Thermistor Selection Guide for Texas Instruments Advanced Fuel Gauges

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ABSTRACT

Accurate temperature measurement of Lithium-ion battery cell is essential for proper safety and operation of your battery design. This application note discusses the use of several different types of thermistors with Texas Instruments (TI) advanced battery fuel gauges with reference to application note literature number: SLUA398. Mitsubishi Materials Corporation (MMTL) offers various Thermistors to accommodate each cell type.

Precise temperature testing was run by MMTL using TI standard Evaluation Modules (EVM) for three different types of Thermistors discussed in more detail below. The "B Value" of each type of Thermistor is calculated and shown along with physical size and a picture of each device.

For TI's 2-4s cell battery configuration products (bq20z**), the temperature coefficient for each Thermistor is calculated using polynomial models discussed in TI Literature # SLUA398. These values are shown in section 4 below.
(** tested with bq20z40, bq20z45, bq20z60, bq20z65, bq20z70, bq20z75, bq20z80, bq20z90, bq20z95 series of gauges)

For some of TI's 1s cell configuration battery fuel gauge (bq27***), the temperature coefficients are not programmable and the data sheet states the use of Semitec 103AT or equivalent. Fortunately designers have many more choices as all the thermistors reviewed in this application note are within +/-1ºC measurement over the temperature range of 0ºC to 80ºC, and better than -1.7ºC from -20 ºC to 80ºC temperature range.
(*** tested with bq27410, bq27500, bq27501, bq27505, bq27510, bq27520-G1, bq27541 series of gauges)

1 Introduction

This report is an application note discussing thermistor temperature accuracy using TI advance fuel gauge battery management IC's. Calculating method of temperature coefficients and measurement results of Mitsubishi Materials Corporation Thermistors is discussed in detail.

2 Calculation of B Values for Three different Types of Thermistors

Thermistor characteristics of three different types of MMTL Thermistors are shown in Table 1. The characteristic of a thermistor is defined by the resistance at 25ºC (R25) and Beta (B) Value characteristics as temperature coefficient (B25/50 or B25/85). The B Value is determined by following formula:

$$B = \ln \frac{R}{R_0} / \left(\frac{1}{T} - \frac{1}{T_0} \right)$$

Where:

R: resistance at absolute temperature T (K)

R_0: resistance at absolute temperature T_0 (K)

B: B Value

*T (K) = t (ºC) +273.15

Table 1. Characteristics of Three Different Types of Thermistors based on Beta Value

No.	Resistance(R25)	B Value		Manufacturer
		$B_{25/85}$	$B_{25/50}$	
TH1	10KΩ±1%	3486K	3450K±1%	MMTL
TH2		3416K	3392K±1%	
TH3		3413K	3370K±1%	
TI Reference		3435K±1%	3392K	—

2-2 MMTL Thermistor lineup

Below Table 2 list three different types of Thermistors based on the characteristic Beta Value for different MMTL Thermistor part number.

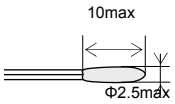
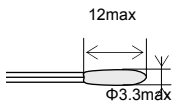
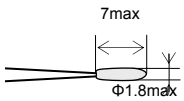
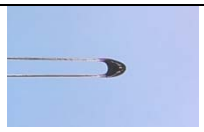
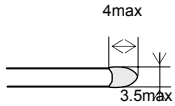
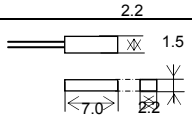
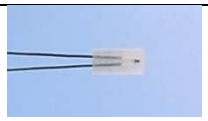
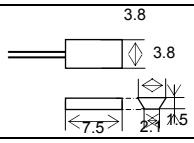
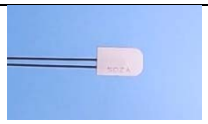
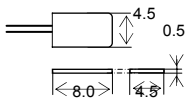
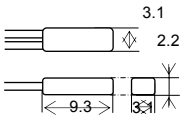
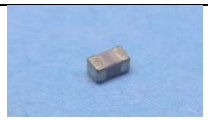
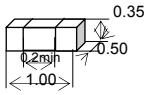
Table 2. Part number of MMTL Thermistor based on Beta (B) Value Characteristic

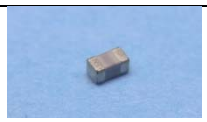
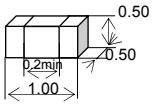
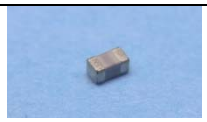
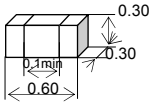
Type	B Value Characters		
	TH1	TH2	TH3
BN25-3H103F	✔		
BN35-3H103F	✔		
RH16-3H103F	✔		
CH25-3H103F	✔		
BM22-3H103F	✔		
BM38-3H103F	✔		
BF05-3I103F		✔	
BH30-3H103F			✔
THF5-3I103F		✔	
TH05-3H103F			✔
TH03-3H103F			✔

3 Shape and Dimension for MMTL Thermistor

Table 3 shows the physical dimensions and appearance for different series of MMTL Thermistors.

Table 3. Appearance, Dimensions and B Values for MMLT Thermistor Lineup

Series	Appearance	Dimensions	B Value $B_{25/50}$	Remark
BN25			3450K±1%	Epoxy resin
BN35			3450K±1%	Epoxy resin
RH16			3450K±1%	Epoxy resin
CH25			3450K±1%	Epoxy resin
BM22			3450K±1%	Thermoplastic resin
BM38			3450K±1%	Thermoplastic resin
BF05			3392K±1%	Film type
BH30			3370K±1%	Thermoplastic resin
THF5			3392K±1%	Chip Thermistor

TH05			3370K±1%	Chip Thermistor
TH03			3370K±1%	Chip Thermistor

4 Calculating method of temperature coefficients by SLUA398 Coefficient calculator

R-T data for each Thermistor was entered into the Thermistor Coefficient Calculator Spreadsheet and calculated suitable temperature coefficients for polynomial models as below. Details are available in Application Report *Thermistor Coefficient Calculator for TI Advance Fuel Gauges*. – TI Literature number SLUA398.

TH1

Temp °C	Resistance
-20	74890
-15	57980
-10	45310
-5	35720
0	28380
5	22720
10	18320
15	14880
20	12160
25	10000
30	8272
35	6881
40	5754
45	4837
50	4085
55	3466
60	2955
65	2530
70	2174
75	1876
80	1624

Polynomial coefficients	Value
A0=ExtCoef4	4024
A1=ExtCoef3	-7842
A2=ExtCoef2	22292
A3=ExtCoef1	-29950

TH2

Temp °C	Resistance
-20	70300
-15	55230
-10	43640
-5	34690
0	27750
5	22340
10	18110
15	14770
20	12120
25	10000
30	8299
35	6924
40	5807
45	4895
50	4147
55	3531
60	3020
65	2593
70	2236
75	1935
80	1682

Polynomial coefficients	Value
A0=ExtCoef4	4037
A1=ExtCoef3	-7889
A2=ExtCoef2	22269
A3=ExtCoef1	-29960

TH3

Temp °C	Resistance
-20	64790
-15	51790
-10	41570
-5	33530
0	27110
5	21990
10	17920
15	14680
20	12090
25	10000
30	8314
35	6946
40	5832
45	4921
50	4171
55	3551
60	3036
65	2606
70	2245
75	1942
80	1686

Polynomial coefficients	Value
A0=ExtCoef4	4034
A1=ExtCoef3	-7827
A2=ExtCoef2	22104
A3=ExtCoef1	-30092

5 Measurement Conditions and Results

5-1 Evaluation Module (EVM) Measurements

MMTL performed temperature test measurements with three of TI battery management EVM listed in table 4. On each of these EVMs, each of the three different types of Thermistors (based on Beta Value described in section 3) was tested. The test conditions were as follows:

- Temperature range : -20ºC to 80ºC (with 5ºC increments)
- Accuracy of temperature measurement : ±0.01ºC
- Standard EVM modules thermistor was swapped out with TH1, TH2, TH3 type Thermistor shown in section 3.

Table 4. Tested Texas Instruments Evaluation Modules with Thermistors

bq20z45 EVM (for 2, 3 or 4 cells)	See Table 5 and 7 below
bq20z75 EVM (for 2, 3 or 4 cells)	See Table 6 and 8 below
bq27541 EVM (for single cell)	See Table 9 below

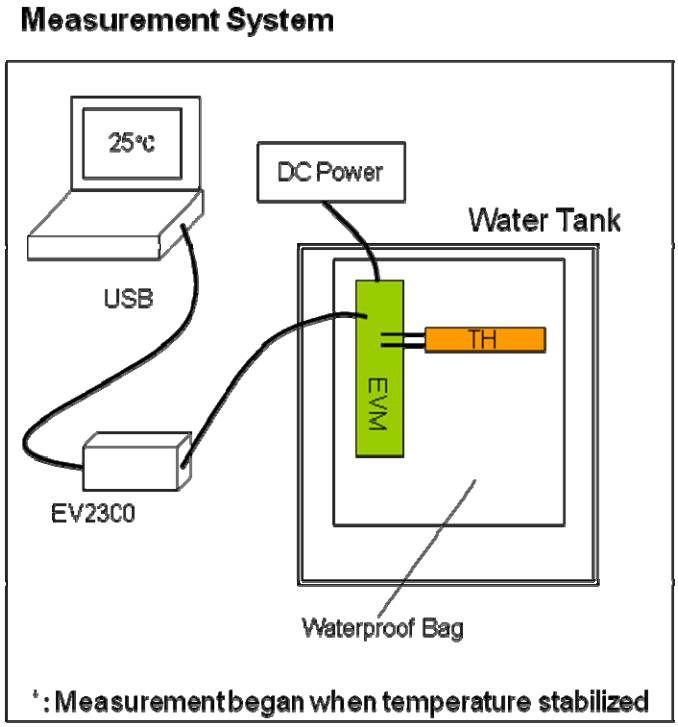


Figure 1. Test setup for MMTL Thermistor Testing with TI Evaluation Module

5-2 Comparison of temperature measurement accuracy

The following tables compare the temperature measurement accuracy of MMTL Thermistors to the TI Reference Thermistor.

(1) Using SLUA398, MMTL was able to calculate suitable coefficients for MMTL Thermistors

(TH1, TH2, and TH3) to fine tune the temperature measurement for the bq20z45 (Table 5) and bq20z75 (Table 6) evaluation modules. See the suitable coefficients below for each Thermistor.

TH1 suitable coefficient Ext Coef : [1, 2, 3, 4] = [-29950, 22292, -7842, 402.4]
TH2 suitable coefficient Ext Coef : [1, 2, 3, 4] = [-29960, 22269, -7889, 403.7]
TH3 suitable coefficient Ext Coef : [1, 2, 3, 4] = [-30092, 22104, -7827, 403.4]

(2) Default temperature coefficients were used for all Thermistors to measure EVM Modules for bq20z45 (Table 7) and bq20z75 (Table 8).

Default coefficient Ext Coef : [1, 2, 3, 4] = [-28285, 20848, -7537, 401.2]

(3) Default temperature coefficients were used for all Thermistors to measure EVM Modules for bq27541 (Table 9).

5-3 Temperature Difference Data for TH1, TH2 and TH3 type MMTL Thermistors

Table 5. bq20z45 EVM collected data (Suitable coefficients)

Temp.	Reference		TH1		TH2		TH3	
[℃]	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT
-20	-18.45	1.55	-18.15	1.85	-18.05	1.95	-18.05	1.95
-15	-14.25	0.75	-14.05	0.95	-14.15	0.85	-13.95	1.05
-10	-9.65	0.35	-9.45	0.55	-9.65	0.35	-9.55	0.45
-5	-4.85	0.15	-4.65	0.35	-4.95	0.05	-4.75	0.25
0	0.25	0.25	0.35	0.35	0.25	0.25	0.15	0.15
5	5.35	0.35	5.45	0.45	5.35	0.35	5.25	0.25
10	10.35	0.35	10.55	0.55	10.35	0.35	10.35	0.35
15	15.35	0.35	15.45	0.45	15.35	0.35	15.35	0.35
20	20.25	0.25	20.35	0.35	20.25	0.25	20.25	0.25
25	25.05	0.05	25.05	0.05	25.05	0.05	25.05	0.05
30	29.85	-0.15	29.85	-0.15	29.85	-0.15	29.95	-0.05
35	34.65	-0.35	34.65	-0.35	34.75	-0.25	34.85	-0.15
40	39.65	-0.35	39.65	-0.35	39.65	-0.35	39.75	-0.25
45	44.65	-0.35	44.65	-0.35	44.75	-0.25	44.85	-0.15
50	49.65	-0.35	49.85	-0.15	49.85	-0.15	49.85	-0.15
55	54.85	-0.15	54.95	-0.05	55.05	0.05	55.15	0.15
60	60.05	0.05	60.15	0.15	60.25	0.25	60.25	0.25
65	65.25	0.25	65.35	0.35	65.45	0.45	65.45	0.45
70	70.25	0.25	70.45	0.45	70.45	0.45	70.45	0.45
75	75.15	0.15	75.35	0.35	75.35	0.35	75.35	0.35
80	79.75	-0.25	79.95	-0.05	79.85	-0.15	79.85	-0.15

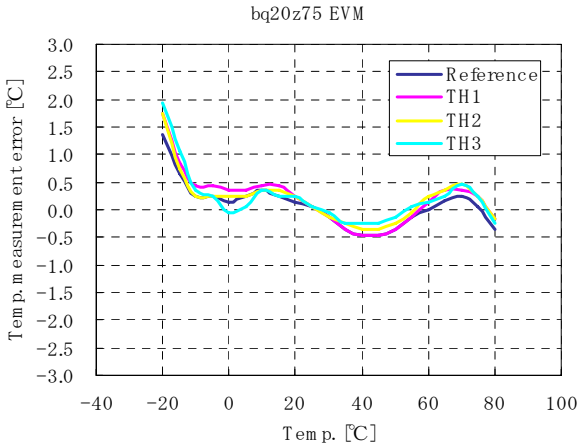


Figure 2. Plotted Temperature Readings from TI bq20z45 EVM with Optimized Coefficients

Note: All Thermistors performed equivalently

Table 6. bq20z75 EVM collected data (Suitable coefficients)

Temp.	Reference		TH1		TH2		TH3	
[℃]	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT
-20	-18.65	1.35	-18.25	1.75	-18.25	1.75	-18.05	1.95
-15	-14.35	0.65	-14.15	0.85	-14.25	0.75	-13.95	1.05
-10	-9.75	0.25	-9.55	0.45	-9.75	0.25	-9.65	0.35
-5	-4.75	0.25	-4.55	0.45	-4.75	0.25	-4.75	0.25
0	0.15	0.15	0.35	0.35	0.25	0.25	-0.05	-0.05
5	5.25	0.25	5.35	0.35	5.25	0.25	5.05	0.05
10	10.35	0.35	10.45	0.45	10.35	0.35	10.35	0.35
15	15.25	0.25	15.45	0.45	15.35	0.35	15.25	0.25
20	20.15	0.15	20.25	0.25	20.25	0.25	20.25	0.25
25	25.05	0.05	25.05	0.05	25.05	0.05	25.05	0.05
30	29.85	-0.15	29.85	-0.15	29.85	-0.15	29.95	-0.05
35	34.65	-0.35	34.65	-0.35	34.75	-0.25	34.75	-0.25
40	39.55	-0.45	39.55	-0.45	39.65	-0.35	39.75	-0.25
45	44.55	-0.45	44.55	-0.45	44.65	-0.35	44.75	-0.25
50	49.65	-0.35	49.65	-0.35	49.75	-0.25	49.85	-0.15
55	54.85	-0.15	54.85	-0.15	54.95	-0.05	55.05	0.05
60	60.01	0.01	60.15	0.15	60.25	0.25	60.15	0.15
65	65.15	0.15	65.35	0.35	65.35	0.35	65.25	0.25
70	70.25	0.25	70.35	0.35	70.45	0.45	70.45	0.45
75	75.05	0.05	75.25	0.25	75.25	0.25	75.25	0.25
80	79.65	-0.35	79.85	-0.15	79.85	-0.15	79.75	-0.25

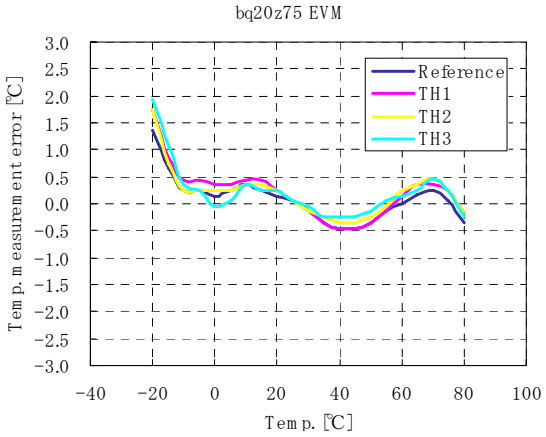


Figure 3. Plotted Temperature Readings from TI bq20z75 EVM with Optimized Coefficients

Note: All Thermistors performed equivalently

Table 7. bq20z45 EVM collected data (Suitable coefficients)

Temp.	Reference		TH1		TH2		TH3	
[℃]	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT
-20	-18.45	1.55	-19.45	0.55	-18.35	1.65	-17.35	2.65
-15	-14.25	0.75	-15.35	-0.35	-14.55	0.45	-13.45	1.55
-10	-9.65	0.35	-10.65	-0.65	-9.85	0.15	-9.15	0.85
-5	-4.85	0.15	-5.85	-0.85	-5.25	-0.25	-4.55	0.45
0	0.25	0.25	-0.65	-0.65	-0.15	-0.15	0.35	0.35
5	5.35	0.35	4.65	-0.35	4.95	-0.05	5.35	0.35
10	10.35	0.35	9.85	-0.15	10.15	0.15	10.45	0.45
15	15.35	0.35	15.05	0.05	15.15	0.15	15.35	0.35
20	20.25	0.25	20.05	0.05	20.15	0.15	20.35	0.35
25	25.05	0.05	25.05	0.05	25.15	0.15	25.15	0.15
30	29.85	-0.15	30.05	0.05	30.05	0.05	29.95	-0.05
35	34.65	-0.35	35.05	0.05	34.95	-0.05	34.85	-0.15
40	39.65	-0.35	40.15	0.15	39.85	-0.15	39.75	-0.25
45	44.65	-0.35	45.25	0.25	44.95	-0.05	44.85	-0.15
50	49.65	-0.35	50.35	0.35	49.95	-0.05	49.85	-0.15
55	54.85	-0.15	55.65	0.65	55.15	0.15	54.95	-0.05
60	60.05	0.05	60.85	0.85	60.25	0.25	60.05	0.05
65	65.25	0.25	66.05	1.05	65.35	0.35	65.15	0.15
70	70.25	0.25	71.05	1.05	70.25	0.25	70.15	0.15
75	75.15	0.15	75.75	0.75	74.95	-0.05	74.85	-0.15
80	79.75	-0.25	80.25	0.25	79.35	-0.65	79.25	-0.75

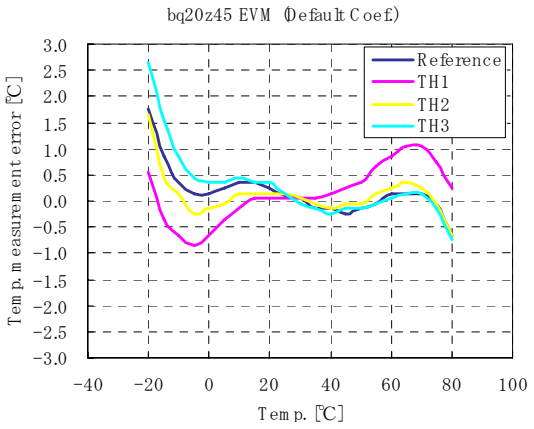


Figure 4. Plotted Temperature Readings from TI bq20z45 EVM Using Non-optimized Temperature Coefficients

Table 8. bq20z75 EVM collected data (Default coefficients)

Temp.	Reference		TH1		TH2		TH3	
[℃]	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT
-20	-18.45	1.55	-19.65	0.35	-18.55	1.45	-17.35	2.65
-15	-14.25	0.75	-15.45	-0.45	-14.65	0.35	-13.45	1.55
-10	-9.65	0.35	-10.85	-0.85	-9.95	0.05	-9.15	0.85
-5	-4.85	0.15	-5.85	-0.85	-5.15	-0.15	-4.45	0.55
0	0.25	0.25	-0.65	-0.65	-0.05	-0.05	0.35	0.35
5	5.35	0.35	4.55	-0.45	4.95	-0.05	5.35	0.35
10	10.35	0.35	9.85	-0.15	10.05	0.05	10.35	0.35
15	15.35	0.35	15.05	0.05	15.15	0.15	15.25	0.25
20	20.25	0.25	20.05	0.05	20.15	0.15	20.35	0.35
25	25.05	0.05	25.05	0.05	25.05	0.05	25.15	0.15
30	29.85	-0.15	30.05	0.05	29.95	-0.05	29.95	-0.05
35	34.65	-0.35	34.95	-0.05	34.85	-0.15	34.85	-0.15
40	39.65	-0.35	40.15	0.15	39.85	-0.15	39.65	-0.35
45	44.65	-0.35	45.15	0.15	44.85	-0.15	44.75	-0.25
50	49.65	-0.35	50.35	0.35	49.95	-0.05	49.75	-0.25
55	54.85	-0.15	55.55	0.55	55.05	0.05	54.95	-0.05
60	60.05	0.05	60.85	0.85	60.25	0.25	60.05	0.05
65	65.25	0.25	65.95	0.95	65.25	0.25	65.05	0.05
70	70.25	0.25	70.95	0.95	70.15	0.15	70.05	0.05
75	75.15	0.15	75.55	0.55	74.85	-0.15	74.75	-0.25
80	79.75	-0.25	80.15	0.15	79.25	-0.75	79.25	-0.75

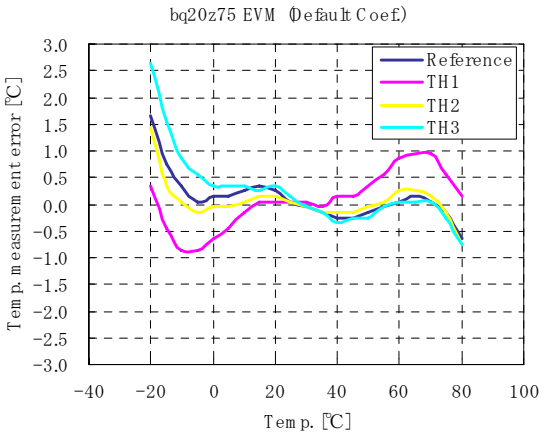


Figure 5. Plotted Temperature Readings from TI bq20z75 EVM Using Non-optimized Temperature Coefficients

Table 9. bq27541 Evaluation Module Collected Data (Default coefficients)

Temp.	Reference		TH1		TH2		TH3	
[℃]	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT	Temp.	ΔT
-20	-19.40	0.60	-20.60	-0.60	-19.40	0.60	-18.40	1.60
-15	-15.20	-0.20	-16.40	-1.40	-15.50	-0.50	-14.40	0.60
-10	-10.60	-0.60	-11.70	-1.70	-10.70	-0.70	-10.00	0.00
-5	-5.60	-0.60	-6.60	-1.60	-5.90	-0.90	-5.30	-0.30
0	-0.50	-0.50	-1.40	-1.40	-0.80	-0.80	-0.40	-0.40
5	4.60	-0.40	4.00	-1.00	4.40	-0.60	4.80	-0.20
10	9.90	-0.10	9.50	-0.50	9.70	-0.30	10.10	0.10
15	15.10	0.10	14.80	-0.20	15.00	0.00	15.10	0.10
20	20.10	0.10	19.90	-0.10	20.00	0.00	20.10	0.10
25	25.00	0.00	25.00	0.00	25.00	0.00	25.10	0.10
30	29.90	-0.10	30.00	0.00	29.90	-0.10	29.80	-0.20
35	34.70	-0.30	34.80	-0.20	34.70	-0.30	34.60	-0.40
40	39.50	-0.50	39.80	-0.20	39.60	-0.40	39.50	-0.50
45	44.50	-0.50	44.80	-0.20	44.50	-0.50	44.40	-0.60
50	49.30	-0.70	49.80	-0.20	49.40	-0.60	49.30	-0.70
55	54.40	-0.60	54.90	-0.10	54.50	-0.50	54.30	-0.70
60	59.60	-0.40	60.30	0.30	59.70	-0.30	59.60	-0.40
65	64.80	-0.20	65.40	0.40	64.80	-0.20	64.50	-0.50
70	69.80	-0.20	70.70	0.70	69.90	-0.10	69.70	-0.30
75	74.80	-0.20	76.00	1.00	74.80	-0.20	74.70	-0.30
80	79.60	-0.40	80.60	0.60	79.60	-0.40	79.50	-0.50

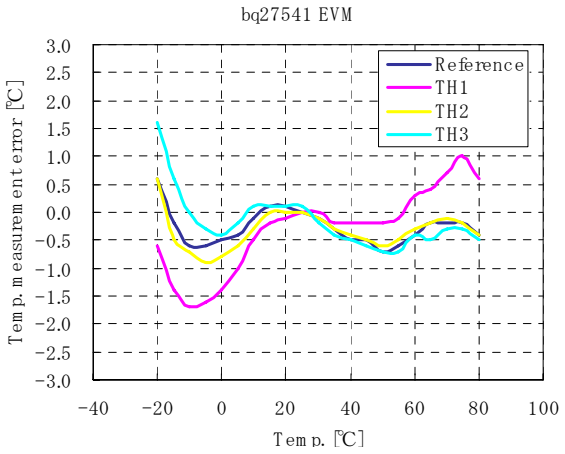


Figure 6. Plotted Temperature Readings from TI bq27541 EVM Using Default Temperature Coefficients.

From Figure 6 results, note TH2 and TH3 Type Thermistor performed equivalent to reference Thermistor (within +/-1ºC measurement over the temperature range of -15ºC to 80 ºC). TH1 type Thermistors are within +/-1℃ measurement over the temperature range of 5ºC to 80 ºC, and better than -2 ºC error from -20ºC to 5ºC temperature range.

6 Conclusion

This application note shows temperature measurement data for three different types of MMTL Thermistors based on different Beta Values characteristics. From this data we find that all three Thermistors types tested (TH1, TH2 and TH3) achieved similar temperature measurement results as TI reference Thermistor.

For the bq20z## products with new Thermistor coefficients calculated based on SLUA398, from figures 3 and 4 we see that temperature measurement is essentially identical.

For some bq27### single cell gas gauge products, default Thermistor coefficients must be used as coefficients are not programmable. From this data we see that TH2 and TH3 type Thermistors performed equivalent to reference Thermistor (within+/-1ºC measurement over the temperature range of -15ºC to 80ºC). TH1 type Thermistor is within +/-1ºC measurement over the temperature range of 5ºC to 80ºC, and better than -2ºC error from -20ºC to 5ºC temperature range.

Therefore, the battery pack designer can comfortably design in any of the Thermistors reviewed in this application note.

For more information on calculating thermistor coefficients, see the application note:
http://www.ti.com/lit/an/slua398/slua398.pdf

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