

Devices Connected/Referenced

ADuC7122	ARM7-Based Microcontroller with 12-Bit, 1 MSPS SAR ADC, VDAC, and PWM
ADP3333	3.3 V Output Linear Regulator

USB Based Temperature Monitor Using the ADuC7122 Precision Analog Microcontroller and an External Thermistor

CIRCUIT FUNCTION AND BENEFITS

This circuit shows how the [ADuC7122](#) precision analog microcontroller can be used in an accurate thermistor temperature monitoring application. The ADuC7122 integrates a multichannel 12-bit SAR ADC, twelve 12-bit DACs, a 1.2 V internal reference, as well as an ARM7 core, 126 kB flash, 8 kB SRAM, and various digital peripherals, such as UART, timers, SPI, and two I²C interfaces. The ADuC7122 is connected to a 4.7 k Ω thermistor.

Due to the small form factor of the ADuC7122 (7 mm \times 7 mm, 108-ball BGA package) the entire circuit will fit on an extremely small PCB, thus further reducing cost.

Similar in function to an RTD, thermistors are low cost temperature sensitive resistors and are constructed of solid semiconductor materials, which exhibit a positive or negative

temperature coefficient. Thermistors are inexpensive and have high sensitivity. They detect small variations in temperature, which could not be observed with an RTD or a thermocouple. However, thermistors are highly nonlinear; thus, they are limited to applications with very narrow temperature ranges if linearization techniques are not applied. Circuit linearization techniques can be accomplished in software; however, that will not be discussed here.

Despite the powerful ARM7 core and high speed SAR ADCs, the ADuC7122 still provides a low power solution. With the ARM7 core running at 326.4 kHz and the primary ADC active and measuring the external temperature sensor, the entire circuit typically consumes 7 mA. Between temperature measurements, the ADC and/or the microcontroller can be switched off to further save on power consumption.

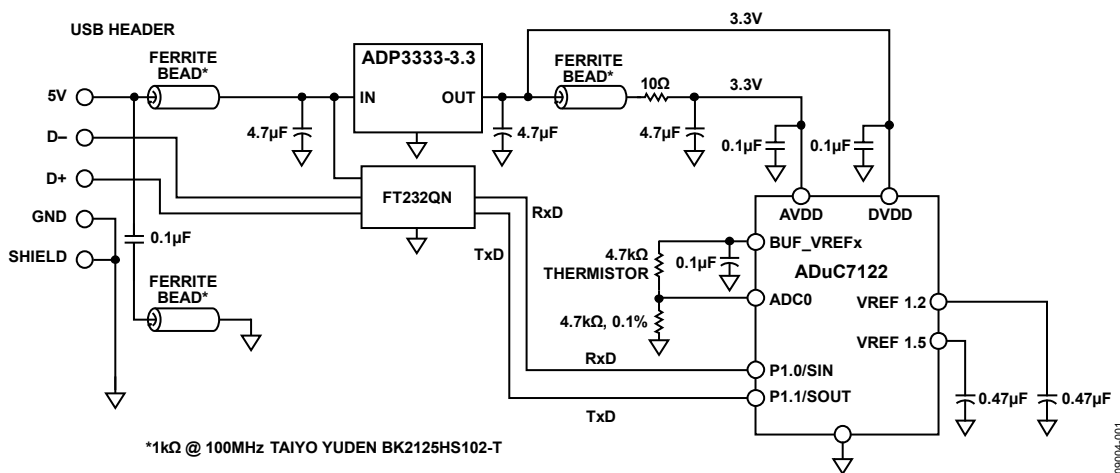


Figure 1. ADuC7122 Used As a Temperature Monitor Interfaced to a Thermistor (Simplified Schematic, All Connections Not Shown)

Rev. 0

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CIRCUIT DESCRIPTION

The circuit shown in Figure 1 is powered entirely from the USB interface. The 5 V supply from the USB is regulated to 3.3 V using the [ADP3333](#) 3.3 V low dropout linear regulator. The regulated 3.3 V supplies the DVDD voltage to the ADuC7122. The AVDD supply to the ADuC7122 has additional filtering as shown. A filter is also placed on the USB supply at the input of the linear regulator.

The following features of the ADuC7122 are used in this application:

- 12-bit SAR ADC
- ARM7TDMI® core: The powerful 16-/32-bit ARM7 core with integrated 126 kB flash and SRAM memory runs the user code that configures and controls the ADC, processes the ADC conversions from the thermistor sensor, and controls the communications over the UART/USB interface.
- UART: The UART was used as the communication interface to the host PC.
- Two external switches/buttons (not shown) are used to force the part into its flash boot mode: By holding DOWNLOAD low and toggling the RESET switch, the ADuC7122 will enter boot mode instead of normal user mode. In boot mode, the internal flash may be reprogrammed through the I2CWSO tool utilizing the USB interface.
- BUF_VREF: The band gap reference also connects through buffers to the BUF_VREF1 and the BUF_VREF2 pins, which can be used as a reference for other circuits in the system. A minimum of 0.1 µF capacitor should be connected to these pins to reduce noise.

The thermistor used in the circuit is a 4.7 kΩ resistor, model number [NCP18XM472](#). It is available in a 0603 surface-mount package. The thermistor used in the circuit in Figure 2 has the following specifications at 25°C: $\beta = 3500$ (the β parameter describes resistance as a function of temperature), resistance (R_{25}) = 4.7 kΩ

The USB interface to the ADuC7122 is implemented with an [FT232R](#) UART to USB transceiver, which converts USB signals directly to the UART protocol.

In addition to the decoupling shown in Figure 1, the USB cable itself should have a ferrite for added EMI/RFI protection. The ferrite beads used in the circuit were Taiyo Yuden, [BK2125HS102-T](#), which have an impedance of 1000 Ω at 100 MHz.

The circuit must be constructed on a multilayer PC board with a large area ground plane. Proper layout, grounding, and decoupling techniques must be used to achieve optimum performance (see [Tutorial MT-031](#), [Tutorial MT-101](#), and the [ADuC7122 Evaluation Board](#) layout).

The input thermistor circuit in Figure 2 is designed to produce accurate temperature measurements from 0°C to 90°C. Note that this system contains no temperature calibration. This circuit contains a simple thermistor circuit that does not contain circuit linearization. If this circuit employed linearization techniques, it could function over a broader range of temperatures; however, this would decrease the resolution of the sensor.

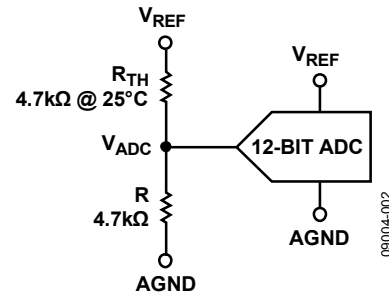


Figure 2. Simple Temperature Sensor Circuit Implemented with the ADuC7122

The circuit in Figure 2 is setup in a voltage divider configuration. This will allow us to transform the ADC result, D, into a measurement of the resistance of R_{TH} (thermistor) using the following formulas:

$$V_{ADC} = V_{REF} \times [R/(R + R_{TH})]$$

$$D = 2^N \times (V_{ADC} / V_{REF})$$

$$R_{TH} = R \times [(2^N/D) - 1]$$

Once the resistance of the thermistor has been calculated, the Steinhart-Hart equation can be used to determine the current temperature of the sensor.

Using the following formula the ADuC7122 is able to determine the sensor temperature:

$$T_2 = \frac{\frac{(T_1 \times \beta)}{\ln\left(\frac{R_{25}}{R_{TH}}\right)}}{\frac{\beta}{\ln\left(\frac{R_{25}}{R_{TH}}\right)} - T_1}$$

where:

T_2 = unknown temperature

$T_1 = 298K$

$\beta = \beta$ parameter of the thermistor @ 298K or 25°C. $\beta = 3500$

R_{25} = resistance of thermistor @ 298K or 25°C. $R_{25} = 4.7 k\Omega$

R_{TH} = resistance of thermistor @ unknown temperature as calculated by formula above

Figure 3 plots the response of the ADuC7122 to the thermistor sensor detailed in Figure 2 over temperature.

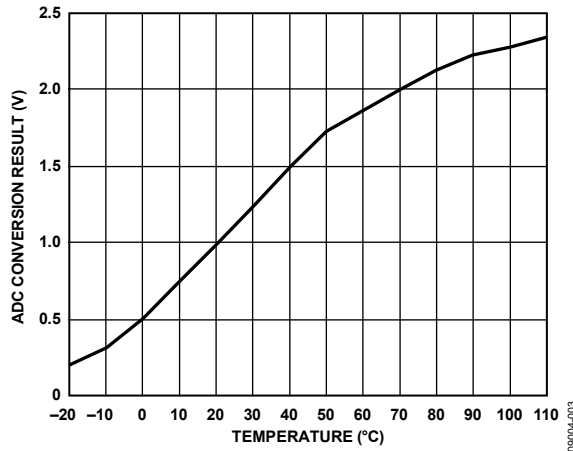


Figure 3. ADuC7122 Thermistor Sensor Measured Output (Converted to Volts) with ADC0 vs. Temperature

CODE DESCRIPTION

The source code and a HyperTerminal configuration file used to test the attached circuit can be downloaded as a zip file at www.analog.com/CN0153_Source_Code.

The UART is configured for a baud rate of 9600, 8 data bits, no parity, no flow control. If the circuit is connected directly to a PC, a communication port viewing application such as HyperTerminal can be used to view the results sent by the program to the UART. See Figure 4. The source code is commented to make it easier to understand and manipulate. The code was compiled and tested using the Keil μ Vision 3 application.

```

ADuC7122 Temperature Measurement:
Sensor Temperature : 23.64degC
ADC0 Result (hex) : 7C9,
Thermistor value : 4959.408ohms,

ADuC7122 Temperature Measurement:
Sensor Temperature : 23.69degC
ADC0 Result (hex) : 7CB,
Thermistor value : 4949.724ohms,

ADuC7122 Temperature Measurement:
Sensor Temperature : 23.72degC
ADC0 Result (hex) : 7CC,
Thermistor value : 4944.890ohms,

```

Figure 4. Output of HyperTerminal Communication Port Viewing Application

COMMON VARIATIONS

The ADP3333 (3.3 V) can be replaced with the ADP120 (2.5 V), which has a wider operating temperature range (-40°C to $+125^{\circ}\text{C}$) and consumes less power (typically $20\ \mu\text{A}$ vs. $70\ \mu\text{A}$) but has a lower maximum input voltage range (5.5 V vs. 12 V). Note that the ADuC7122 can be programmed or debugged via a standard JTAG interface. For a standard UART to RS-232 interface, the FT232R transceiver could be replaced with a device such as the ADM3202, which requires a 3 V power supply.

The thermistor circuit described here can be adapted to operate with other precision analog microcontrollers, such as the ADuC7020 series, the ADuC7023, and the ADuC7061 series.

LEARN MORE

Source code zip file: www.analog.com/CN0153_Source_Code
ADIsimPower Design Tool. Analog Devices.

CN-0075 Circuit Note, *USB Based Temperature Monitor Using the ADuC7061 Precision Analog Microcontroller and an External RT*. Analog Devices.

Kester, Walt. *Sensor Signal Conditioning*. Chapter 7, "Temperature Sensors." 1999. Analog Devices.

Kester, Walt. *Sensor Signal Conditioning*. Chapter 8, "ADCs for Signal Conditioning." 1999. Analog Devices.

Looney, Mike. *RTD Interfacing and Linearization Using an ADuC706x Microcontroller*, AN-0970 Application Note. Analog Devices.

MT-031 Tutorial, *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND,"* Analog Devices.

MT-101 Tutorial, *Decoupling Techniques*, Analog Devices.

Data Sheets and Evaluation Boards

[ADM3202 Data Sheet](#)

[ADP120 Data Sheet](#)

[ADP3333 Data Sheet](#)

[ADuC7020 Data Sheet](#)

[ADuC7020 Evaluation Board and Tools](#)

[ADuC7023 Data Sheet](#)

[ADuC7023 Evaluation Board and Tools](#)

[ADuC7061 Data Sheet](#)

[ADuC7061 Evaluation Board and Tools](#)

[ADuC7122 Data Sheet](#)

[ADuC7122 Evaluation Board](#)

REVISION HISTORY

4/10—Revision 0: Initial Version

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