage
- Tank weighing
- Truck, vehicle, and livestock scales
- Static and dynamic check scales
- Aviation baggage, and parcel shippers

Programmable Variable Gain AFE



LMP7312

- SPI programmable
- Input voltage up to ±15V, 0 to 20 mA, and 4 mA to 20 mA input
- Differential/single-ended input/output

Pressure Sensor

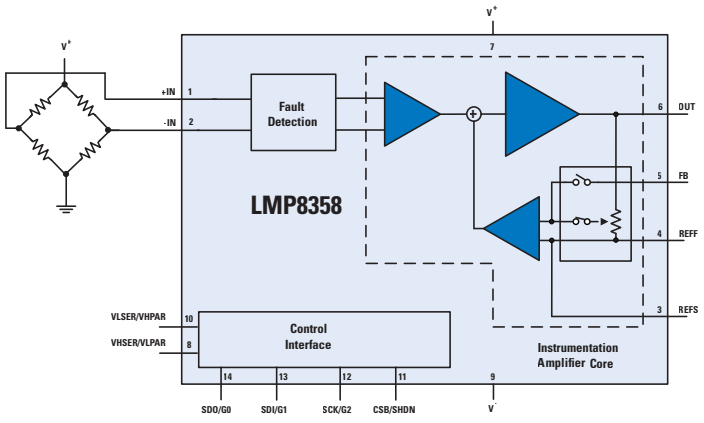
Typical Parameters:

- Accuracy range from ±0.1% of span accuracy to ±1.0% of span
- Sensitivity in the 5 mV/V to 15 mV/V range with a bridge impedance between 3 KΩ and 10 KΩ
- Sensor drive: Constant current (typically 1.5 mA to 2 mA) or constant voltage (usually 5V to 15V)
- Typical overall signal accuracy: 0.5% to 5%

Applications

- Pressure calibrators
- HVAC measurement (pitot tube for flow)
- Gas, chemical monitors, and analyzers
- Industrial / process controllers
- Discrete volumetric valves
- Pneumatic control
- Level sensing (pressure head)
- Flow (diff. press. across orifice/restriction)
- Vacuum systems

High-Performance Instrumentation Amp (< 200 mV bridge output)



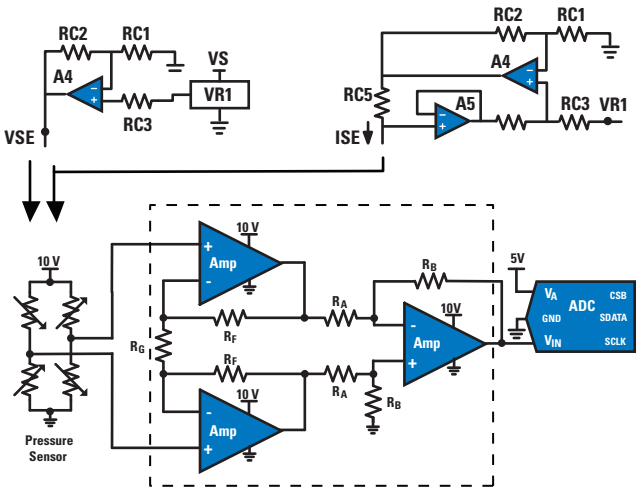
LMP8358

- SPI programmable
- Voltage monitoring: Voltage change, open, short-circuit detection
- < 1 uA when powered down
- Allows signal below ground and up to Vdd-1.4V to be processed
- Very low V_{OS} and high CMRR

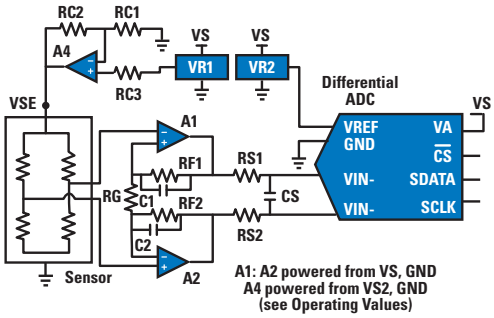
National Semiconductor

Pressure, Load, and Force Sensors

Instrumentation Amp/Three Op Amp Configuration



Two Op Amp Configuration

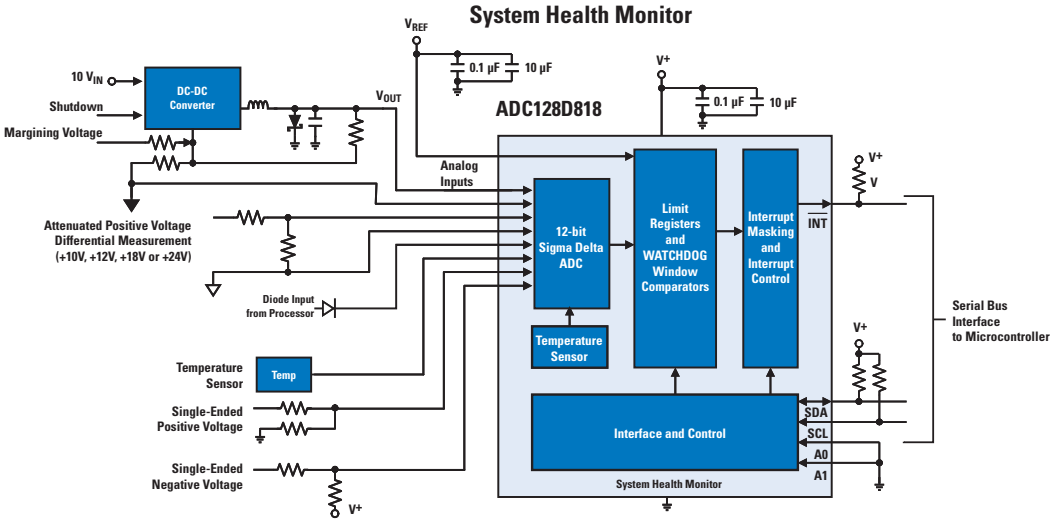


Pressure, Load, and Force Sensors

Product ID	Description	Features	Benefits
Amplifiers			
LMP8358	Zero-drift, programmable instrumentation amplifier with diagnostics	Programmable gain though SPI-compatible serial or parallel interface, V_{OS} and T_CV_{OS} continuously corrected	Senses differential input voltages Ideal for precision and long-term stability
LMP7715/16	Single/dual precision, 17 MHz, low-noise, CMOS-input amplifiers	Wide bandwidth, low I_{BIAS}, low noise	Ideal for instrumentation and low-power applications
LMP2021/22	Single/dual, zero-drift, low-noise, EMI-hardened amplifiers	Continuous correction circuitry Very low input voltage noise and high open-loop gain Low input bias current 23 pA	Ideal for low-frequency apps Minimal gain error in high-gain apps Ideal for impedance circuit
LMP7701/02/04	Precision, CMOS-input, RRIO, wide supply range amplifiers	Low V_{OS}, low I_{BIAS}, low noise	For applications where CMOS parts cannot operate under desired voltage conditions
LMV793/4	88 MHz, low-noise, 1.8V CMOS-input, decompensated amplifiers	Performance in low-voltage, low-noise systems at gains 10V/V and higher	Ideal for low-power sensor applications
LMP7721	3 Femtoamp, input-bias current precision amplifier	Low I_{BIAS}, low noise, low V_{OS}	Ideal for sensor interface and prevents PCB leakage current from reaching the input pins
ADCs			
ADC141S626/ ADC161S626	Single-channnel, 14-/16-bit ADCs with sample rates from 50 kSPS to 250 kSPS	Low power, small package Pin compatible across sample rate	Supports high-performance apps over wide temperatures Pin compatibility and package size simplify board layout
ADC121S021/ ADC124S101	1-/4-channel, 12-bit ADCs supporting sample rates up to 1 MSPS	Low power, small package Part of 8-/10-/12-bit pin- and function-compatible family across sample rate	
ADC121C021/27 ADC101C021/27	I^2C compatible, 10-/12-bit ADCs with alert pin	Low power, small package Configurable alarm Part of 8-/10-/12-bit pin- and function-compatible family across sample rate	Supports high-performance apps over wide temperatures Alarms to indicate out-of-range condition Pin compatibility and package size simplify board layout
Power Management			
LP3871	Low-Dropout (LDO) regulator	Supports 800 mA output current 73 dB PSRR at 120 Hz	High output power with LDO simplicity Reduces voltage ripple to isolate sensing circuitry from noise
LP5900	Low-noise LDO	85 dB PSRR at 100 Hz Low output noise of 6.5 μV_{RMS} No bypass capacitor required	Reduces voltage ripple to isolate sensing circuitry from noise Minimizes effect on sensor precision Smaller solution size

Hardware/System Monitors, Temperature Switches, and Remote Diode Temperature Sensors

Hardware/system monitors measure temperature, voltage, and currents. Some products provide outputs for processor clocking or fan control to regulate temperature.



Hardware Monitors, Temperature Switches, and Remote Diode Temperature Sensors

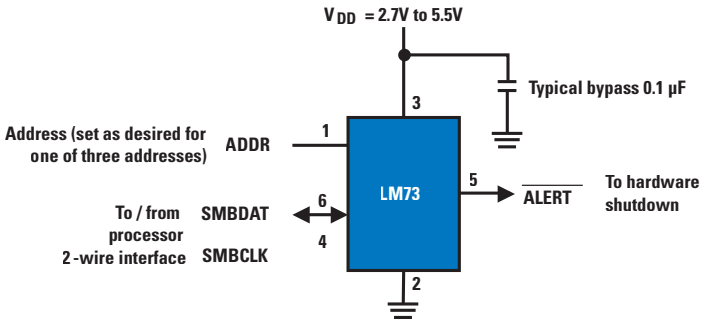
Product ID	Description	Features	Benefits
Hardware Monitors			
ADC128D818	8-channel, 12-bit system monitor with I²C interface and internal reference	Single-ended or differential inputs Configurable alarms on each channel Internal reference and temp sensor Individual channel shut down	Complete integrated system monitoring solution Easy input configuration Internal temp sensor allows internal alarm capability
LM96080	8-channel, 10-bit system monitor with I²C interface and internal reference	Voltage monitoring, fan control, internal temp sensor Configurable alarms on each channel	Complete integrated system monitoring solution with fan tachs Internal temp sensor allows internal alarm capability
LM96163	Remote diode, digital with integrated fan control	DAC / PWM output, 12-step lookup table, 11-bit remote diode with TruTherm beta compensation, improved analog front end, digital filter	Look-up table allows programming of a non-linear fan speed vs. temp transfer function, enabling less acoustic fan noise
LM96194	Hardware monitor with PI fan control	TruTherm® beta compensation, 4 TruTherm remote diodes, 4 tach inputs, 2 fan controls, 9 voltage monitors, closed-loop fan control for 4-pin fans	Complete system monitoring solution with 4 fan tachs to measure fan speed Digital filters smooth temp readings for better fan speed control, enabling less acoustic fan noise
Temperature Switches			
LM26/26LV/27	Factory set temperature switch LM26LV: 1.6V	SOT23-5 small package footprint LM26: Wide temp range of -55°C to +125°C LM27: High temp range of +120°C to +150°C	Supports high temperature switching in small form factor
LM57B/C	Resistor-programmable temperature switch	User programmable, high accuracy LLP-8 small package footprint -50°C to +150°C temp range	Supports very wide temperature switching in very small form factor
Remote Diode Temperature Sensors			
LM95213/31	Dual-input remote diode and local digital temp sensor	2-wire interface and ouptuts	Accurately senses die temp of 2 remote ICs or diode junctions and local temp
LM95214	Quad remote diode and local temp sensor	2-wire interface and ouptuts	Accurately senses die temp of 4 remote ICs or diode junctions and local temp
LM95233/34/35(Q)	Remote diode and local temp sensor	TruTherm beta compensation 2-wire SMBus interface	Supports 90 nm, 65 nm processors Accurately senses die temp of 2 remote ICs or diode junctions plus sub-micron process thermal diodes
LM95245	Precision, 11-bit digital remote diode		Supports 45 nm processors

Thermal Management

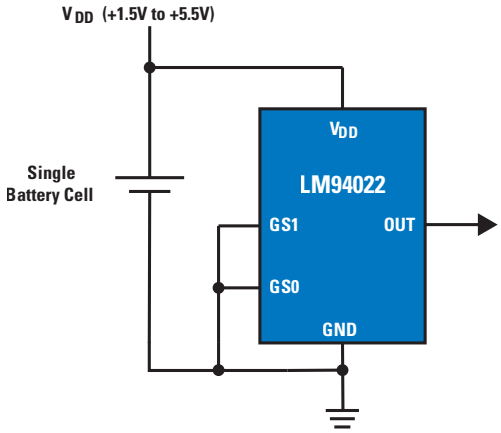
Analog and Digital Temperature Sensing

National's analog and digital temperature sensors solve most thermal management design issues. If an A/D channel is available in the system, analog sensors are usually the easiest temperature sensors to use. If a microcontroller, baseband controller, or a communication bus is available, a digital temperature sensor can interface directly with the processor. Key considerations include accuracy, temperature range, package, supply, and power consumption.

Digital Temperature Sensor



Analog Temperature Sensor



Analog and Digital Temp Sensors

Analog Temperature Sensors			
Product ID	**Description**	**Features**	**Benefits**
LM94021/22(Q)	1.5V, multi-gain, Class AB output analog temp sensors	Low voltage, low power Small package –50°C to +150°C operation	Wide temp range operation High performance
LM94023	1.5V, dual-gain, Class AB output analog temp sensor	micro SMD package –50°C to +150°C operation Low voltage, low power	Smallest footprint Wide temp range operation High performance
Digital Temperature Sensors			
LM73/75A/76/77/92	I^2C compatible digital temp sensors	2-wire, shutdown mode ± 0.33°C to ± 2.0°C accuracy Most operate down to –55°C to up to +150°C Small packages	Wide temp range operation High accuracy over temp range
LM70/71, LM95071(Q), LM95172(Q)	SPI digital temp sensors	Shutdown mode Most operate down to –55°C to up to +150°C Small packages	Wide temp range operation High accuracy over temp range Small package footprints

Thermocouples and RTDs

Thermocouples support applications from -200˚C to 2300˚C and accuracies starting at 0.5˚C or 0.4% of span. They are rugged and available in standard configurations characterized by type (types J, K, T, E, N, R, S, B, G, C, D)

Resistance Temperature Detectors (RTDs) make use of a metal's resistance change over temperature. They are more accurate than thermocouples, but not as rugged and do not support extreme temperature applications. Performance ranges from ±0.15%˚C (Class A) to ±0.3%˚C (Class B) at temp = 0%˚C with types defined by resistance change over temperature. Common RTDs include PT100 (100Ω from -200˚C to 0˚C), PT500 (500Ω from -200˚C to 0˚C) and PT1000 (1000Ω from -200˚C to 0˚C).

Thermocouple Interface

- Op amps: LMP7715
- ADC: ADC122S021, ADC121C021/27
- Cold junction compensation: LM94022, LM57
- Power: LP5900, LP3878-ADJ

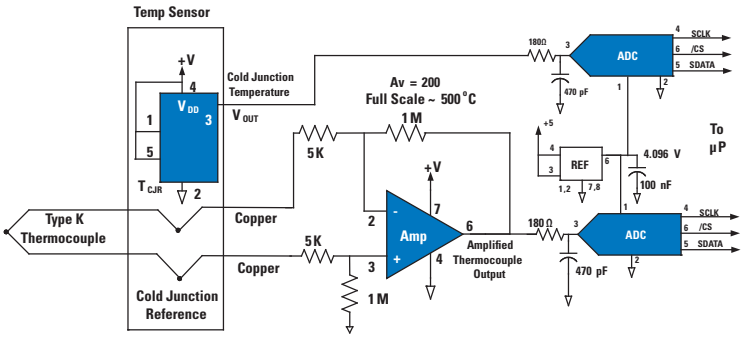
Thermocouple and RTD Applications

- Industrial, HVAC, process controllers
- Smart temperature transducers
- Gas monitors
- Discrete volumetric valves

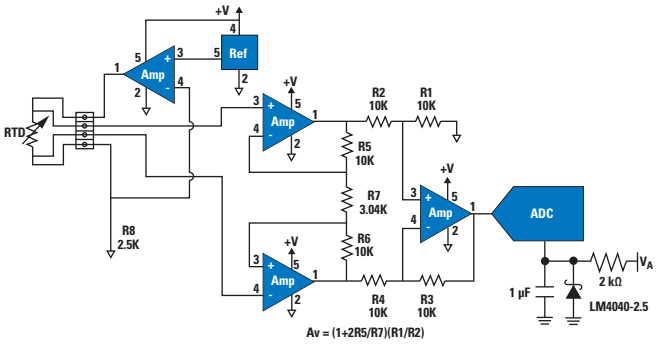
RTD Interface

- Op amps: LMP2011, LMP2021/22
- Converters: ADC121S02, ADC121C021/27
- Reference: LM4140
- Power: LP5900, LP2992

Thermocouple Interface



RTD Interface



Thermocouple and RTDs

Product ID	Description	Features	Benefits
Amplifiers			
LMP7715/16	Single/dual, precision, 17 MHz, low-noise, CMOS-input amplifier	Wide bandwidth, low I_{BIAS}, low noise	Ideal for instrumentation and low power applications
LMP2021/22	Single/dual, zero-drift, low-noise, EMI-hardened amplifiers	Continuous correction circuitry Very low input voltage noise Very high open-loop gain Low input bias current 23 pA	Ideal for low-frequency apps Continuous correction and reduced calibration frequency Minimal gain error in high-gain apps Ideal for impedance circuit
ADCs			
ADC121S021/ ADC122S021	Single-/dual-channel, 12-bit ADCs supporting sample rates up to 1 MSPS	Low power, small package Part of 8-/10-/12-bit pin- and function-compatible family across sample rate	Supports high-performance apps over wide temperatures Pin compatibility and package size simplify board layout
ADC121C021/27	I²C compatible, 12-bit ADCs with alert pin	Low power, small package Configurable alarm Part of 8-/10-/12-bit pin- and function-compatible family across sample rate	Supports high-performance apps over wide temperatures Alarms to indicate out of range condition Pin compatibility and package size simplify board layout

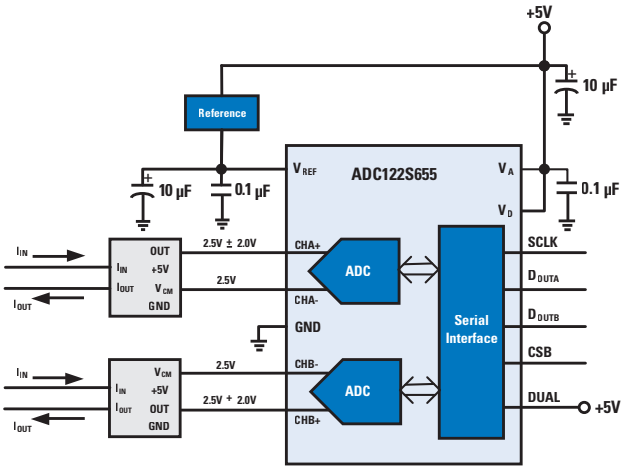
Current, pH, and Chemical Sensing

Current Sensor (Hall Effect)

A Hall Effect sensor measures an electrical field that is proportional to current. Hall Effect sensors provide an output voltage proportional to a changing current. The actual voltage output of the Hall Effect element is very small, and the element is usually integrated with an amplifier to provide a low-level voltage output, which can directly drive an ADC.

Hall Effect sensors are non contacting, can be used over a wide temperature range, and support a wide range of sample rates (frequencies).

Hall Effect Sensing Interface



Applications

- Current sensing
- Motor control sensing (current, position)
- Position and proximity
- Sequencing sensors
- Level /tilt measurement sensor
- Flow rate
- Temperature or pressure sensor
- Angle sensor

Hall Effect Sensor Interface

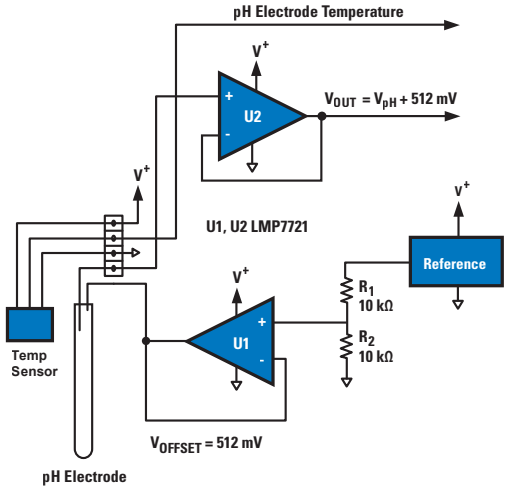
- ADC: ADC122S655

pH Sensing

pH sensors measure hydrogen ion (H+) concentration and provide an electric output when two liquids of different pH come into contact at opposite sides of a thin electrode. The pH electrode is a passive sensor (no excitation source). The electrode is bipolar and produces a voltage output proportional to the pH of the solution being measured.

The source impedance of a pH electrode is very high, typically 10 MΩ to 1000 MΩ. A small input-bias current can produce a large voltage error when injected into the very high impedance of a pH electrode, so the most critical significant parameter to consider in amplifier selection is the amplifier's input -bias current. Since the sensitivity of the electrode can change with temperature, it is critical to measure temperature as well as pH in order to ensure an accurate pH measurement.

pH Sensing Interface



Applications

- Water treatment
- Chemical processing
- Medical instrumentation
- Environmental test systems

pH Sensor Interface

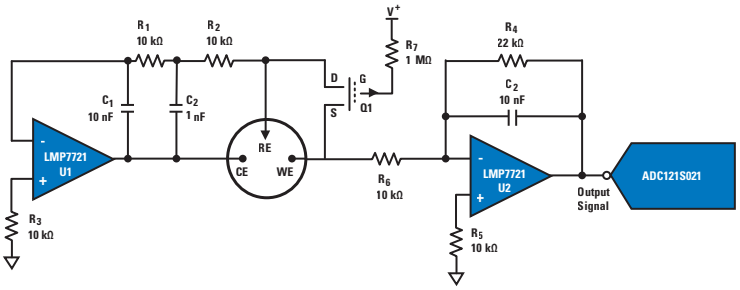
- Op amp: LMP7721
- ADC: ADC122S021
- Reference: LM4140
- Temperature sensor: LM94022, LM57B/C
- Power: LP5900, LP38511-ADJ

Chemical Sensing

Electro-chemical sensors require control circuitry (potentiostatic circuit) to operate. The main purpose of this circuit is to maintain a voltage between the reference electrode (RE) and the working electrode (WE). This controls the electro-chemical reaction and delivers an output signal proportional to the WE current (gas concentration).

The input bias current of the control amplifier (U1) is one of the critical specifications. The inverting input of U1, which is connected to RE, cannot draw any significant current from the reference electrode. An ultra-low input bias amplifier will assure that the reference electrode will maintain a constant potential.

Chemical Sensing Interface



Current, pH, and Chemical Sensing

Product ID	Description	Features	Benefits
ADCs			
ADC122S655	12-bit, low power, simultaneous sampling ADCs with SPI interface	±0.024% signal accuracy Part of pin- and function-compatible family across sample rate SPI: 50 kSPS to 1 MSPS family I²C: All three interface speeds with alert/alarm	Supports high-performance apps over a wide temperatures Pin compatibility and package size simplify board layout Alarms indicate out-of-range condition
ADC121S021, ADC122S021, ADC12C021/27	12-bit, low-power ADCs SPI (ADCxxxSxxx) interface I²C (ADCxxxCxxx) interface		
Power Management			
LM4140	Voltage reference	Tempco of 3, 6, or 10 ppm/°C Initial accuracy of 0.1% 60 ppm V_{REF} performance after 1,000 hours	Minimal change in V_{REF} over entire temperature range Ultra-high precision initial accuracy for use with high-precision ADCs Stable V_{REF} over life of application
LP5900	Low-noise LDO	85 dB PSRR at 100 Hz Low output noise of 6.5 μV_{RMS} No bypass capacitor required	Reduces voltage ripple to isolate sensing circuitry from noise Minimizes effect on sensor precision Smaller solution size
LP3878-ADJ	LDO	Low output noise of 18 μV_{RMS} Supports 800 mA output current Sub 10 µA quiescent current consumption	Minimal effect on sensor precision High output power with LDO simplicity Minimal power consumption
LP38511-ADJ	LDO	Supports 800 mA output current Error pin 1 µA quiescent current consumption	High output power with LDO simplicity Enables robust system design Minimal power consumption
Amplifiers			
LMP7721	3 Femtoamp input-bias current, precision amplifier	Low I_{BIAS}, low noise, low V_{OS}	Ideal for sensor interface and prevents PCB leakage current from reaching the input pins
Temperature Sensors			
LM94022	1.5V, multi-gain, Class AB output analog temp sensor	Low voltage, low power Small package –50°C to +150°C operation	Wide temp range operation High performance
LM57B/C	Resistor-programmable temperature switch with -50°C to +150°C temp range	User programmable, high accuracy LLP-8 small package footprint	Supports very wide temperature switching in very small form factor

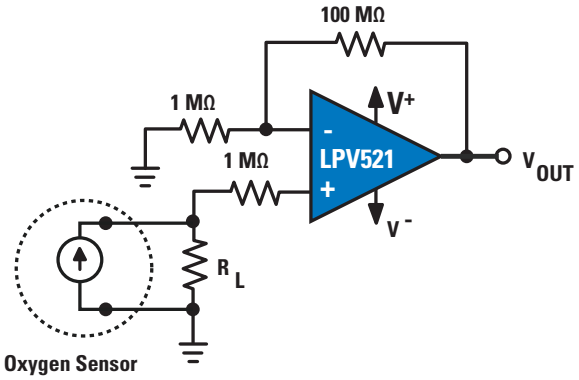
Oxygen Sensing

Oxygen Sensing

Gas sensors are used in many different industrial and medical applications. They generate a current proportional to the percentage of a particular gas sensed in an air sample. This current goes through a load resistor and the resulting voltage drop is measured. Depending on the sensed gas and sensitivity of the sensor, the output current can be in the order of tens of microamperes to a few milliamperes.

In the case of oxygen sensors, the sensor typically has a life of one to two years. The use of a nanopower op amp like the LPV521 means minimal power usage, extending battery life.

Depending on other components present in the circuit design, the battery could last for the entire life of the oxygen sensor.



Product ID	Description	Features	Benefits
Amplifiers			
LPV521	Nanopower, 1.8V, RRIO, CMOS-input amplifier	1.6V to 5.5V operating power 400 nA consumption Small SC70 package	Ideal for low-power applications Minimum board space
Power Management			
LP3878-ADJ	LDO	Low output noise of 18 µVRMS Supports 800 mA output current Sub 10 µA quiescent current consumption	Minimal effect on sensor precision High-power-output power with LDO simplicity Minimal power consumption
LP2992	LDO	Wide V_{IN} range of 2.2V to 16V Max 15 µA quiescent current consumption	Wide input range provides maximum flexibility Minimal power consumption
LP3961	1A step-down converter	Only 3 external components required Synchronous switching regulator +/-1% output accuracy	Minimal BOM, solution size < 15 mm^2 High-efficiency minimizes energy consumption Precision output voltage

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