Industrial Automation Solutions

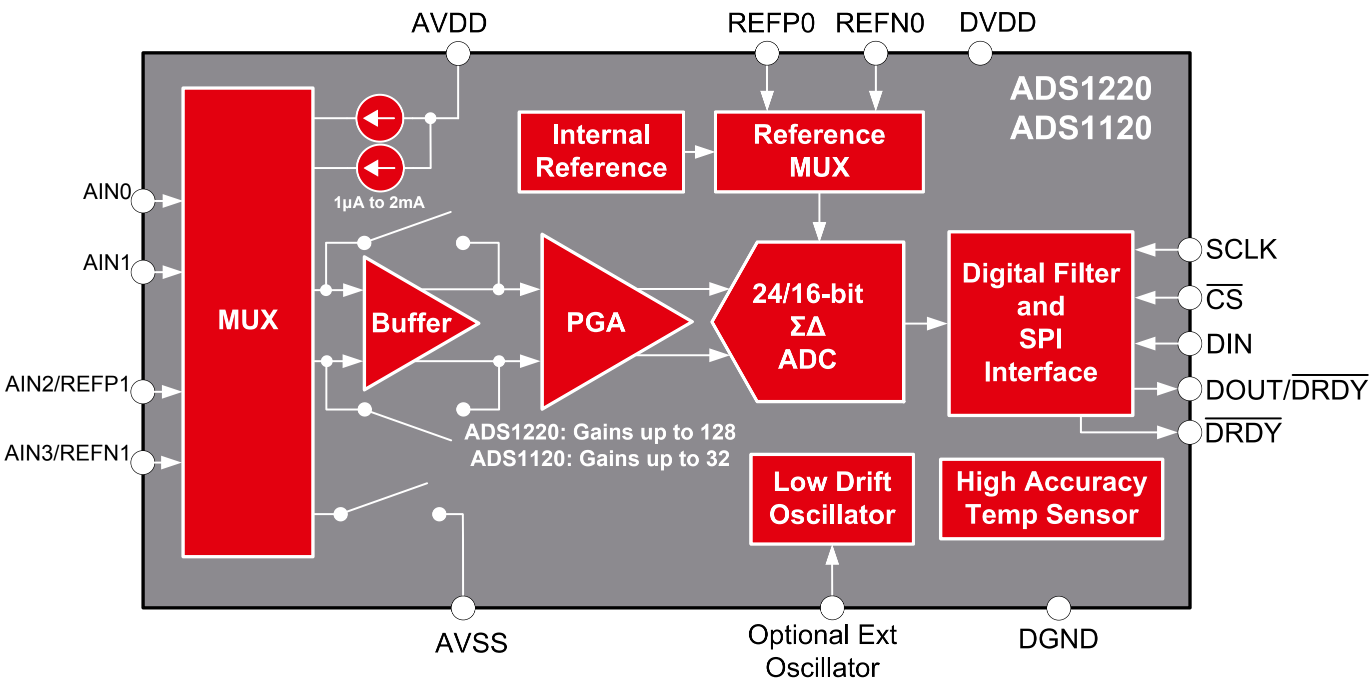
Temperature Sensing

Texas Instruments

TI's portfolio speeds the design cycle with the right sensor signal acquisition solutions, software, tools and support.

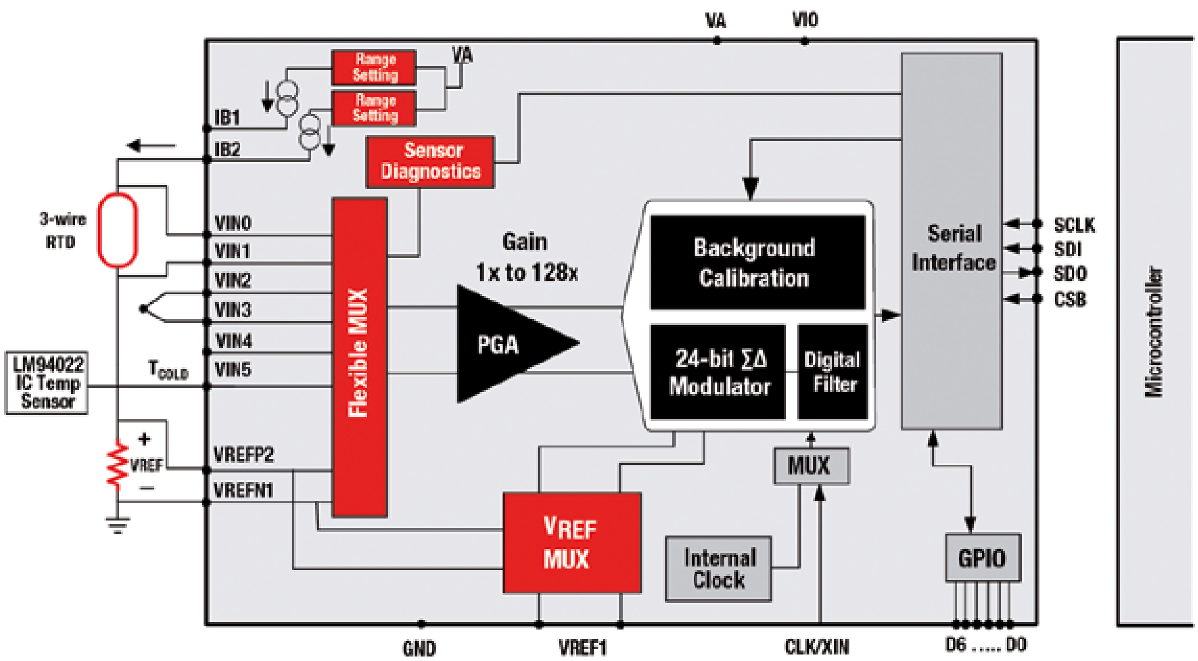
ADS1220, ADS1120

24-Bit (16-Bit for ADS1120) low-power Analog Front End for Precision Signal (DC) Sensor applications, incl. 4 – 20mA loop applications. High integration and small package size enable the use in space sensitive applications.



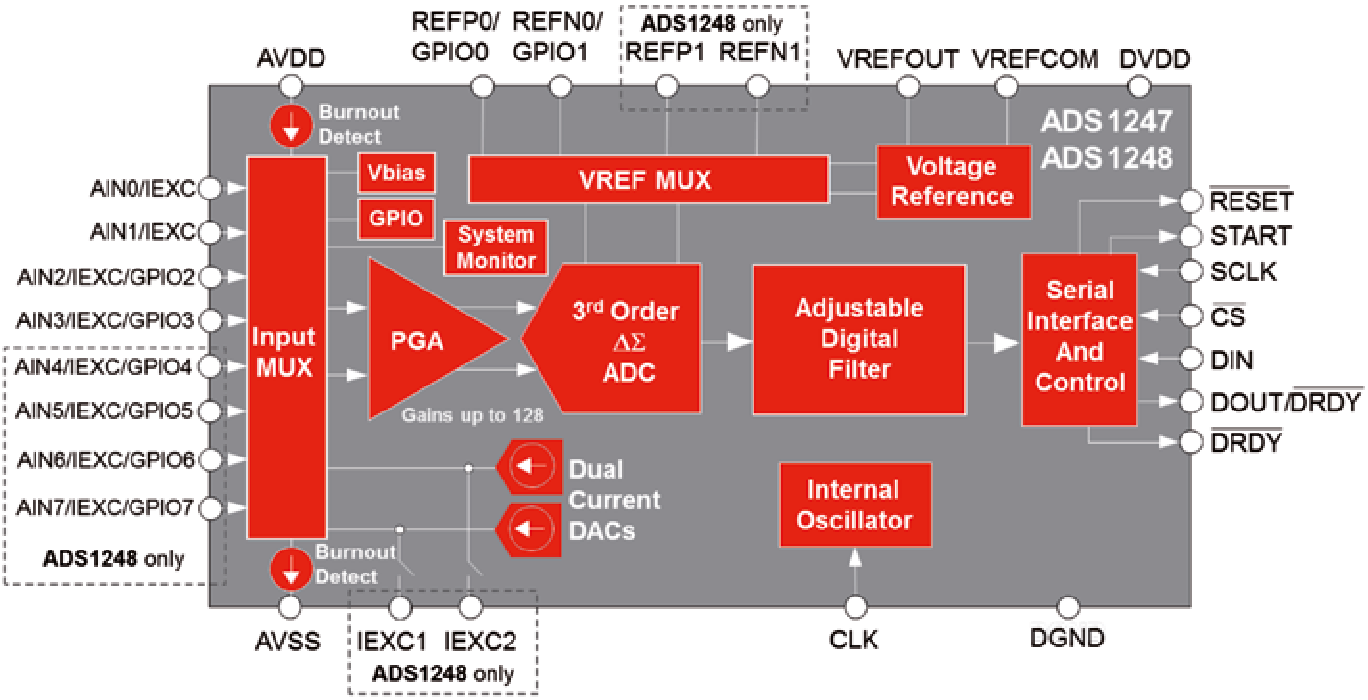
LMP90100, LMP90077-80, LMP90097-99

Multi-Channel, low power 24/16-Bit Sensor AFE with true continuous background calibration that eliminates gain and offset errors across temperature and time, without interrupting the signal path. The AFEs provide as well sensor diagnostics and SPI 4/3-wire with CRC data link error detection.



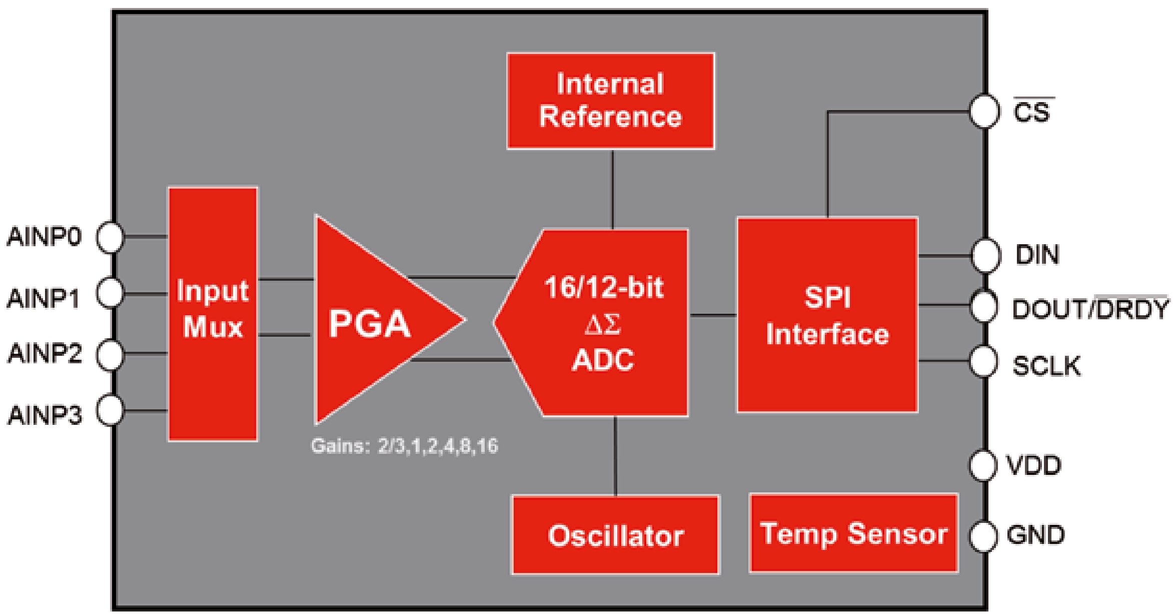
ADS1248, ADS1247

24-Bit, complete and ultimate temperature measurement ADC providing the most flexible front end for a wide range of industrial sensors. It offers high integration without compromising performance and provides for scalable solutions.



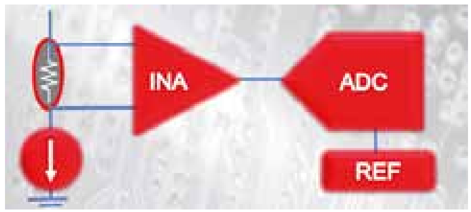
ADS1118, ADS1018

16-Bit (12-Bit for ADS1018) world's smallest temperature measurement ADC with a 0.5°C (max) (1°C (max) for ADS1018) accurate internal temperature sensor. A single ADS1118/ADS1018 can perform data acquisition of multiple signals from a wide variety of sensors. Provided in a small package that senses ambient temperature to perform cold junction compensation in thermocouple applications. Its size and low power consumption make these device the first choice for portable applications where extended battery life is critical.



Discrete Components Solutions

- Current generation & analog linearization circuits
- Instrumentation amplifier
- Data converter and references

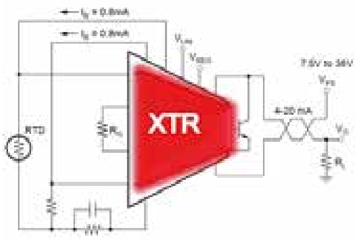


Current Generation & Analog Linearization Circuits	Instrumentation Amplifier	Data Converter and References
REF200 Matched dual current source 2.5V to 40V Also include current mirror	**INA326, 327** Precision, rail-to-rail I/O INA 2.7V to 5.5V Low offset: 100µV (max)	**ADS1118, ADS1120, ADS1248** Highly integrated AFE for temperature measurements
OPA333 MicroPower, zero drift CMOS Op Amp 1.8V, 17µA, Low offset: 50µV (max)	**INA333** MicroPower, zero-drift, rail-to-rail out INA 1.8V, 50µA Low offset: 25µV (max)	**ADS1240** Low noise, excellent 50 & 60 Hz rejection, 24-Bit 15 SPS Analog-to-Digital Converter
OPA378/OPA376 Low noise, low Iq Op Amp 2.2V to 5.5V, 760µA e-trim™ series, 5µV offset	**INA826/827** Precision, INA with rail-to-rail out 2.7-V to 36-V 200-µA Input bias current 2pA	**ADC161S626** 16-Bit SAR, 50 to 250 kSPS, differential input, MicroPower ADC
OPA2188/OPA188 0.03-µV/°C drift, low-noise, rail-to-rail output 4V to 36V, 450µA Zero-drift	**INA114** Precision Instrumentation Amplifier 2V to 18V, 2mA Low bias current: 2nA max	**ADS8326** 16-Bit , 250kSPS, Precision ADC in MSOP-8 and QFN, <4mW @ 2.7V
LPV521 Nanopower, rail-to-rail, CMOS input Op Amp 1.8V, 400 nA Input bias current 40 fA		**REF3112/REF3212** Precision, low drift voltage references 20ppm/50ppm/°C, SOT23-3

4–20mA Transmitters

Advantages versus discrete solution:

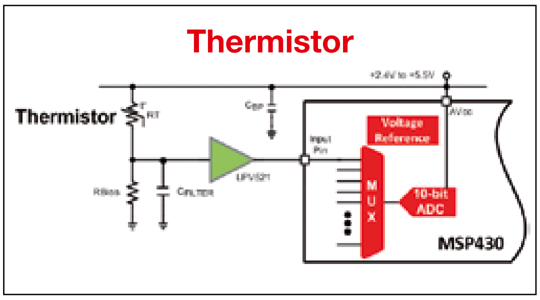
- Smallest solution
- Higher accuracy
- Digital-calibration (XTR108)
- Automatic scaling
- HART compatible interface



Part Number	Description	Sensor Excitation	Loop Voltage (V)	Full Scale Input Range	Package
XTR105	100Ω RTD conditioner with linearization	two 800µA	7.5 to 36	5mV to 1V	DIP-14, SOIC-14
XTR108	10Ω to 10kΩ RTD conditioner, 6 channel input MUX, calibration stored in external EEPROM	two 500µA	7.5 to 24	5mV to 320mV	SSOP-24
XTR112	1kΩ RTD conditioner with linearization	two 250µA	7.5 to 36	5mV to 1V	SOIC-14
XTR114	10kΩ RTD conditioner with linearization	two 100µA	7.5 to 36	5mV to 1V	SOIC-14
DAC161P997	Ultra-low power (<190 µA), 16 bit current output DAC, with internal reference and HART-compatible interface			0x0000 to 0xFFFF	16WQFN

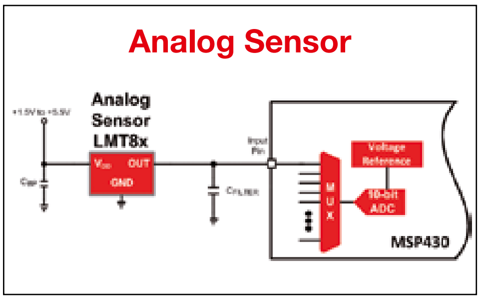
Thermal Management Solutions

Replacing thermistors by temperature sensor ICs (example)



Analog temp sensor advantages:

- Higher accuracy over wider temperature range
- Linear across temp range
- Lower power dissipation
- Simpler design that utilizes less board space – no additional external components
- Simpler to use



www.ti.com/analogtempsensors

Local Sensors

Part Number	Max Accuracy	Interface	Iq(Typ)(uA)	Resolution	Temp Range(C)	Supply Range (V)	Special Features	Packages	1k price $
LM35	0.5	Analog	56	10mV/°C	-55 to 150	4 to 30	Precision centigrade	3TO, 3TO-92, 8SOIC, 3TO-220	0.56
LM57	0.7	Analog	24	-5 to -13mV/°C	-50 to 150	2.4 to 5.5	Resistor-programmable	8WSON	0.65
LM50	2	Analog	130	-10mV/°C	-40 to +125	4.5 to 10	Most popular	3SOT-23	0.32
TMP20	2.5	Analog	2,6	-12mV/°C	-55 to 150	1.8 to 5.5	Low power	5SC70, 6SOT	0.38
LMT84	2.7	Analog	5.4	-5.5mV/°C	-50 to +150	1.5 to 5.5	Push-pull output	5SC70	0.195
LMT87	2.7	Analog	5.4	-13.6mV/°C	-50 to +150	2.7 to 5.5	Push-pull output	5SC70	0.195
TMP102	2	I2C, SMBus	10	12 bit	-40 to 125	1.4 to 3.6	Programmable alert	6SOT	0.75
TMP112	0.5	I2C, SMBus	7	12 bit	-40 to 125	1.4 to 3.6	High precision, small size	6SOT	0,85
TMP275	0.5	I2C, SMBus	50	12 bit	-40 to 125	2.7 to 5.5	High precision, programmable alert, pin compatible to TMP75/LM75	8SOIC, 8VSSOP	0.95
TMP122	1.5	SPI	50	12 bit	-40 to 125	2.7 to 5.5	Programmable high/low setpoints	6SOT-23	0.99
LM95172-Q1	1	SPI, QSPI, Microwire	400	16 bit	-40 to 200	3.0 to 5.5	One shot conversion control, configurable temperature resolution	10CLGA	100

Contactless Sensor (IR Sensor)

Part Number	Max Accuracy	Interface	Iq(Typ)(uA)	Resolution	Temp Range(C)	Supply Range (V)	Special Features	Packages	1k price $
TMP006	1 (local), 3 (IR)	I2C, SMBUS	240	14 bit	-40 to 125	2.2 to 3.6	Infrared thermopile sensor	8DSBGA	1.50

Remote Sensors

Part Number	Max Accuracy	Interface	Iq(Typ)(uA)	Resolution	Temp Range(C)	Supply Range (V)	Special Features	Packages	1k price $
LM96163	0.75	SMBus	456	11 bit	-40 to 125		Remote diode digital temp sensor with integrated fan controller & beta compensation & tachometer input	10SON	1.14
TMP411	2.5	2-Wire, SMBus	400	12 bit	-40 to 125	2.7 to 5.5	Programmable alert, N-factor and series resistance correction, 1 remote channel	8SOIC, 8VSSOP	0.45
TMP512	1	I2C, SMBus	55	13 bit	-40 to 125	3.0 to 26	All-in-one thermal and power monitoring solution with 2 remote channels, programmable alert	14SOIC, 16QFN	1.45

Switches

Part Number	Max Accuracy	Output Type	Iq(Typ)(uA)	Resolution	Temp Range(C)	Supply Range (V)	Features	Packages	1k price $
LM26	3	Open drain or push pull	40	-11mV/°C	-55 to 125	2.7 to 5.5	Factory programmable	5SOT-23	0.43
LM57	1.5	Open drain and push pull	24	-5…13mV/°C	-50 to 150	2.4 to 5.5	Resistor programmable; analog temp sensor output	8WSON	0.65
TMP302A	2	Open drain	8		-40 to 125	1.4 to 3.6	Low power, fixed setpoints	6SOT	0.2
TMP708	3	Open drain	25		-40 to 125	2.7 to 5.5	Resistor programmable, 10C/30C hysteresis options	5SOT-23	0.3

Temperature Sensing Principles

Temperature is the most frequently measured physical parameter and can be measured using a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic. Three of the most common types are Thermocouples, Resistance Temperature Detectors (RTDs), and NTC-Thermistors.

Thermocouples consist of two dissimilar metal wires welded together to form two junctions. Temperature differences between the junctions cause a thermoelectric potential (i.e. a voltage) between the two wires. By holding the reference junction at a known temperature and measuring this voltage, the temperature of the sensing junction can be deduced. Thermocouples have very large operating temperature ranges and the advantage of very small size. However, they have the disadvantages of small output voltages, noise susceptibility from the wire loop, and relatively high drift.

Resistance Temperature Detectors (RTDs) are wire winding or thin-film serpentines that exhibit changes in resistance with changes in temperature. While metals such as copper, nickel and nickel-iron are often used, the most linear, repeatable and stable RTDs are constructed from platinum. Platinum RTDs, due to their linearity and unmatched long-term stability, are firmly established as the international temperature reference transfer standard. Thin-film platinum RTDs offer performance matching for all but reference grade wire-wounds at improved cost, size and convenience. Early thin-film platinum RTDs suffered from drift, because their higher surface-to-volume ratio made them more sensitive to contamination. Improved film isolation and packaging have since eliminated these problems making thin-film platinum RTDs the first choice over wire-wounds and NTC thermistors.

NTC Thermistors are composed of metal oxide ceramics, are low cost, and the most sensitive temperature sensors. They are also the most nonlinear and have a negative temperature coefficient. Thermistors are offered in a wide variety of sizes, base resistance values, and Resistance vs. Temperature (R-T) curves are available to facilitate both packaging and output linearization schemes. Often two thermistors are combined to achieve a more linear output. Common thermistors have interchangeabilities of 10% to 20%. Tight 1% interchangeabilities are available but at costs often higher than platinum RTDs. Common thermistors exhibit good resistance stability when operated within restricted temperature ranges and moderate stability (2%/1000 hr at 125°C) when operated at wider ranges.

IC temperature sensors use internal bandgap sensors which can be typically integrated into an IC at low cost. The making of a temperature sensor depends upon exploiting a property of some material which preferably is a linear function for the temperature range of interest. Thus, the linearity over the temperature range is one of the most significant advantages of IC temperature sensors besides their overall noise immunity, ease of use and low cost. Current limitations might be seen in the temperature range these sensors can typically cover, which is restricted to -55 to 200°C. As such, IC temperature sensors are an excellent choice for applications that require accuracy, linearity (without additional software effort) and operate within the given temperature range.

Criteria	Thermocouple	RTD	Thermistor	Semiconductor
Temperature Range	Very wide −200°C +2000°C	Wide −200°C +650°C	Short to medium −50°C +300°C	Narrow −55°C +200°C
Accuracy	Medium	High	Medium	High
Repeatability	Fair	Excellent	Fair to good	Good to excellent
Long-Term Stability	Poor to fair	Good	Poor	Good
Sensitivity (out)	Low	Medium	Very high	High
Linearity	Fair	Good	Poor	Good
Response	Medium to fast	Medium	Medium to fast	Medium to fast
Size/Packaging	Small to large	Medium to small	Small to medium	Small to medium
Interchangeability	Good	Excellent	Poor to fair	Good
Point (End) Sensitive	Excellent	Fair	Good	Good
Lead Effect	High	Medium	Low	Low
Self Heating	No	Very low to low	High	Very low to low
Overal Advantages	Self powered, simple, rugged, variety of physical forms, wide range of temperature	Most stable, most accurate, more linear than thermocouple	High output, two-wire ohms measurement	Most linear, high output, inexpensive, analog or digital IF
Overall Disadvantages	Non-linear, low voltage, reference required, least stable, least sensitive	Expensive, slow, current source required, small resistance change, four-wire measurement	Non-linear, limited temperature range, fragile, current source required	T < +250°C, power supply required

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