测量内部温度传感器

NuMicro® 32 位系列微控制器范例代码介绍

文件信息

代码简述	ADC 测量微控制器内部温度传感器范例代码
BSP 版本	M051 Series BSP CMSIS v3.01.001
开发平台	NuTiny–EVB–M051_V3.0

1 功能介绍

1.1 简介

微控制器广泛的应用在不同的环境温度下，Nuvoton NuMicro® Cortex®–M0 M051 系列内建温度传感器，此范例将说明如何使用ADC取得温度传感器的摄氏温度。

1.2 原理

ADC 将参考电压作为基准，将参考电压平均对应至数阶，阶数与ADC的解析度相关。在测量温度传感器电压前，必须先得知参考电压，才能将量测温度传感器的数值换算成电压。

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

公式1-1 Band-gap电压与参考电压关系式

M051 ADC可量测Band-gap电压，Band-gap电压是固定电压，M051的Band-gap电压为1.2V，透过公式1-1 可算出ADC 参考电压。

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

公式 1-2 温度传感器电压计算公式

ADC测量温度传感器数值后，参考公式1-2得以计算出温度传感器的电压。

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

公式 1-3 温度传感器电压温度转换公式

M051内建的温度传感器为负温度系数传感器，参考图1-1，当温度越低，电压越高。其中Gain为负温度系数，Offset则为误差调整。由公式1-3可将温度传感器的电压转换为摄氏温度。实际温度传感器参数与Band-gap电压规格请参考M051的相关文件。

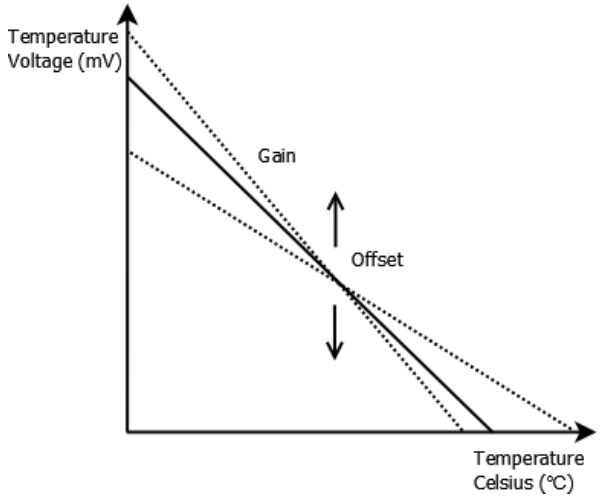

图1-1 温度传感器电压温度关系图

1.3 执行结果

```
UART #1
System clock rate: 50000000 Hz
+------------------------------------------------------------------------+
|                  ADC for temperature sensor example code               |
+------------------------------------------------------------------------+

In this example, software will get value from temperature sensor.
Conversion result of channel 7: 0x38F (29.53 ℃)
Conversion result of channel 7: 0x38D (30.61 ℃)
Conversion result of channel 7: 0x38F (29.29 ℃)
Conversion result of channel 7: 0x38D (30.14 ℃)
Conversion result of channel 7: 0x38C (30.79 ℃)
Conversion result of channel 7: 0x38C (30.32 ℃)
Conversion result of channel 7: 0x38D (30.14 ℃)
Conversion result of channel 7: 0x38D (30.14 ℃)
Conversion result of channel 7: 0x38C (30.32 ℃)
Conversion result of channel 7: 0x38D (30.37 ℃)
Conversion result of channel 7: 0x38D (30.14 ℃)
Conversion result of channel 7: 0x38E (29.71 ℃)
Conversion result of channel 7: 0x38C (30.79 ℃)
```

2 代码介绍

开启温度传感器:

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

如图 2-1 所示，ADC 通道 7 可选择三个测量来源，下列代码分别为 ADC 通道 7 来源设定为 Band-Gap(VBG) 及 ADC 通道 7 来源设定为内建温度传感器(VTEMP):

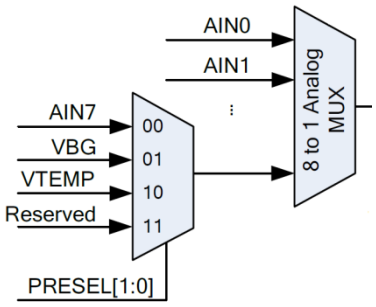

图 2-1 ADC 通道 7 来源

```
/* 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 测量 Bandgap 的转换数值,推测 ADC 外部参考电压:

```
/* 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测量 温度的转换数值，计算出摄氏温度:

```
/* 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 软件与硬件环境

- 软件环境
  - BSP 版本
    - M051 Series BSP CMSIS v3.01.001
  - IDE 版本
    - Keil uVersion 5.24
- 硬件环境
  - 电路组件
    - NuTiny–EVB–M051_V3.0

4 目录信息

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

5 如何执行范例程序

1. 根据目录信息章节进入 ExampleCode 路径中的 KEIL 文件夹，双击 Measure_Internal_Temperature_Sensor.uvproj。
2. 进入编译模式接口
   a. 编译
   b. 下载代码至内存
   c. 进入 / 离开除错模式
3. 进入除错模式接口
   a. 执行代码

6 修订纪录

Date	Revision	Description
Jun. 30, 2019	1.00	1. 初始发布.

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