LM94021,LM94022

Temperature sensor solutions for low-voltage systems

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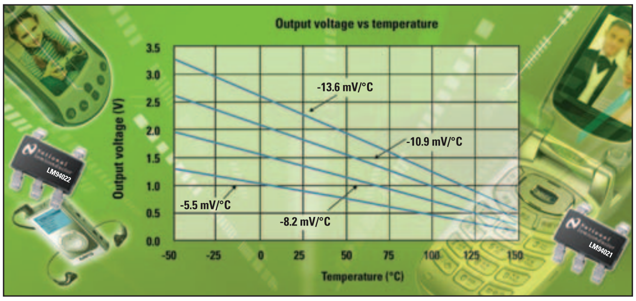

First precision analog temperature sensors with four user-selectable gains and operation down to 1.5V

The LM94021 and LM94022 are precision analog output CMOS integrated-circuit temperature sensors that operate at supply voltages as low as 1.5V and as high as 5.5V. Operating over a wide temperature range of -50°C to +150°C, the LM94021/22 deliver an output voltage that is inversely proportional to measured temperature. The low supply current of the LM94021/22 make them ideal for battery-powered systems as well as general temperature-sensing applications.

The LM94022 can be connected directly to any ADC without a need for any external components.

Features

- Low 1.5V operation
- Four selectable gains
- Very accurate over wide temperature range of -50°C to +150°C
- Low quiescent current
- Output is short-circuit protected
- Supply voltage 1.5V to 5.5V
- Supply current 9 µA (typ)

The LM94021/22 are available in space-saving SC70-5 packaging and are ideal for use in cell phones, wireless transceivers, battery management, automotive, disk drives, games, and appliances.

www.national.com/tempsensors
www.national.com/pf/LM/LM94021.html
www.national.com/pf/LM/LM94022.html

DESIGN | *idea:* Temp Sensor Solutions ▶ ▶

Super-small 1.8V rail-to-rail input/output operational amplifier

The LMV931 is a low-voltage, low-power operational amplifier. It is guaranteed to operate from a 1.8V supply voltage and have rail-to-rail input and output. The input common-mode voltage of the LMV931 extends 200 mV beyond the supplies, which enables user-enhanced functionality beyond the supply voltage range. The output can swing rail-to-rail unloaded and within 80 mV from the rail with 600Ω load. The LMV931 is optimized to work at 1.8V, which makes it ideal for portable two-cell, battery-powered systems and single-cell, Li-Ion systems.

The LMV931 exhibits an excellent speed-power ratio, achieving 1.4 MHz gain bandwidth product at 1.8V supply voltage with very low supply current.

Features

- Guaranteed 1.8V supply operation
- Output swing
  - with 600Ω load – 80 mV from rail
  - with 2 kΩ load – 30 mV from rail
- V_{CM} 200 mV beyond rails
- Supply current (per channel) 100 µA
- Maximum V_{OS} 4.0 mV
- Very accurate over temperature range -40°C to +125°C

The LMV931 is offered in tiny SC70-5 and SOT23-5 packaging and is ideal for space-constrained PC boards, portable electronics such as cellular phones, PDAs, and MP3 players, and supply current- and battery-monitoring applications.

amplifiers.national.com
www.national.com/pf/LM/LMV931.html

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Technical Marketing Manager
National Semiconductor

Temperature sensor solutions for low-voltage systems

To follow Moore's law and provide higher performance and expanded features at lower cost, processor manufacturers have moved to lower geometry or deep sub-micron processes. One of the characteristics of smaller geometry processes is a drop in supply voltage. The supply voltage requirements vary based on process design. A drop in the supply voltage can be delayed but it cannot be prevented as the geometry size is reduced. For example, a 0.35 micron process has sufficient oxide isolation to accept a maximum supply voltage of 5V. However for 0.13 micron and 90 nm processes, the maximum supply voltage is 3.3V and 1.8V, respectively.

A drop in supply voltage provides advantages and challenges to portable system designers. Since portable systems are battery operated, a drop in supply voltage requirement will increase the battery life. Battery life is one of the important characteristics of portable devices. Therefore, portable system designers would like to take advantage of this reduction in the supply voltage requirement and reduce the number of higher power supply regulators in their systems. Eliminating higher supply voltage regulators creates new challenges. One of the challenges is component selection since designers need to choose all of the components in their system to be operational in low voltage.

A system designer has a choice in maintaining the higher voltage regulators in their system. This will help in the selection of some of the components. But it presents the challenge of selecting components to interface with these low-voltage processors. Let's assume that a 90 nm microcontroller has been selected. This microcontroller has a maximum supply voltage requirement of 1.8V. Also, the threshold of the serial interface to this part (SPI or I^2C) has a maximum voltage requirement of 1.8V. By choosing this microcontroller, all of the components communicating with this microcontroller will be required to have a maximum of 1.8V serial interfaces.

To discuss the low-voltage system requirement and challenges that designers face in detail, let's examine the temperature sensor design and selection in such a system.

Possible temp sensor solutions

One of the most common components used in a system is a temperature sensor. Temperature sensors are usually used for system protection or temperature compensation. A temperature sensor can be simply used to change the fan speed or shut down the system in the case of thermal runaway. The most common temperature sensor used in different applications is a local temperature sensor. Local temperature sensors provide their die temperature in either analog or digital format.

Outputs of analog temperature sensors are voltage or current, which change depending on the die temperature. Besides silicon analog temperature sensors, thermistors are a possible component because their resistance will change based on the temperature. Therefore, by pushing the current and monitoring the voltage, it will provide the temperature information. Usually, the output of the analog sensor is connected to an analog-to-digital converter (ADC) to provide the temperature information in the digital domain. This ADC can be discrete or integrated in the microcontroller or other devices.

A local digital temperature sensor can be considered as an analog temperature sensor with integrated ADC. The temperature information will be provided digitally. These components are accessed by using an available serial interface on the parts. The common serial interfaces are 2-wire interfaces (I^2C or SMBus), 3-wire interfaces (SPI or MICROWIRE), and a 4-wire interface (SPI). Most microcontrollers have built in one or more of the serial interfaces mentioned above.

Let's again consider a system with a 90 nm microcontroller. If an ADC channel is available, either discrete or integrated in the microcontroller, the designer has a choice of using a digital or analog temperature sensor. If the only voltage available in the system is the microcontroller supply voltage, there is no other choice but to use a true 1.8V analog or digital temperature sensor. If other supply voltages are available, then there is an option to use any analog temperature sensor as long as its outputs do not exceed 1.8V. For a digital temperature sensor, the designer can choose either a true 1.8V temperature sensor or add a pull-up level shifter to raise the 1.8V interface to the suitable level of the target digital temperature sensor. Since ADCs with 1.8V supplies are not common, true 1.8V or 1.8V serial-interface digital temp sensors are becoming more popular.

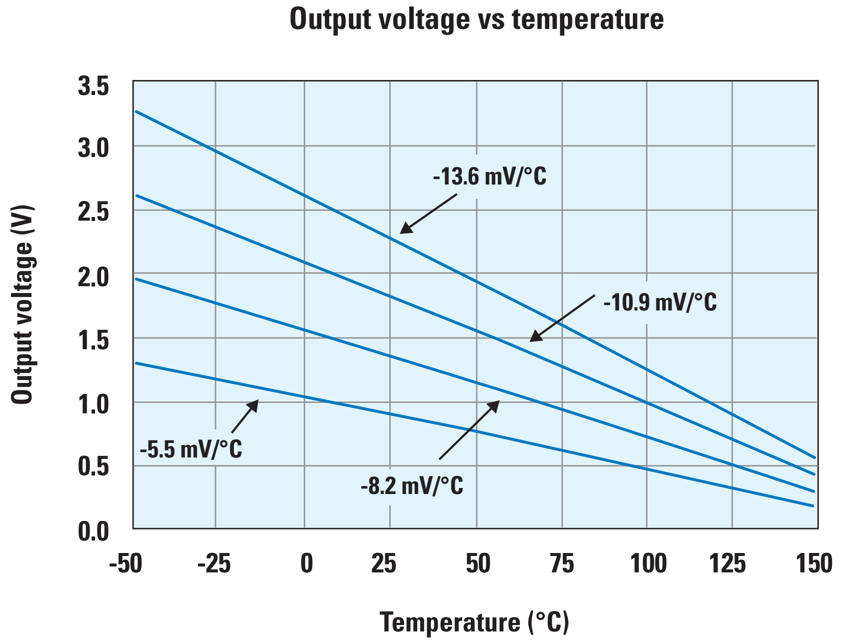
Another option is to use a low-voltage analog temperature sensor. Using an analog temperature sensor in low-voltage systems has its own criteria, which will be described in the next section.

Issues with analog temp sensors

The output voltage of an analog temperature sensor cannot exceed the input supply voltage. Let's consider a supply voltage of 1.8V. The normal temperature range for a temp sensor is -50°C to +150°C (mil spec). Based on the above requirement, the highest gain an analog sensor can have is:

$$\text{Sensor gain} = \frac{\text{Supply voltage}}{\text{Temp range}} = \frac{1.8\text{V}}{200°\text{C}} = 9\ \text{mV/°C}$$

However this is an ideal case and is also impossible: the analog temperature sensor requires head room and 1.8V is a nominal voltage and the regulator tolerance can cause a voltage output of 1.6V or lower. Therefore, to monitor a location by using an analog temperature sensor from -50°C to +150°C with a supply voltage of 1.8V nominal, the maximum gain that analog sensor can have is 6 mV/°C. To handle this gain and monitor the temperature accurately, a high-resolution ADC needs to be used. This requirement will add to the system cost since usually the integrated ADCs are not high resolution and the designer would be required to use discrete ADCs. The other option for a designer is to use an amplifier, which will introduce other errors and reduce the accuracy of temperature measurement.



National's analog temperature solution

National has introduced two low-voltage analog temperature sensors, the LM94021 and LM94022. These analog sensors are the industry's first analog sensors that operate down to 1.5V supply and cover -50°C to +150°C. Also, these devices have user-selectable gains. Two logic inputs select the gain of the temperature-to-voltage output transfer function (***see above***). In the lowest gain configuration, the LM94021 and LM94022 can operate with a 1.5V supply while measuring temperature from -50°C to +150°C. The gain-select inputs can be tied directly to V_{DD} or GND without any pull-up or pull-down resistors. These inputs can also be driven by a logic signal, allowing the system to optimize the gain during operation.

If the resolution of the temperature read-out at cold is not important for the system design, then the LM94021 and LM94022 can be used at 1.5V supply voltage in combination with low resolution ADCs. When the part is monitoring cold temperature, the lowest gain can be used. As the temperature increases, the microcontroller can change the polarity of gain-selection pins, increase the transfer function gain, and raise the sensitivity of temperature read-out by using the same ADCs.

The difference between the LM94021 and LM94022 is the output drive, supply noise rejection, and quiescent current. The LM94021 has a current source output whereas the LM94022 has a push-pull output. The LM94021 has a lower drive capability with great power supply rejection ratio (PSRR). The LM94022 has high drive capability and lower quiescent current.

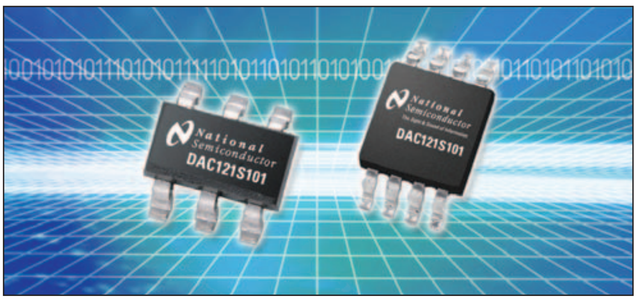
The LM94021 and LM94022 are ideal analog temperature sensors for low-voltage and portable designs. ■

Featured products

12-bit Micropower digital-to-analog converter with rail-to-rail output

The DAC121S101 is a full-featured, general-purpose 12-bit voltage-output DAC that can operate from a single 2.7V to 5.5V supply and consumes just 177 µA of current at 3.6V. The on-chip output amplifier allows rail-to-rail output swing. The 3-wire serial interface operates at clock rates up to 30 MHz over the specified supply voltage range and is compatible with standard SPI, QSPI, MICROWIRE, and DSP interfaces.

The supply voltage for the DAC121S101 serves as its voltage reference, providing the widest possible output dynamic range. A power-on reset circuit ensures that the DAC output powers up to zero volts and remains there until there is a valid write to the device. A power-down feature reduces power consumption to less than a microwatt. The low power consumption and small packages of the DAC121S101 make it an excellent choice for use in battery-operated equipment.

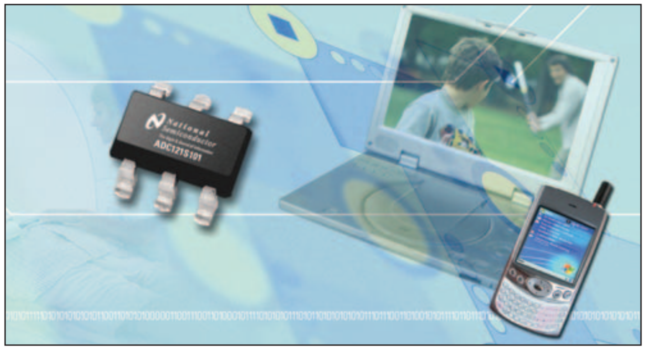


Features (typical)

- Resolution 12 bits
- DNL ±0.25 LSB
- Output settling time 8 µs
- Zero code error 4 mV
- Full-scale error -0.15% FS
- Power consumption
  - Normal mode 0.64 mW (3.6V)/1.43 mW (5.5V) typ
  - Power-down mode 0.17 µW (3.6V)/0.39 µW (5.5V) typ

The DAC121S101 operates over the extended industrial temperature range of -40°C to +105°C. It is housed in SOT23-6 and MSOP-8 packaging and is ideal for use in battery-powered instruments, digital gain and offset adjustment, programmable voltage and current sources, and programmable attenuators.

www.national.com/ADC
www.national.com/pf/DA/DAC121S101.html



1 MSPS, 12-bit analog-to-digital converter in a SOT-23 package

The ADC121S101 is a low-power, monolithic CMOS 12-bit analog-to-digital converter that operates at 1 MSPS. It is based on a successive approximation register architecture with internal track-and-hold. The serial interface is compatible with several standards, such as SPI, QSPI, MICROWIRE, and many common DSP serial interfaces.

The ADC121S101 uses the supply voltage as a reference. This enables the device to operate with a full-scale input range of 0 to V_{DD}. The conversion rate is determined from the serial clock (S_{CLK}) speed. The device offers a shutdown mode, which can be used to trade throughput for power consumption. The ADC121S101 is operated with a single supply that can range from 2.7V to 5.25V.

Features

- Single 2.7V to 5.25V supply operation
- DNL +0.5, -0.3 LSB (typ)
- INL ± 0.4 LSB (typ)
- Power consumption
  - 3V Supply 2 mW (typ)
  - 5V Supply 10 mW (typ)

The ADC121S101 is designed for operation over the industrial temperature range of -40°C to +125°C and is available in a SOT23-6 package, which provides an extremely small footprint for applications where space is a critical consideration. It is ideal for use in automotive navigation, FA/ATM equipment, portable systems, medical instruments, mobile communications, and instrumentation and control systems.

www.national.com/ADC
www.national.com/pf/DC/ADC121S101.html

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