Measure internal temperature sensor

Example Code Introduction for 32-bit NuMicro® Family

Information

Application	ADC measure internal temperature sensor example code of microcontrollers
BSP Version	M051 Series BSP CMSIS v3.01.001
Hardware	NuTiny–EVB–M051_V3.0

1 Function Description

1.1 Introduction

Microcontrollers are widely used in different ambient temperatures. Nuvoton NuMicro® Cortex®–M0 M051 Series built-in a temperature sensor. This example shows how to use the ADC to get the Celsius temperature of the temperature sensor.

1.2 Principle

The ADC uses the reference voltage as a reference base. Equally distributed the reference voltage to a few steps. The step is related to the resolution of the ADC. Before measuring the temperature sensor voltage, the reference voltage must be known before the value of the measured temperature sensor can be converted into a voltage.

$$\text{Bandgap Voltage} = \frac{ADC\ Reference\ Voltage}{ADC\ Bandgap\ data}$$

Equation 1-1 Band-gap voltage and reference voltage relationship

The M051 ADC measures the Band-gap voltage. The Band-gap voltage is a fixed voltage. The Band-gap voltage of the M051 is 1.2V. The ADC reference voltage can be calculated by Equation 1-1.

$$\text{Conversion Data} = \frac{\text{Temperature Voltage} \times 4096\ (12\ Bits\ Resoulation)}{ADC\ Reference\ Voltage}$$

Equation 1-2 Temperature sensor voltage calculation formula

After the ADC measures the temperature sensor value, the voltage of the temperature sensor can be calculated by referring to Equation 1-2.

$$\text{Temperature Celsius} = \frac{(\text{Temperature Voltage} \times 1000) - \text{Sensor Offset}}{Gain}$$

Equation 1-3 Temperature sensor voltage temperature conversion formula

The built-in temperature sensor of M051 is a negative temperature coefficient sensor. Refer to Figure 1-1. The lower the temperature, the higher the voltage. Gain is the negative temperature coefficient and Offset is the compensation value adjustment. The temperature of the temperature sensor can be converted to Celsius by Equation 1-3. Please refer to the relevant documents of M051 for the actual temperature sensor parameters and Band-gap

voltage specifications.

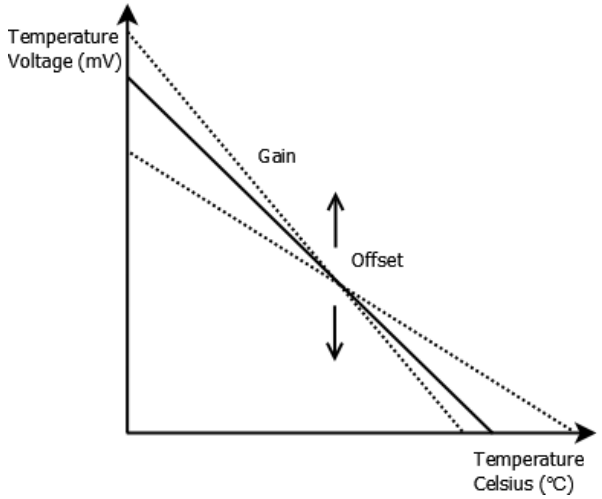
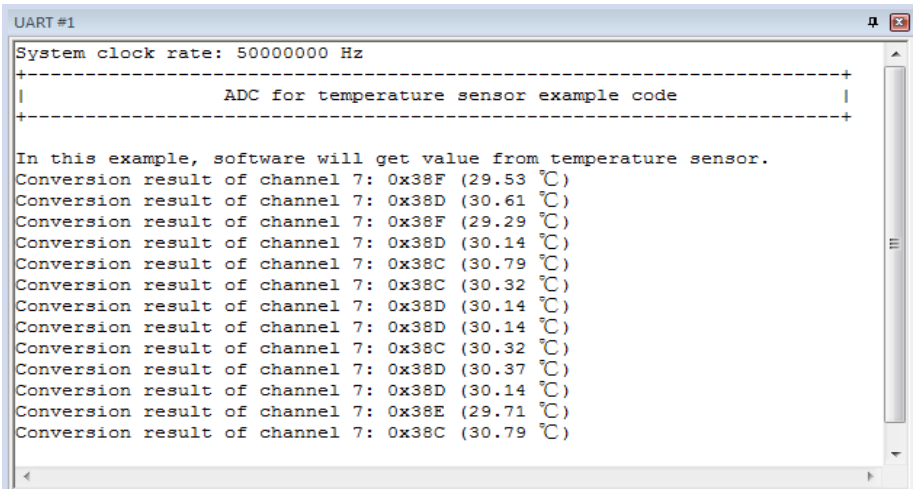


Figure 1-1 Temperature sensor voltage temperature diagram

1.3 Demo Result



2 Code Description

Enable temperature sensor

```
/* Enable Temperature Sensor function */
    SYS->TEMPCR |= SYS_TEMPCR_VTEMP_EN_Msk;
```

As shown in Figure 2-1, ADC channel 7 can select three measurement sources. The following codes are set for ADC channel 7 source as Band-Gap (VBG) and ADC channel 7 source is set to built-in temperature sensor (VTEMP):

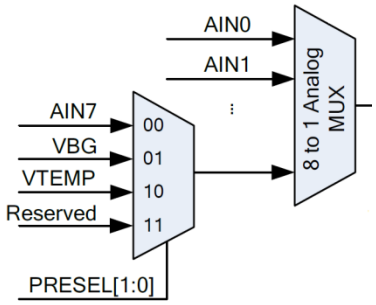


Figure 2-1 Source of ADC Channel 7

```
/* Configure the analog input source of channel 7 */
    ADC_CONFIG_CH7(ADC, ADC_ADCHER_PRESEL_INT_BANDGAP);
/* Configure the analog input source of channel 7 */
    ADC_CONFIG_CH7(ADC, ADC_ADCHER_PRESEL_INT_TEMPERATURE_SENSOR);
```

Get the ADC measurement Band-gap conversion value, guess the ADC external reference voltage.

```
/* Calculate dVref by using conversion result of VBG */
/* ConversionData = VBG * 4096 / Vref */
    i32ConversionData = ADC_GET_CONVERSION_DATA(ADC, 7);
    dVref = VBG * 4096 / (double)i32ConversionData;
```

Get the conversion value of the ADC measurement temperature and calculate the Celsius temperature.

```
/* Calculate value from temperature sensor  */
/* ConversionData = Vtemp(V) * 4096 / dVref */
/* Vtemp(mV) = Gain * Temperature + Offset  */
    i32ConversionData = ADC_GET_CONVERSION_DATA(ADC, 7);
    dTempData = (((double)i32ConversionData * dVref / 4096) * 1000 - Offset) / Gain;
```

Software and Hardware Environment

Software Environment

- BSP version
  - M051 Series BSP CMSIS v3.01.001
- IDE version
  - Keil uVersion 5.24

Hardware Environment

- Circuit components
  - NuTiny–EVB–M051_V3.0

3 Directory Information

- EC_M480_CMOS_V1.00
  - Library — Sample code header and source files
    - CMSIS — Cortex® Microcontroller Software Interface Standard (CMSIS) by Arm® Corp.
    - Device — CMSIS compliant device header file
    - StdDriver — All peripheral driver header and source files
  - SampleCode
    - ExampleCode — Source file of example code

4 How to Execute Example Code

1. Browsing into sample code folder by **Error! Reference source not found.** (section 4) and double click Measure_Internal_Temperature_Sensor.uvproj.
2. Enter Keil compile mode
   a. Build
   b. Download
   c. Start/Stop debug session
3. Enter debug mode
   a. Run

5 Revision History

Date	Revision	Description
Jun. 30, 2019	1.00	1. Initially issued.

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