AN701: SCM7B

Application Note: Thermocouple Modules and CJC

A. VOLTAGE-TO-TEMPERATURE CONVERSION

When SCM7B37 thermocouple modules are used to measure temperature, the measured output voltage must often be converted back to temperature. This is readily done with the SCM7B37 series because Cold Junction Compensation (CJC) is incorporated into the module and SCM7B backpanels.

The conversion method is illustrated with an example:

A type "K" thermocouple (TC) is to be used with the SCM7B37K-02:

1. Identify the TC and Module Voltage ranges:

Temperature Input	Module Voltage Output
–100°C	+1V
+1350°C	+5V

The Minus Full Scale Module Output (known as the "Pedestal") = +1V

The "Module V_{OUT} Range" is 5 – 1 = 4V

2. From the type "K" TC tables determine the full scale voltages:

V(–100°C) = –3.5531mV (TC Neg. F.S. Voltage)

V(+1350°C) = +54.138mV (TC Pos. F.S. Voltage)

TC V_{IN} Range = TC Pos. F.S. Voltage – TC Neg. F.S. Voltage

The SCM7B37K module gain (G), is given by:

G = Module V_{OUT} Range / TC V_{IN} Range

$\therefore$ G = (4) / [0.054138 – (–0.0035531)] = 69.335 V/V

3. Calculate the effective TC voltage (V_T) from the Measured Module Output Voltage (V_{OUT}) using the following formula:

SCM7B37 Module Output Voltage-to-Thermoelectric Voltage

$$V_T = [(V_{OUT} - \text{Pedestal}) / G] + (\text{TC Neg. F.S. Voltage}) \qquad \textbf{Equation 1}$$

$\therefore V_T$ = (Module Measured V_{OUT} – 1V) / 69.335) + (–0.003553)

4. Find the value of the field temperature being measured by crossing V_T to thermocouple temperature in your application program's thermocouple looktable (referenced to a 0°C CJC temperature, which is the case as long as the thermocouple-backpanel junction is within the specified CJC ambient range).

SCM7B37 Module values used in Equation 1 are shown in the following table. ITS-90 characteristics were used to calculate.

MODULE TYPE	G (V/V)	PEDESTAL, V	Thermocouple Neg. Full Scale (mV)
SCM7B37J-01	84.120	+1	–4.6325
SCM7B37J-01A	105.150	0	–4.6325
SCM7B37J-01D	210.300	0	–4.6325
SCM7B37J-10	371.101	+1	0.0
SCM7B37J-10A	463.876	0	0.0
SCM7B37J-10D	927.752	0	0.0
SCM7B37J-11	183.083	+1	0.0
SCM7B37J-11A	228.853	0	0.0
SCM7B37J-11D	457.707	0	0.0
SCM7B37J-12	120.837	+1	0.0

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MODULE TYPE	G (V/V)	PEDESTAL, V	Thermocouple Neg. Full Scale (mV)
SCM7B37J-12A	151.046	0	0.0
SCM7B37J-12D	302.093	0	0.0
SCM7B37J-13	238.447	+1	+16.3272
SCM7B37J-13A	298.059	0	+16.3272
SCM7B37J-13D	596.118	0	+16.3272
SCM7B37K-02	69.335	+1	–3.5531
SCM7B37K-02A	86.669	0	–3.5531
SCM7B37K-02D	173.338	0	–3.5531
SCM7B37K-20	327.639	+1	0.0
SCM7B37K-20A	409.549	0	0.0
SCM7B37K-20D	819.097	0	0.0
SCM7B37K-21	160.607	+1	0.0
SCM7B37K-21A	200.759	0	0.0
SCM7B37K-21D	401.518	0	0.0
SCM7B37K-22	81.903	+1	0.0
SCM7B37K-22A	102.379	0	0.0
SCM7B37K-22D	204.758	0	0.0
SCM7B37K-23	167.135	+1	+24.9055
SCM7B37K-23A	208.919	0	+24.9055
SCM7B37K-23D	417.837	0	+24.9055
SCM7B37T-03	164.945	+1	–3.3786
SCM7B37T-03A	206.181	0	–3.3786
SCM7B37T-03D	412.362	0	–3.3786
SCM7B37E-04	58.151	+1	0.0
SCM7B37E-04A	72.689	0	0.0
SCM7B37E-04D	145.377	0	0.0
SCM7B37R-05	191.598	+1	0.0
SCM7B37R-05A	239.497	0	0.0
SCM7B37R-05D	478.994	0	0.0
SCM7B37S-06	216.177	+1	0.0
SCM7B37S-06A	270.221	0	0.0
SCM7B37S-06D	540.441	0	0.0
SCM7B37B-07	294.331	+1	0.0
SCM7B37B-07A	367.914	0	0.0
SCM7B37B-07D	735.828	0	0.0

When the **SCM7B47 thermocouple modules** are used to measure temperature, the measured output voltage is also often converted back to temperature. This is readily done with the SCM7B47 series because, like the SCM7B37 Modules, Cold Junction Compensation (CJC) is incorporated into the module and SCM7B backpanels. However, unlike the SCM7B37 Modules, the module output voltage is a linear representation (Y = M X + B) of the input temperature.

The conversion method is illustrated with an example.

A type "T" thermocouple (TC) is to be used with the SCM7B47T-06.

1. Determine the Module Transfer Function:

Temperature Input	Module Voltage Output
–100°C	+1V
+200°C	+5V

Let T_{LOW} ≡ Neg. Full Scale Temperature = –100°C

Let M ≡ (Output Voltage Span)/(Input Temp Span) = +13.333mV / °C

2. Find the Temperature corresponding to Module Output Voltage:

Since Y = MX + B, with X = (Field Temperature – T_{LOW})

V_{OUT} = M x (Field Temperature – T_{LOW}) + Pedestal

Solving for the Field Temperature gives:

SCM7B47 Voltage-to-Temperature Conversion

Temperature = (V_{OUT} – Pedestal) / M + T_{LOW}

with M = (Module Output Volt Span) / (Input Temp Span) **Equation 2**

In this case, Temperature (°C) = (V_{OUT} – 1V) / 13.333mV + (–100°C)

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SCM7B47 Module values used in Equation 2 are shown in the following table:

MODULE TYPE	M (mV/°C)	Pedestal, V	T_{LOW}, °C
SCM7B47J-01	5.2632	+1	0
SCM7B47J-01A	6.5790	0	0
SCM7B47J-01D	13.1579	0	0
SCM7B47J-02	10.0000	+1	–100
SCM7B47J-02A	12.5000	0	–100
SCM7B47J-02D	25.0000	0	–100
SCM7B47K-03	3.0769	+1	0
SCM7B47K-03A	3.8462	0	0
SCM7B47K-03D	7.6923	0	0
SCM7B47K-04	6.6667	+1	0
SCM7B47K-04A	8.3333	0	0
SCM7B47K-04D	16.6667	0	0
SCM7B47T-05	10.0000	+1	0
SCM7B47T-05A	12.5000	0	0
SCM7B47T-05D	25.0000	0	0
SCM7B47T-06	13.3333	+1	–100
SCM7B47T-06A	16.6667	0	–100
SCM7B47T-06D	33.3333	0	–100
SCM7B47E-07	4.4444	+1	0
SCM7B47E-07A	5.5555	0	0
SCM7B47E-07D	11.1111	0	0
SCM7B47R-08	3.2000	+1	+500
SCM7B47R-08A	4.0000	0	+500
SCM7B47R-08D	8.0000	0	+500
SCM7B47S-09	3.8095	+1	+700
SCM7B47S-09A	4.7619	0	+700
SCM7B47S-09D	9.5238	0	+700
SCM7B47B-10	4.0000	+1	+800
SCM7B47B-10A	5.0000	0	+800
SCM7B47B-10D	10.0000	0	+800
SCM7B47N-11	3.6364	+1	+200
SCM7B47N-11A	4.5455	0	+200
SCM7B47N-11D	9.0909	0	+200

B. COLD JUNCTION COMPENSATION (CJC)

A negative temperature coefficient Thermistor is used as the SCM7B CJC sense element in a voltage divider configuration. It is mounted underneath each field side terminal block. A nonlinear current is used to develop a linear voltage potential which is input to the modules X^+ input pin. This potential changes over temperature. Inside the module, this slope is modified to match the thermocouple type's Seebeck Coefficient (at+25°C) which offsets the effect of the thermocouple to backplane junction potential. Thus, the module high-level output potential is the field Thermocouple temperature and NOT the difference between the field temperature and backpanel temperature.

This Thermistor is manufactured by BetaTHERM, P/N 100K6A1 (other manufacturers of acceptable replacements are listed in the "Other Part Numbers of Interest" at end of the SCM7B catalog section).

The Thermistor is rated at 100kΩ at +25°C, ±0.2°C from 0°C to +70°C. For temperatures other than +25°C, the Steinhart-Hart Equation can be used with coefficients provided by the Thermistor manufacturer.

STEINHART-HART EQUATION

$$1/T = A + B \bullet \ln(R) + C \bullet [\ln(R)]^3 \qquad \text{Equation 3}$$

Where T is in Kelvin, Thermistor Resistance (R) in Ohms, and coefficients A,B,C are given by:

A = 8.27153E-04

B = 2.08796E-04 (per BetaTHERM for model 100K6A1)

C = 8.060985E-08

To convert to °C, simply subtract 273.15 from the Kelvin temperature result.