測量內部溫度傳感器

NuMicro® 32 位系列微控制器範例代碼介紹

文件資訊

代碼簡述	ADC 測量微控制器內部溫度傳感器範例代碼
BSP 版本	M051 Series BSP CMSIS v3.01.001
開發平台	NuTiny–EVB–M051_V3.0

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1 功能介紹

1.1 簡介

微控制器廣泛的應用在不同的環境溫度下，Nuvoton NuMicro® Cortex®–M0 M051 系列內建溫度傳感器，此範例將說明如何使用ADC取得溫度傳感器的攝氏溫度。

1.2 原理

ADC 將參考電壓作為基準，將參考電壓平均對應至數階，階數與ADC的解析度相關。在測量溫度傳感器電壓前，必須先得知參考電壓，才能將量測溫度傳感器的數值換算成電壓。

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

公式 1-1 Band-gap 電壓與參考電壓關係式

M051 ADC可量測Band-gap電壓，Band-gap電壓是固定電壓，M051的Band-gap電壓為1.2V，透過公式1-1 可算出ADC 參考電壓。

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

公式 1-2 溫度傳感器電壓計算公式

ADC測量溫度傳感器數值後，參考公式1-2得以計算出溫度傳感器的電壓。

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

公式 1-3 溫度傳感器電壓溫度轉換公式

M051內建的溫度傳感器為負溫度係數傳感器，參考圖1-1，當溫度越低，電壓越高。其中Gain為負溫度係數，Offset則為誤差調整。由公式1-3可將溫度傳感器的電壓轉換為攝氏溫度。實際溫度傳感器參數與Band-gap電壓規格請參考M051的相關文件。

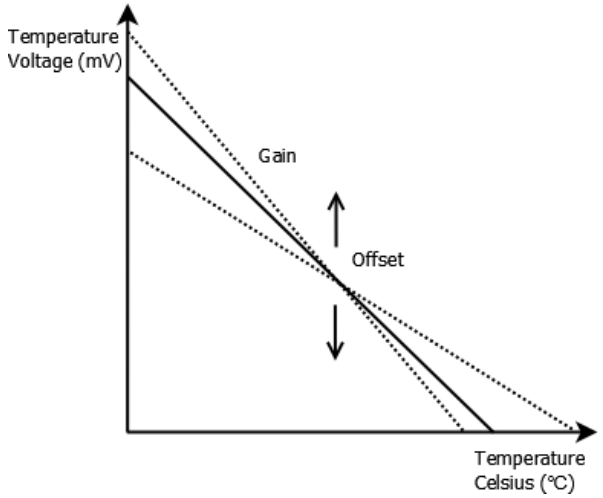

圖1-1 溫度傳感器電壓溫度關係圖

1.3 執行結果

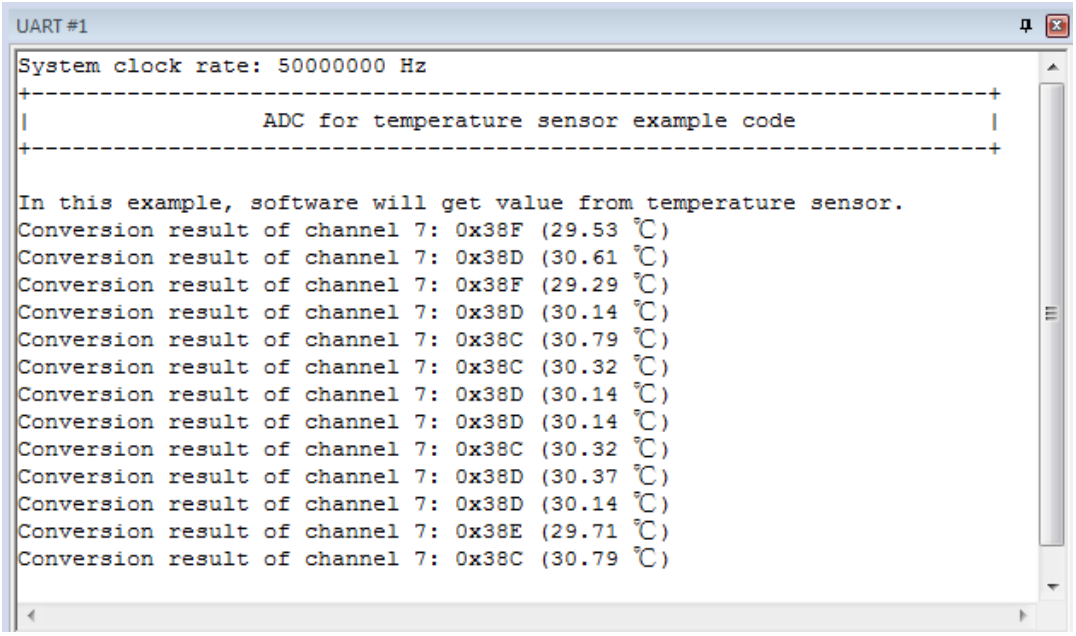

圖1-2 範例執行結果

2 代碼介紹

開啟溫度傳感器:

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

如圖 2-1 所示，ADC 通道 7 可選擇三個測量來源，下列代碼分別為 ADC 通道 7 來源設定為 Band-Gap(VBG) 及 ADC 通道 7 來源設定為內建溫度傳感器(VTEMP):

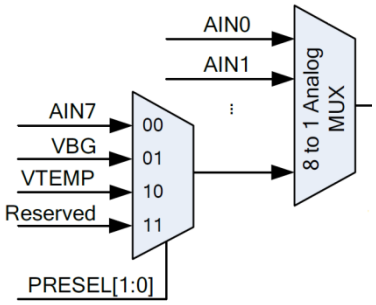

圖2-1 ADC 通道7來源

```
/* 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);
```

取得 ADC 測量 Band-gap 的轉換數值，推測 ADC 外部參考電壓:

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

取得 ADC 測量 溫度的轉換數值，計算出攝氏溫度:

```
/* 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;
```

3 軟體與硬體環境

- **軟體環境**
  - BSP 版本
    - M051 Series BSP CMSIS v3.01.001
  - IDE 版本
    - Keil uVersion 5.24
- **硬體環境**
  - 電路元件
    - NuTiny–EVB–M051_V3.0

4 目錄資訊

- EC_M051_Measure_Internal_Temperature_Sensor_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

5 如何執行範例程式

1. 根據目錄資訊章節進入 ExampleCode 路徑中的 KEIL 資料夾，雙擊 Measure_Internal_Temperature_Sensor.uvproj。
2. 進入編譯模式介面
   a. 編譯
   b. 下載代碼至記憶體
   c. 進入 / 離開除錯模式
3. 進入除錯模式介面
   a. 執行代碼

6 修訂紀錄

Date	Revision	Description
Jun. 30, 2019	1.00	1. 初始發佈.

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