



Figure 1: NTC Voltage Divider and Filter

The following calculation is based on the Look-Up Table (LUT) provided by Vishay[3], which is used in the AMS software.

Since the characteristic curve of the NTC thermistor is nonlinear, determining the absolute maximum measurement error is not straightforward. Therefore, we will calculate the maximum error specifically at 60 °C.

As seen in Fig.1 our voltage measurement system consists of an NTC thermistor (NTCLE413E2103F102L) and a 10kΩ 0.1% resistor forming a voltage divider. The output voltage is then passed through an RC filter before being fed to an ADC.

To estimate the error, we calculate the highest possible measured voltage at 60 °C. According to the design of the voltage divider, the lower the temperature, the higher the output voltage.

As shown in Fig. 2, the supply voltage VREF2 for the voltage divider can reach a maximum value of 3.006 V. Additionally, the total measurement error of the GPIO is ±0.0028 V (as shown in Fig. 3). Lastly, the maximum resistance of the NTC at 60 °C, according to the LUT (Tab. 1), is 3086.8 Ω. The maximum possible voltage measurement can then be calculated as such:

$$V_{worstcase} = V_{REF2} \cdot \frac{R_{NTC}}{R_{NTC} + R_1} + V_{err} \quad (1)$$

$$= 3.006 \text{ V} \cdot \frac{3086.8 \Omega}{3086.8 \Omega + 9990 \Omega} + 0.0028 \text{ V} \quad (2)$$

$$\approx 0.7124 \text{ V} \quad (3)$$

To find the largest possible error, the lowest possible matching temperature should be calculated, which theoretically can produce the same voltage output. The calculation is as follows:

$$V_{worstcase} = V_{REF2} \cdot \frac{R_{NTC}}{R_{NTC} + R_1} + V_{err} \quad (4)$$

$$0.7124 \text{ V} = 2.994 \text{ V} \cdot \frac{R_{NTC}}{R_{NTC} + 10010 \Omega} - 0.0028 \text{ V} \quad (5)$$

$$R_{NTC} \approx 3141.6 \Omega \quad (6)$$

Since the LUT is used to match the voltage to the temperature, and the nominal resistance from the LUT is used for the calculation, the closest matching temperature is 58.7 °C.

Table 5. Voltage Reference Specifications

| Parameter                                            | Test Conditions/Comments               | Min   | Typ | Max   | Unit     |
|------------------------------------------------------|----------------------------------------|-------|-----|-------|----------|
| FIRST REFERENCE VOLTAGE                              | V <sub>REF1</sub> pin, no load         | 3     | 3.2 | 3.3   | V        |
| FIRST REFERENCE VOLTAGE TEMPERATURE COEFFICIENT (TC) | V <sub>REF1</sub> pin, no load         |       | 3   |       | ppm/°C   |
| FIRST REFERENCE VOLTAGE HYSTERESIS                   | V <sub>REF1</sub> pin, no load         |       | 20  |       | ppm      |
| FIRST REFERENCE VOLTAGE LONG-TERM DRIFT              | V <sub>REF1</sub> pin, no load         |       | 20  |       | ppm/√kHr |
| SECOND REFERENCE VOLTAGE                             | V <sub>REF2</sub> pin, no load         | 2.994 | 3   | 3.006 | V        |
|                                                      | V <sub>REF2</sub> pin, 1 kΩ load to V- | 2.994 | 3   | 3.006 | V        |
| OUTPUT CURRENT                                       | ΔV <sub>REF2</sub> < ± 2 mV            | -0.2  |     | +5    | mA       |
| SECOND REFERENCE VOLTAGE TC                          | V <sub>REF2</sub> pin, no load         |       | 10  |       | ppm/°C   |
| SECOND REFERENCE VOLTAGE HYSTERESIS                  | V <sub>REF2</sub> pin, no load         |       | 100 |       | ppm      |
| SECOND REFERENCE VOLTAGE LONG-TERM DRIFT             | V <sub>REF2</sub> pin, no load         |       | 60  |       | ppm/√kHr |

Figure 2: Voltage Reference Specifications

Table 3. Auxiliary (AUX) ADC DC Specifications

| Parameter                                | Test Conditions/Comments                                | Min  | Typ   | Max              | Unit   |
|------------------------------------------|---------------------------------------------------------|------|-------|------------------|--------|
| MEASUREMENT RESOLUTION                   |                                                         |      | 0.15  |                  | mV/bit |
| INPUT RANGE                              | GPIOx to V-                                             | -0.3 |       | V <sub>REG</sub> | V      |
| ADC OFFSET VOLTAGE <sup>1</sup>          |                                                         |      | -0.2  |                  | mV     |
| ADC GAIN ERROR <sup>1</sup>              |                                                         |      | ±0.01 |                  | %      |
| ADC UPDATE RATE                          |                                                         | 0.9  | 1     | 1.1              | kHz    |
| ADC TRANSITION NOISE                     |                                                         |      | 50    |                  | µV rms |
| GPIOx TOTAL MEASUREMENT ERROR            | 0 V < GPIOx to V- ≤ 3.3 V                               |      |       | ±2.8             | mV     |
|                                          | 3.3 V < GPIOx to V- ≤ 5 V                               |      |       | ±4.2             | mV     |
| DIAGNOSTIC MEASUREMENTS                  | Internal temperature, T = maximum specified temperature |      | ±5    |                  | °C     |
|                                          | V <sub>REG</sub> pin                                    |      | ±0.1  | ±0.25            | %      |
|                                          | V <sub>REF2</sub> , V <sub>RES</sub>                    |      | ±0.02 | ±0.2             | %      |
|                                          | Digital supply voltage, V <sub>REGD</sub>               |      | ±0.1  | ±1.6             | %      |
|                                          | V+ to V-, V+ > 20 V                                     | -1   | ±0.05 | +0.5             | %      |
|                                          | -0.1 V ≤ S1N to V- ≤ 0.1 V                              |      | ±0.02 | 0.2              | %      |
| INPUT LEAKAGE CURRENT                    | AUX ADC off, GPIOx = 5 V                                |      | 10    | ±250             | nA     |
| INPUT RESISTANCE                         | AUX ADC on                                              | 1.5  | 2.7   | 3.5              | MΩ     |
| INPUT CURRENT DURING OPEN WIRE DETECTION | Pull-down current: GPIOx > 1.5 V                        | -140 | -200  | -260             | µA     |
|                                          | Pull-up current: GPIOx < V <sub>REG</sub> - 1.5 V       | 140  | 200   | 260              | µA     |
| ADC SAMPLING FREQUENCY                   |                                                         | 3.7  | 4.1   | 4.5              | MHz    |

Figure 3: Auxiliary (AUX) ADC DC Specifications

Table 1: NTC Look Up Table

| Temp. [°C] | R <sub>nom</sub> [Ω] | R <sub>min</sub> [Ω] | R <sub>max</sub> [Ω] | ΔR/R [%] | ΔT [°C] |
|------------|----------------------|----------------------|----------------------|----------|---------|
| 58         | 3214.99              | 3145.6               | 3284.4               | 2.16     | 0.69    |
| 58.1       | 3204.88              | 3135.6               | 3274.2               | 2.16     | 0.69    |
| 58.2       | 3194.81              | 3125.6               | 3264.0               | 2.17     | 0.69    |
| 58.3       | 3184.78              | 3115.7               | 3253.9               | 2.17     | 0.69    |
| 58.4       | 3174.78              | 3105.8               | 3243.7               | 2.17     | 0.69    |
| 58.5       | 3164.81              | 3096.0               | 3233.7               | 2.18     | 0.69    |
| 58.6       | 3154.89              | 3086.2               | 3223.6               | 2.18     | 0.69    |
| 58.7       | 3145.00              | 3076.4               | 3213.6               | 2.18     | 0.69    |
| 58.8       | 3135.15              | 3066.7               | 3203.6               | 2.18     | 0.70    |
| 58.9       | 3125.33              | 3056.9               | 3193.7               | 2.19     | 0.70    |
| 59         | 3115.55              | 3047.3               | 3183.8               | 2.19     | 0.70    |
| 59.1       | 3105.80              | 3037.7               | 3173.9               | 2.19     | 0.70    |
| 59.2       | 3096.09              | 3028.1               | 3164.1               | 2.20     | 0.70    |
| 59.3       | 3086.41              | 3018.5               | 3154.3               | 2.20     | 0.70    |
| 59.4       | 3076.77              | 3009.0               | 3144.6               | 2.20     | 0.70    |
| 59.5       | 3067.17              | 2999.5               | 3134.9               | 2.21     | 0.71    |
| 59.6       | 3057.60              | 2990.0               | 3125.2               | 2.21     | 0.71    |
| 59.7       | 3048.06              | 2980.6               | 3115.5               | 2.21     | 0.71    |
| 59.8       | 3038.56              | 2971.2               | 3105.9               | 2.22     | 0.71    |
| 59.9       | 3029.09              | 2961.9               | 3096.3               | 2.22     | 0.71    |
| 60         | 3019.66              | 2952.5               | 3086.8               | 2.22     | 0.71    |
| 60.1       | 3010.26              | 2943.3               | 3077.3               | 2.23     | 0.71    |

## Reference

- [1] *Table 3 AUX Data Sheet ADBMS6830B Rev.0 page 5.* analog.com, 01.2024
- [2] *Table 5 VREF Data Sheet ADBMS6830B Rev.0 page 5.* analog.com, 01.2024
- [3] *NTC RT Calculation Tool.* www.vishay.com, 03.2025