TEMPERATURE SENSORS

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Overview of the LM35 and Thermistor temperature sensors used with the S.H.D.S. LabVIEW program.

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INTRODUCTION

This student paper sets out to elucidate the effectiveness and limitations of the LM35 and Thermistor sensors. It also particulars other alternative sensors that may be used with the S.H.D.S. LabVIEW program.

It is intrinsically interconnected with the 'S.H.D.S. User Manual' - which should be read in conjunction with this report.

LabVIEW

LabVIEW is a graphical programming language that has been widely adopted throughout Industry, Academia and Government labs as the standard for data acquisition, instrument control software and analysis software (Bishop, 2001).

Sensors and Transducers

Sensors can generate electrical signals to measure physical phenomena, such as temperature, force, sound, or light. Some commonly used sensors are strain gauges, thermocouples, thermistors, angular encoders, linear encoders, and resistance temperature detectors (RTDs).

To measure signals from these various transducers, you must convert them into a form that a DAQ device can accept. For example, the output voltage of most thermocouples is very small and susceptible to noise. Therefore, you may need to amplify or filter the thermocouple output before digitising it. The manipulation of signals to prepare them for digitising is called signal conditioning (National Instruments Corporation, 2009).

CIRCUIT BOARD DESIGN

The small 5 x 2 circuit board attached to the analogue DAQ connector has the following circuitry layout and wire connection colouring.

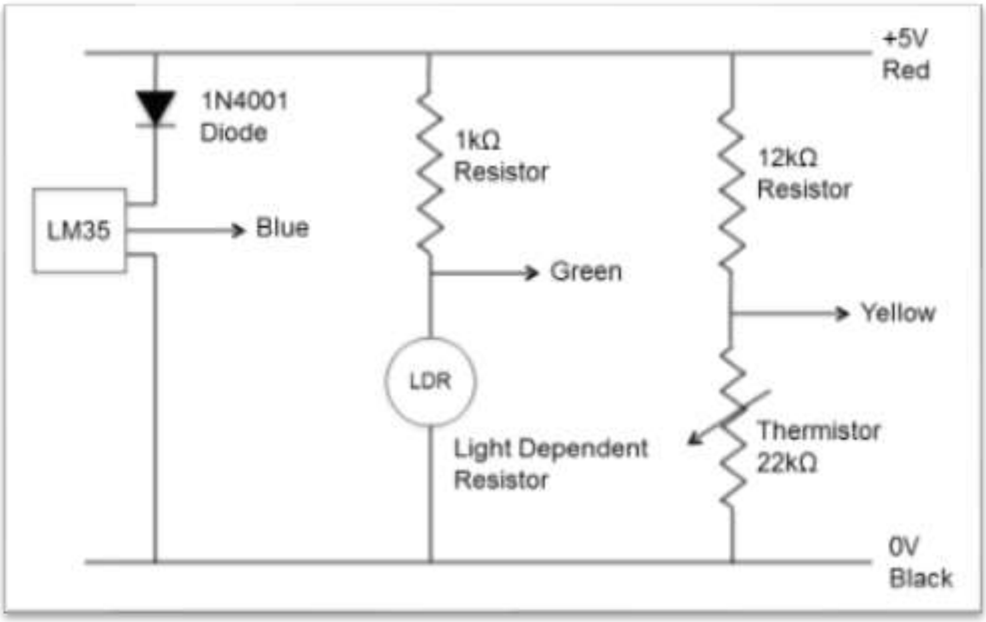

Figure 1 – Circuit board layout

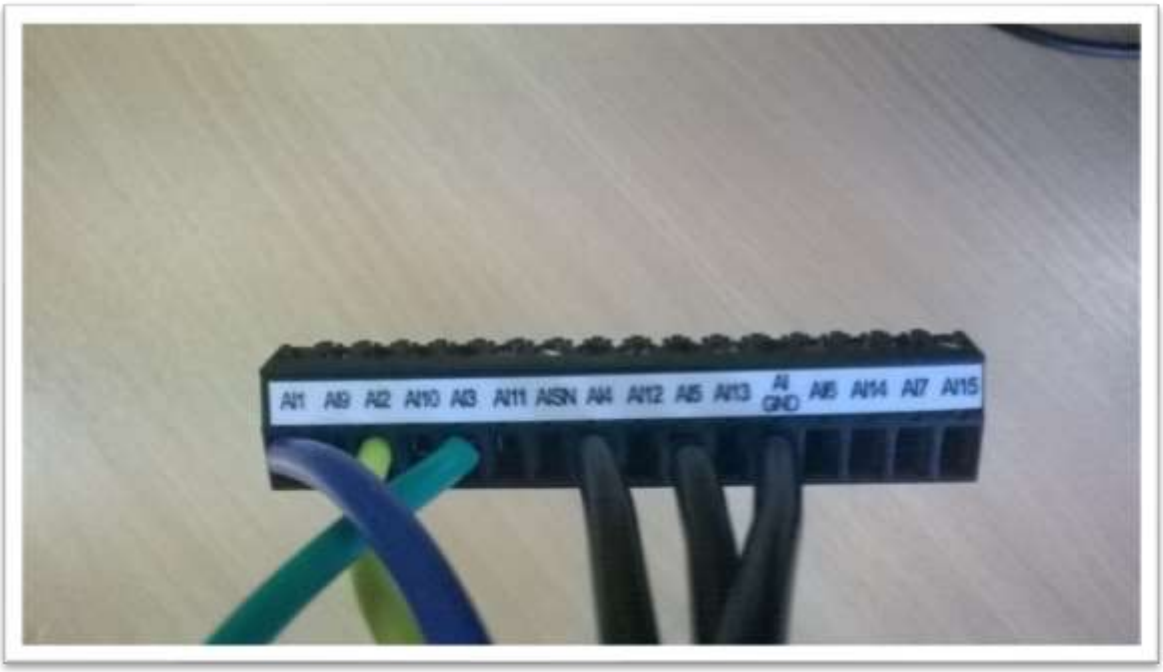

Figure 2 – Analogue DAQ connector

In addition it has the following temperature sensors attached.

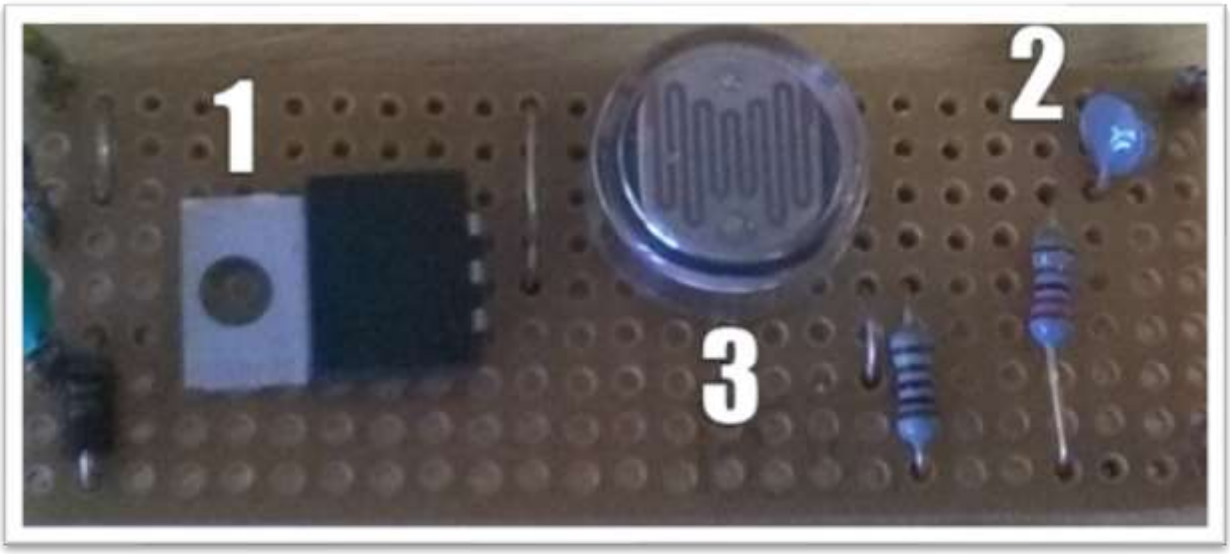

Figure 3 – Circuit board sensors

This all fits together as shown below in table 1.

No.	DAQ Connect	Sensor Type	Wire Colour
1	AI1	Linear IC temperature sensor (LM35)	Blue
2	AI3	Temperature Dependant Resister (Thermistor)	Green
3	AI2	Light Dependant Resister (LDR) sensor	Yellow

Table 1 – Compilation table

That said, this report is principally concerned with sensors 1 and 2 only.

Attaching Analogue Sensors

The above three analogue sensors are combined with the S.H.D.S. LabVIEW program by using the DAQ Assist protocol build into the LabVIEW program as shown below.

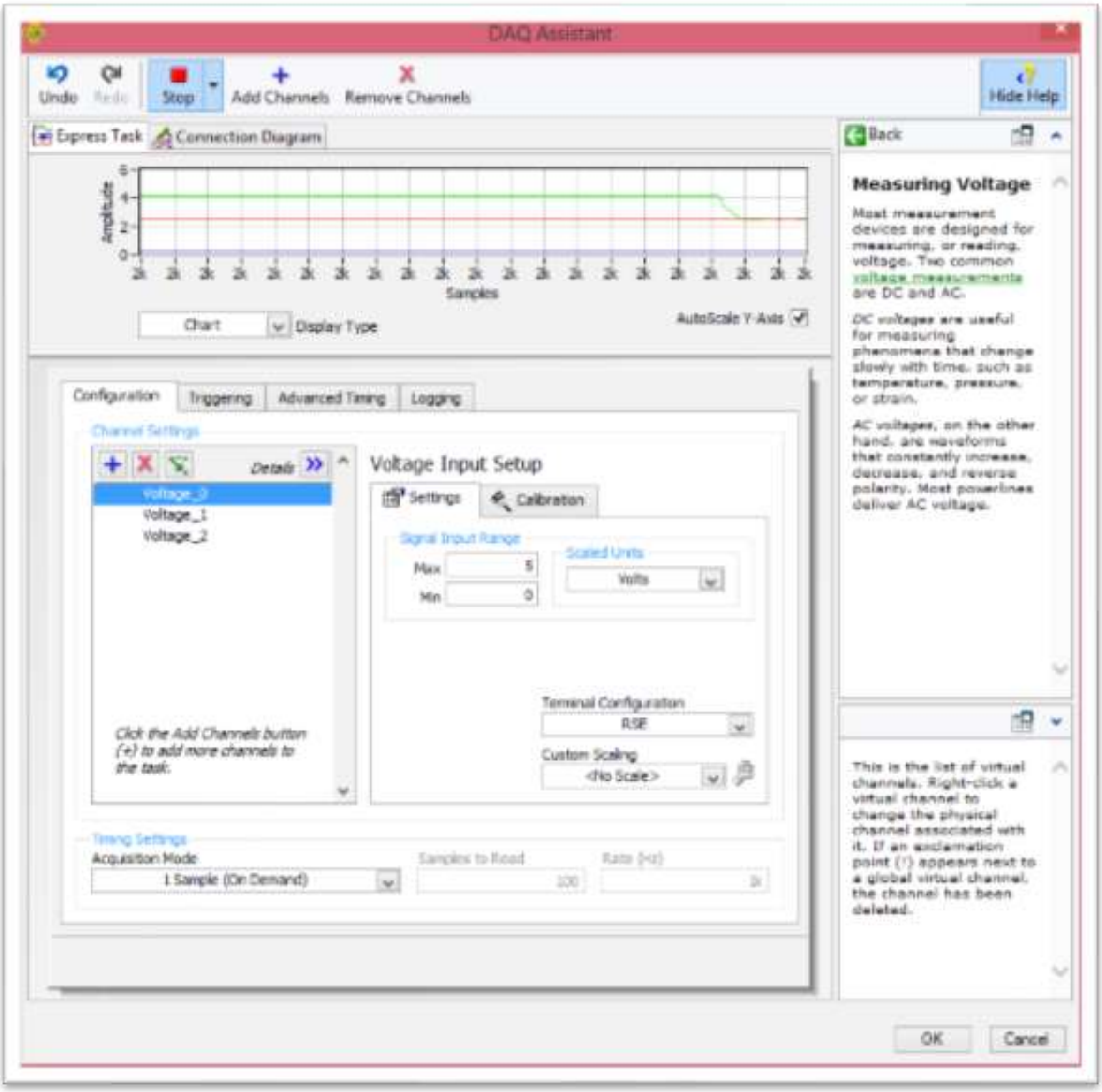

Figure 4 – DAQ assistant protocol

Acquisition mode was set to '1 sample (On Demand)' and terminal configuration set to RSE with a signal input range of 0 to 5 volts.

This gave the following three signal outputs:-

DAQ Connector	Configuration	Signal Output	Amplitude
AI1 – LM35	Voltage_0	Blue display line	≈ 0.15 Volts.
AI2 – LDR	Voltage_1	Red display line	≈ 2.5 Volts
AI3 - Thermistor	Voltage_2	Green display line	≈ 2.5 Volts.

Table 2 – Analogue amplitude output

However, during the initial testing phase it was observed that stimulating anyone of the three sensors only changed the amplitude of the green analogue signal up to a maximum of 4 Volts.

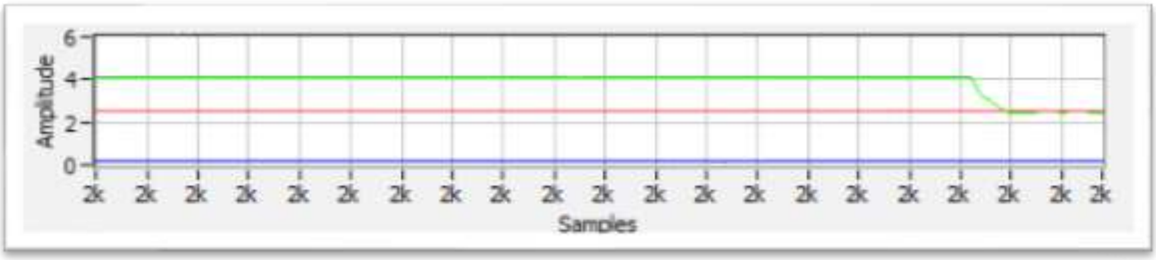

Figure 5 – Analogue signal output

Consequently, this DAQ analogue connector was exchanged for another analogue connector with a different circuit board which revealed an improved but not perfect set of data results.

During the second testing phase it was observed that stimulating the LM35 sensor increased the amplitude of the blue analogue signal very slightly. Stimulating the Thermistor sensor rapidly increased the amplitude of the green analogue signal. Activating the LDR had no effect on the red analogue signal at all which remained constant.

One would expect that each analogue signal would register their own separate amplitudes based on the stimulation received by their corresponding sensors.

Consequently, the S.H.D.S. program was designed to read in the single blue analogue signal (AI1) and act as the external heat trigger (0.27 Volts) for the Chamber room. It was also designed to read in the single green analogue signal (AI3) and act as the external heat trigger (3.0 Volts) for the Library.

SENSOR EFFECTIVENESS

As connected to this circuit board they form a voltage divider. Output is proportional to resistance values – so if both are equal, voltage output will be 0.5 of supply voltage i.e. 2.5 Volts.

Hence as the LDR & Thermistor sensor values change the output voltage will also change.

LM35

The LM35 sensor is very slow and not at all responsive.

As detailed above in 'Sensors and Transducers' (page 6) the LM35 would require some form of signal conditioning - although none has currently been designed into the S.H.D.S. program.

The LM35 is sluggish because there are small slow increments made from its initial resting value of ≈ 0.15 Volts to its activation trigger value of 0.27 Volts.

In fact at the point of trigger it can be observed to drop off – so that the trigger is on… off… on… off… on etc. until the voltage value is greater than 0.27 Volts.

Thermistor

As detailed above in 'Sensors and Transducers' (page 6) the Thermistor sensor would not require any form of signal conditioning.

The Thermistor has quick sharp increments from its initial resting value of ≈ 2.5 Volts to its activation trigger value of 3.0 Volts.

SENSOR LIMITATIONS

Detailed below is a comparison table for judging the limitations of sensors based on relevant criteria.

Criteria	Thermocouple	RTD	Thermistor
Temperature Range	-267°C to 2316°C	-240°C to 649°C	-100°C to 500°C
Accuracy	Good	Best	Good
Linearity	Better	Best	Good
Sensitivity	Good	Better	Best
Cost	Best	Good	Better

Table 3 – Comparison table

LM35

This semiconductor integrated circuit temperature sensor is highly linear in nature. It has a large voltage range and the output is directly calibrated to degrees Celsius.

The particular sensor used is of the family encapsulation TO-220 pattern.

Thermistor

Thermistors have a fast output and are relatively inexpensive but are fragile and have a limited range. They also require a current source and do experience more self-heating than an RTD and are nonlinear:-

As temperature increases resistance decreases. This decrement is non-linear within the following range:

Vout = 5 * 22000 / (22000 + Rt)

Where Rt = thermistor resistance (nominally 22k).

RT conversion characteristics are shown in Appendix A.

ALTERNATIVE SENSORS

Temperature sensors are required for a variety of monitoring and industrial applications. The most common temperature sensors are thermocouples, resistance temperature detectors (RTDs), and thermistors. They offer different performance and cost trade-offs, depending on their application.

When you combine them with NI measurement devices and software, you can easily create a complete measurement system to acquire from a single channel or thousands of temperature channels.

NI LabVIEW system design software and the NI-DAQmx driver provide easily configured measurements and predefined scaling coefficients for temperature sensors and return synchronised temperature data in units of degrees (National Instruments Corporation, 2015).

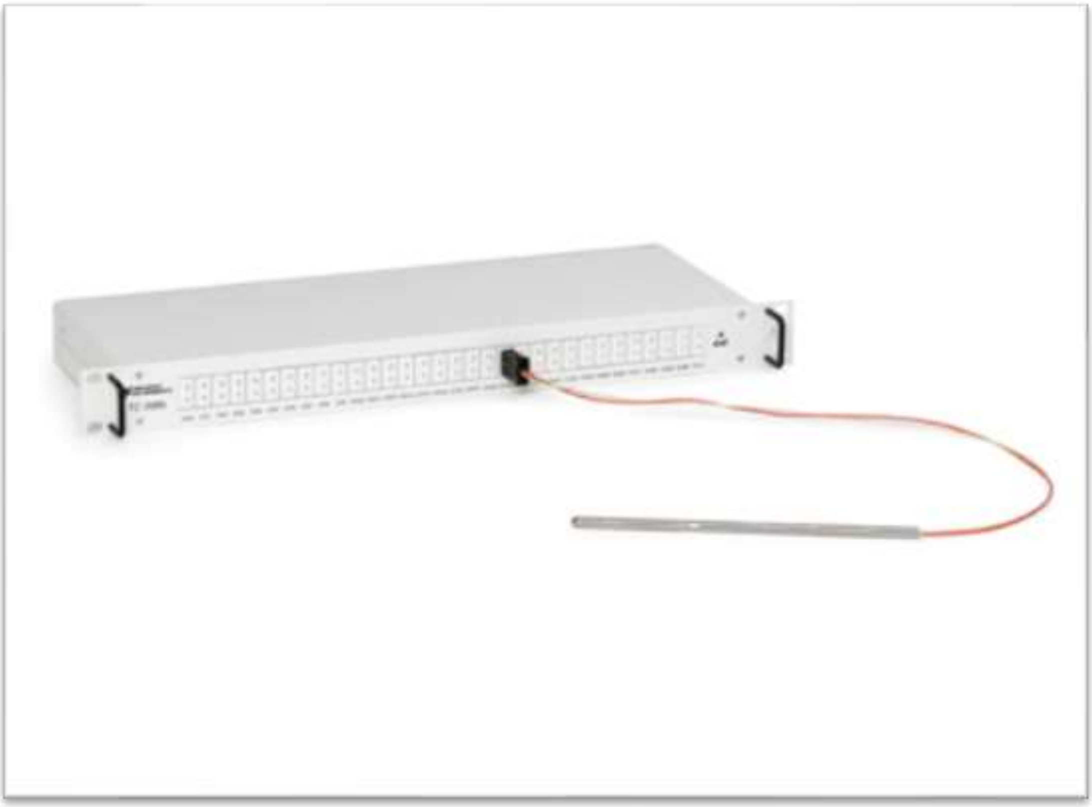

Figure 6 – NI measurement device

Thermocouples

Thermocouples from NI can be used for a variety of low-cost temperature applications. Types J, K, T, and E thermocouples provide for a variety of temperature conditions.

For cost-sensitive applications, National Instruments offers ready-made thermocouples individual packets of thermocouple wire with the measuring junction provided at one end. These thermocouples are available in 1m (39.4 in.) and 2m (78.7 in.) lengths (National Instruments Corporation, 2015).

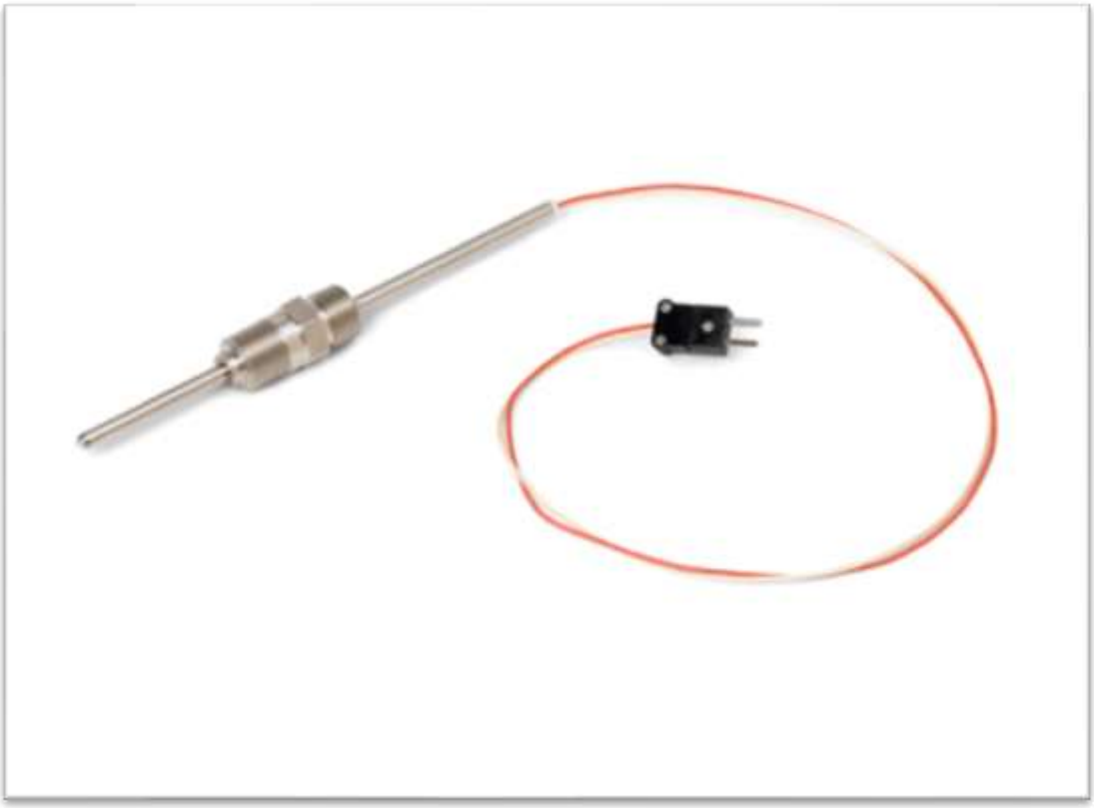

Figure 7 - Thermocouple

Ready-made thermocouples are ideal for starter or educational applications.

Resistance Temperature Detectors (RTDs)

Resistance temperature detectors (RTDs) from NI offer outstanding accuracy and stability for industrial applications that require high precision. By combining RTDs with NI measurement devices and software, you can easily create a complete measurement system to acquire from a single channel or thousands of channels.

NI-DAQmx driver software and NI LabVIEW system design software provide easily configured measurements and predefined scaling coefficients for RTD sensors and return synchronised temperature data in units of degrees (National Instruments Corporation, 2015).

Figure 8 – Resistance temperature detectors (RTD)

Thermistors

PTC thermistors increase their resistance as temperature increases, while NTC thermistors decrease their resistance as temperature rises. You can use PTC thermistors, or posistors, as current-limiting devices for circuit protection (in place of fuses) and as heating elements in small temperature-controlled ovens. Meanwhile, NTC thermistors are used mainly to measure temperature, and are widely present in digital thermostats and in automobiles to monitor engine temperatures. Be sure to select the proper type of thermistor, PTC or NTC, based on the performance your applications requires (National Instruments Corporation, 2009).

Figure 9 – Thermistor

APPENDIX A

Shown below are the RT characteristics.

EPCOS

Temperature measurement and compensation

Leaded NTC thermistors, lead spacing 5 mm

R/T characteristics

R/T No.	1011		1012		1013	
T (°C)	$B_{25/100}$ = 3730 K		$B_{25/100}$ = 4300 K		$B_{25/100}$ = 3900 K	
	R_T/R_{25}	α (%/K)	R_T/R_{25}	α (%/K)	R_T/R_{25}	α (%/K)
−55.0	70.014	6.9	87.237	6.8	77.285	7.0
−50.0	49.906	6.7	62.264	6.7	54.938	6.7
−45.0	36.015	6.4	44.854	6.5	39.507	6.5
−40.0	26.296	6.2	32.599	6.3	28.722	6.3
−35.0	19.411	6.0	23.893	6.1	21.099	6.1
−30.0	14.479	5.8	17.654	6.0	15.652	5.9
−25.0	10.903	5.6	13.098	5.8	11.715	5.7
−20.0	8.2923	5.4	9.8059	5.7	8.8541	5.6
−15.0	6.3591	5.2	7.4266	5.5	6.7433	5.4
−10.0	4.9204	5.1	5.6677	5.4	5.1815	5.2
−5.0	3.8279	4.9	4.3213	5.3	4.0099	5.1
0.0	3.0029	4.8	3.3208	5.1	3.1283	4.9
5.0	2.3773	4.6	2.5842	5.0	2.4569	4.8
10.0	1.8959	4.5	2.0238	4.9	1.9438	4.6
15.0	1.5207	4.3	1.5858	4.8	1.5475	4.5
20.0	1.228	4.2	1.2507	4.7	1.2403	4.4
25.0	1.0000	4.1	1.0000	4.5	1.0000	4.3
30.0	0.81779	3.9	0.7964	4.4	0.81104	4.1
35.0	0.67341	3.8	0.64053	4.3	0.66146	4.0
40.0	0.55747	3.7	0.51772	4.2	0.54254	3.9
45.0	0.46357	3.6	0.41958	4.1	0.44727	3.8
50.0	0.3874	3.6	0.34172	4.1	0.37067	3.7
55.0	0.32368	3.5	0.27877	4.0	0.30865	3.6
60.0	0.272	3.4	0.22861	3.9	0.25825	3.5
65.0	0.23041	3.3	0.18872	3.8	0.21707	3.4
70.0	0.19604	3.2	0.15645	3.7	0.18323	3.3
75.0	0.16735	3.1	0.13012	3.6	0.15535	3.3
80.0	0.14342	3.0	0.10863	3.6	0.13223	3.2
85.0	0.12347	3.0	0.091115	3.5	0.11302	3.1
90.0	0.10668	2.8	0.0767	3.4	0.096951	3.0
95.0	0.092734	2.8	0.064867	3.3	0.083487	3.0
100.0	0.080903	2.8	0.055047	3.3	0.072139	2.9
105.0	0.070616	2.7	0.046797	3.2	0.062559	2.8
110.0	0.061826	2.6	0.039904	3.1	0.054425	2.8
115.0	0.054282	2.6	0.034255	3.1	0.047508	2.7
120.0	0.047793	2.5	0.029498	3.0	0.041594	2.6
125.0	0.042249	2.4	0.025448	3.0	0.036532	2.6

Figure 10 - RT temperature measurement and compensation chart

REFERENCES

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