Temperature Sensing

Introduction

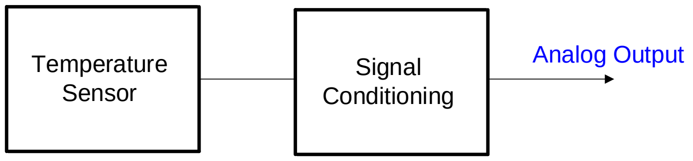
The measurement and control of temperature is fundamental to many applications and processes. Consider for example thermal management systems in computers and disk drives, or the need to control temperatures in industrial processes. In recent times the rise of smartphones and environmental monitoring systems has driven the development of low power, connected temperature sensors. This broad range of applications has led to the development of a wide variety of temperature sensors, each with its own advantages for a particular system.

Analog or Digital Output

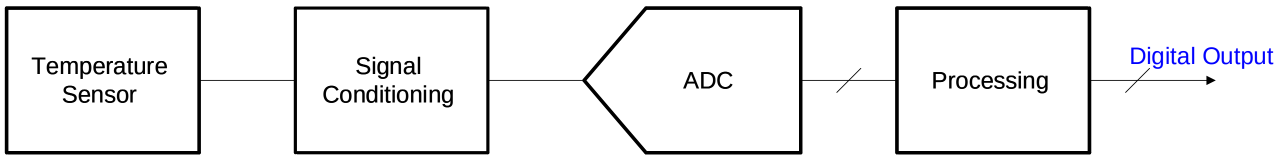
Analog temperature sensors produce an analog output signal (voltage or current) which is proportional to temperature. They are useful in applications where the analog signal can be used directly in the system. Analog temperature sensors can be obtained pre-calibrated for high linearity.

Digital temperature sensors incorporate an ADC in the signal chain to digitise the temperature sensor output. The digitisation of the temperature sensor data is key to the control and communication intensive world of IoT. It allows for example the communication of temperature alerts. It facilitates the use of the temperature data in control systems. Having the temperature sensor data in digital format simplifies the accessing of sensor calibration data which can be stored in look-up tables.

Temperature Sensor with Analog Output



Temperature Sensor with Digital Output



Local and Remote Temperature Sensors

Local temperature sensors

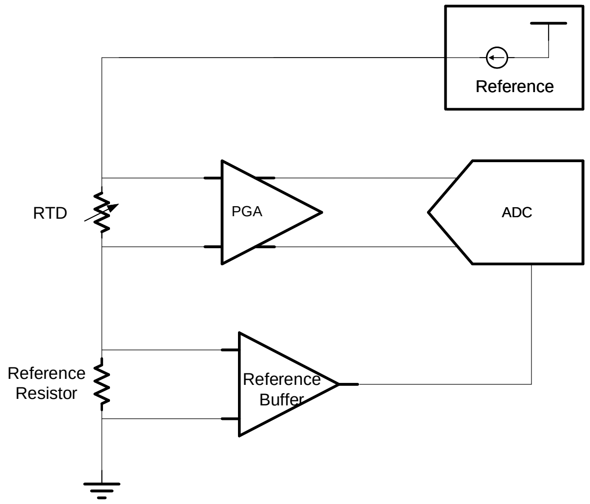
Local temperature sensors are local in the sense that they measure the temperature locally on the IC itself. This IC will also include circuitry to digitise, calibrate and communicate the sensed temperature. The operating range of such local temperature sensors is limited to the typical operating range of the IC itself, generally -40ºC to 125ºC for consumer and industrial applications and -55ºC to 150ºC for automotive applications. Typical applications for local on-chip temperature sensors are the monitoring of temperature in electronic equipment or on a PCB in a computer. In these cases, the temperature sensor may be part of a closed-loop temperature control system where for example a control signal can be used to activate a fan if a certain temperature is exceeded.

On-chip temperature sensors generally rely on the negative temperature coefficient of the base emitter voltage of a bipolar transistor or on the positive temperature coefficient of the difference in base emitter voltage between two transistors with different areas. With calibration these types of temperature sensors achieve an accuracy of +/- 3ºC.

Remote temperature sensors

Remote temperature sensors have the sensing element remote to the IC and their temperature sensing range is therefore not limited to the temperature range of the IC. They are ideal for industrial applications where extreme temperatures need to be monitored, but are also used for moderate temperature applications where the temperature measurement point is remote to the processing IC. There are many different types of remote sensors available, each having its own optimal application area.

Resistor Temperature Detectors (RTDs) utilise the variation of metal wire resistance with temperature. Platinum is commonly used for example the PT100 or PT1000 RTD types, where 100Ω or 1000Ω is the resistance of the RTD at 0ºC. RTDs feature a wide temperature range (up to 800ºC) making them suitable for many industrial applications. They also have relatively high accuracy, good repeatability and reasonable linearity. As resistance is the physical quantity which varies with temperature, some conditioning circuitry is required to convert this to a voltage or current which can be more readily digitised.



Thermocouples are based on the Seebeck effect - the voltage difference generated by two junctions of dissimilar metals at different temperatures, one being designated the hot junction and one the cold. Thermocouples have the widest temperature range (-270 to 1260ºC for the common K-type Nickel-Chromium / Nickel-Alumel) and so are very suitable for industrial applications. They are relatively inexpensive and as they generate a voltage which varies with temperature, their output could in principle be digitised directly. However, they have a low sensitivity (~40µV/ºK for a K type) so require a large and precise gain to scale the output voltage to the input range of the ADC. Thermocouples have only moderate linearity so a look-up table is required to interpret the voltage measurement. In addition, the temperature measurement is differential so an absolute temperature reference measurement is required as for the cold junction.

Thermistors are thermally sensitive resistors usually based on ceramic or polymer. They have a narrower temperature range than RTDs, up to 200ºC, but a higher sensitivity. Thermistors are relatively non-linear and the measurement must be linearised using curve fitting.

Diodes or bipolar transistors which form the basis of local on-chip temperature sensors can also be used as remote temperature sensors. These can either be discrete component instantiations or embedded transistors on processor ICs. The temperature range is typically limited to -55ºC to 150ºC. Typical applications are temperature monitoring in telecoms equipment and data centres. External diodes offer a relatively low-cost and accurate solution. The multiplexing of multiple temperature sensing diodes both on and off chip enables a cost effective zonal temperature measuring system.

Adesto Temperature Measurement Solutions

Adesto's ASIC & IP division has silicon proven temperature measurement reference designs for both local and remote temperature sensors. These can be readily integrated into an SoC. For example, the S3ADTS1M12BGF65 is a silicon proven 12-bit digital temperature sensor. For remote temperature sensing signal chains Adesto has the constituent key silicon proven building blocks such the S3PGAC40LP PGA together with the high precision integrated SAR ADC, S3ADS1M14BT40ULP. Should the signal chain obligate a higher precision, then a proven sigma-delta converter can be incorporated in the path, such as the S3AD01M16BGF65LPE. All other elements of the signal path, such as the signal conditioning and digital filtering can be readily integrated with the converters on a single SmartEdge™ ASIC. No more need for discrete components to build that temperature sensor.