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FACULTY OF ELECTRICAL ENGINEERING
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SKE 3732/3712

INSTRUMENTATION LABORATORY
MEASUREMENT AND CALIBRATION OF TEMPERATURE SENSOR

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PRELIMINARY EXERCISE (15 marks)

Important Note: You are required to do this exercise BEFORE the lab session.

1. Explain briefly what is
    a) thermocouple
    b) Resistance Temperature Detectors
2. Briefly discus the procedures for thermocouple can be used for sensing temperature of water and converting from voltage.
3. Write the necessary equations for the practical use of thermocouples, derived from the basic definition of the Seebeck Effect
4. List the meterias example made of thermoucouple. At least 3 pair of material (J,K and T) should be given.
5. What is reference junction. From a standard table given (J Type), Estimate the output voltage generated from thermoucouple if we are used;
    a) an ice water as reference junction
    b) room temperature water (25ºC) as reference junction.
6. What is the range of operation for thermocouple.?
7. List three type of sensors (other than example in Question 1) can be used for temperature measurement.

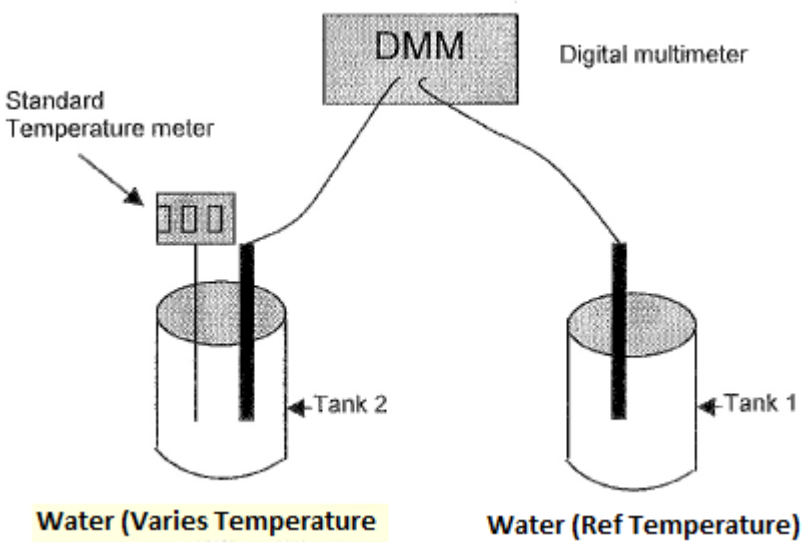

Figure 1

Objectives

The objectives of these experiment are:

i. To calibrate three types of thermocouples which is J, K and T
ii. To understand and use of temperature sensor in measurement
iii. To determine the characteristics of transducers and transmitters
iv. To determine the coefficients of transducers and transmitter
v. To design an applications of temperature sensor.

Apparatus and Equipment:

FLUKE 725 Multifunction Process Calibrator, Multimeter, thermometer, heating element, container, water, ices, Thermocouple, temperature sensor, SU6808B/ ED6803B/CU6802 /OU6801/ ED6805B/ Digiac 1750

PROCEDURE

Background
Temperature sensor do not provide direct temperature readings. It produces a physical parameter changes or voltage. The reading will be translate into temperature measurements. One of the temperature sensor isThermocouples. Thermocouple are accurate over different ranges of temperatures.

Perecaution
Make sure the heating element is inside the tank at the suitable level of water

Experiment 1; ***Type J thermocouple***

1) Thermocouple is placed in a bath, to provide reference point for temperature readings. This thermocouple is then placed in a water or dry ice bath in container and the other junction in other container as shown in figure 1. Record the value of reference temperature.
2) By using the Digiac 1750 or SU6808B/ ED6803B/CU6802 /OU6801, design a signal conditioning circuit to produce a maximum voltage from a boiling water. (Hint: Use a standard data of thermocouple to design a signal conditioning). **FLUKE 725** Multifunction Process Calibrator can be used to generate the source of electrical signal or for measurement in circuit design.
3) If you are using amplifier in your signal conditioning circuit, make sure ***offset*** an amplifier before it used. Used. Be careful for the amplifier used in circuit design and should not at saturated condition.
4) Varies the temperature of water and measure the voltages output from temperature sensor and also from your signal conditioning circuit. Record all the results in appropriate table for a varies of water temperature and voltages. Also make sure record the value of reference temperature from time to time.
5) Repeat the experiment steps 4 to observe the repeatibility, error and other terms of measurement and instrumentation.
6) Plot a graph voltage versus tempreature and compared to standard table.
7) Plot a graph for voltage from signal conditioning circuit versus temperature.
8) Your task is to use the collected data and plot a graphs. You are require to prepare a short experimental report describing the project, the procedure, measurement technique, calibration and the results.

Experiment 2: ***Type K thermocouple***

Repeat the experiment 1 from steps 1 to 8 for type K thermocouple

Experiment 3: ***Type T thermocouple***

Repeat the experiment 1 from steps 1 to 8 for type T thermocouple

Experiment 4: ***Application of sensor***

1) Choose one type of thermocouple or other temperature sensor,
    a) Design a circuit for an application controlling speeds of DC motor on DIGIAC 1750 or ED6805B. Your circuit should able to increase the speed of DC motor by varing the temperature of water. Propose a circuit and discuss with your supervisor before you construct any circuit.
    b) Other application. (discuss with supervisor)
2) Varies the temperature of water and record the voltages output from signal conditioning and the speeds of DC motor.
3) Record all your results in an appropriate table for variable changes (such as speed, voltage etc).

Discussion and general conclusion.

1) Plot a graphs and calculate correlation value of your graph characteristic.
2) Compare and discuss the graphs to the standard table.
3) Using the obtained data determine the characteristic and sensitivity of the thermocouple temperature before and after signal conditioning.
4) Discuss error in measurement.
5) Discuss the instrument and calibration term from these experiment and the behavior of the graphs.
6) Compared the characteristic of experiments.
7) Discuss the characteristic of application in experiment 4.

Thermocouple tables.

Type J Thermocouple Table[2]
Voltages are in mV

Temperature (°C)	0	1	2	3	4	5	6	7	8	9
0	0.0000	0.0504	0.1009	0.1514	0.2020	0.2527	0.3034	0.3541	0.4050	0.4558
10	0.5068	0.5578	0.6088	0.6599	0.7111	0.7623	0.8136	0.8649	0.9162	0.9677
20	1.0191	1.0707	1.1223	1.1739	1.2256	1.2773	1.3291	1.3809	1.4328	1.4847
30	1.5367	1.5887	1.6407	1.6928	1.7450	1.7972	1.8494	1.9017	1.9541	2.0064
40	2.0588	2.1113	2.1638	2.2164	2.2689	2.3216	2.3742	2.4269	2.4797	2.5325
50	2.5853	2.6382	2.6911	2.7440	2.7970	2.8500	2.9031	2.9562	3.0093	3.0625
60	3.1157	3.1689	3.2222	3.2755	3.3288	3.3822	3.4356	3.4890	3.5425	3.5960
70	3.6495	3.7031	3.7567	3.8103	3.8640	3.9177	3.9714	4.0252	4.0789	4.1327
80	4.1866	4.2404	4.2943	4.3483	4.4022	4.4562	4.5102	4.5642	4.6183	4.6724
90	4.7265	4.7806	4.8348	4.8890	4.9432	4.9974	5.0517	5.1059	5.1602	5.2146
100	5.2689	5.3233	5.3777	5.4321	5.4865	5.5410	5.5955	5.6500	5.7045	5.7591
110	5.8136	5.8682	5.9228	5.9774	6.0321	6.0867	6.1414	6.1961	6.2508	6.3056
120	6.3603	6.4151	6.4699	6.5247	6.5795	6.6343	6.6892	6.7440	6.7989	6.8538
130	6.9087	6.9637	7.0186	7.0736	7.1285	7.1835	7.2385	7.2936	7.3486	7.4036
140	7.4587	7.5137	7.5688	7.6239	7.6790	7.7341	7.7893	7.8444	7.8996	7.9547
150	8.0099	8.0651	8.1203	8.1755	8.2307	8.2859	8.3412	8.3964	8.4517	8.5069
160	8.5622	8.6175	8.6728	8.7281	8.7834	8.8387	8.8940	8.9494	9.0047	9.0601
170	9.1154	9.1708	9.2262	9.2815	9.3369	9.3923	9.4477	9.5031	9.5585	9.6139
180	9.6694	9.7248	9.7802	9.8356	9.8911	9.9465	10.002	10.057	10.113	10.168
190	10.224	10.279	10.335	10.390	10.446	10.501	10.557	10.612	10.668	10.723
200	10.779	10.834	10.890	10.945	11.001	11.056	11.112	11.167	11.223	11.278
210	11.334	11.389	11.445	11.501	11.556	11.612	11.667	11.723	11.778	11.834
220	11.889	11.945	12.000	12.056	12.111	12.167	12.222	12.278	12.334	12.389
230	12.445	12.500	12.556	12.611	12.667	12.722	12.778	12.833	12.889	12.944
240	13.000	13.056	13.111	13.167	13.222	13.278	13.333	13.389	13.444	13.500
250	13.555	13.611	13.666	13.722	13.777	13.833	13.888	13.944	13.999	14.055
260	14.110	14.166	14.221	14.277	14.332	14.388	14.443	14.499	14.554	14.609
270	14.665	14.720	14.776	14.831	14.887	14.942	14.998	15.053	15.109	15.164
280	15.219	15.275	15.330	15.386	15.441	15.496	15.552	15.607	15.663	15.718
290	15.773	15.829	15.884	15.940	15.995	16.050	16.106	16.161	16.216	16.272
300	16.327	16.383	16.438	16.493	16.549	16.604	16.659	16.715	16.770	16.825

Type K Thermocouple Table[1]
Voltages are in mV

Temperature (°C)	0	1	2	3	4	5	6	7	8	9
0	0.0000	0.0395	0.0790	0.1186	0.1582	0.1979	0.2376	0.2773	0.3171	0.3570
10	0.3969	0.4368	0.4768	0.5168	0.5569	0.5970	0.6371	0.6773	0.7175	0.7578
20	0.7981	0.8385	0.8789	0.9193	0.9597	1.0002	1.0408	1.0814	1.1220	1.1626
30	1.2033	1.2440	1.2847	1.3255	1.3663	1.4072	1.4480	1.4889	1.5299	1.5708
40	1.6118	1.6528	1.6939	1.7349	1.7760	1.8171	1.8583	1.8994	1.9406	1.9818
50	2.0231	2.0643	2.1056	2.1469	2.1882	2.2296	2.2709	2.3123	2.3537	2.3951
60	2.4365	2.4779	2.5193	2.5608	2.6023	2.6437	2.6852	2.7267	2.7682	2.8097
70	2.8513	2.8928	2.9343	2.9758	3.0174	3.0589	3.1005	3.1420	3.1836	3.2251
80	3.2666	3.3082	3.3497	3.3913	3.4328	3.4743	3.5159	3.5574	3.5989	3.6404
90	3.6819	3.7234	3.7649	3.8063	3.8478	3.8892	3.9306	3.9721	4.0135	4.0549
100	4.0962	4.1376	4.1789	4.2203	4.2616	4.3029	4.3442	4.3854	4.4267	4.4679
110	4.5091	4.5502	4.5914	4.6325	4.6737	4.7148	4.7558	4.7969	4.8379	4.8789
120	4.9199	4.9609	5.0018	5.0427	5.0836	5.1244	5.1653	5.2061	5.2469	5.2877
130	5.3284	5.3691	5.4098	5.4505	5.4911	5.5318	5.5724	5.6129	5.6535	5.6940
140	5.7345	5.7750	5.8155	5.8559	5.8963	5.9367	5.9771	6.0174	6.0578	6.0981
150	6.1384	6.1786	6.2189	6.2591	6.2993	6.3395	6.3797	6.4198	6.4600	6.5001
160	6.5402	6.5803	6.6204	6.6605	6.7005	6.7406	6.7806	6.8206	6.8606	6.9006
170	6.9406	6.9806	7.0205	7.0605	7.1005	7.1404	7.1803	7.2203	7.2602	7.3001
180	7.3400	7.3800	7.4199	7.4598	7.4997	7.5396	7.5795	7.6194	7.6593	7.6992
190	7.7391	7.7791	7.8190	7.8589	7.8988	7.9388	7.9787	8.0186	8.0586	8.0985
200	8.1385	8.1785	8.2184	8.2584	8.2984	8.3384	8.3784	8.4185	8.4585	8.4985
210	8.5386	8.5787	8.6188	8.6589	8.6990	8.7391	8.7792	8.8194	8.8595	8.8997
220	8.9399	8.9801	9.0203	9.0606	9.1008	9.1411	9.1814	9.2217	9.2620	9.3024
230	9.3427	9.3831	9.4235	9.4639	9.5043	9.5447	9.5852	9.6257	9.6661	9.7066
240	9.7472	9.7877	9.8283	9.8689	9.9094	9.9501	9.9907	10.031	10.072	10.113
250	10.153	10.194	10.235	10.276	10.316	10.357	10.398	10.439	10.480	10.520
260	10.561	10.602	10.643	10.684	10.725	10.766	10.807	10.848	10.889	10.930
270	10.971	11.012	11.053	11.094	11.135	11.176	11.217	11.259	11.300	11.341
280	11.382	11.423	11.465	11.506	11.547	11.588	11.630	11.671	11.712	11.753
290	11.795	11.836	11.877	11.919	11.960	12.002	12.043	12.084	12.126	12.167
300	12.209	12.250	12.292	12.333	12.374	12.416	12.457	12.499	12.541	12.582

T°C

TABLE 17 ***Type T Thermocouple*** *— thermoelectric voltage as a function of temperature (°C); reference junctions at 0 °C*

°C	0	1	2	3	4	5	6	7	8	9	10	°C
						Thermoelectric Voltage in Millivolts						
-270	-6.258											-270
-260	-6.232	-6.236	-6.239	-6.242	-6.245	-6.248	-6.251	-6.253	-6.255	-6.256	-6.258	-260
-250	-6.180	-6.187	-6.193	-6.198	-6.204	-6.209	-6.214	-6.219	-6.223	-6.228	-6.232	-250
-240	-6.105	-6.114	-6.122	-6.130	-6.138	-6.146	-6.153	-6.160	-6.167	-6.174	-6.180	-240
-230	-6.007	-6.017	-6.028	-6.038	-6.049	-6.059	-6.068	-6.078	-6.087	-6.096	-6.105	-230
-220	-5.888	-5.901	-5.914	-5.926	-5.938	-5.950	-5.962	-5.973	-5.985	-5.996	-6.007	-220
-210	-5.753	-5.767	-5.782	-5.795	-5.809	-5.823	-5.836	-5.850	-5.863	-5.876	-5.888	-210
-200	-5.603	-5.619	-5.634	-5.650	-5.665	-5.680	-5.695	-5.710	-5.724	-5.739	-5.753	-200
-190	-5.439	-5.456	-5.473	-5.489	-5.506	-5.523	-5.539	-5.555	-5.571	-5.587	-5.603	-190
-180	-5.261	-5.279	-5.297	-5.316	-5.334	-5.351	-5.369	-5.387	-5.404	-5.421	-5.439	-180
-170	-5.070	-5.089	-5.109	-5.128	-5.148	-5.167	-5.186	-5.205	-5.224	-5.242	-5.261	-170
-160	-4.865	-4.886	-4.907	-4.928	-4.949	-4.969	-4.989	-5.010	-5.030	-5.050	-5.070	-160
-150	-4.648	-4.671	-4.693	-4.715	-4.737	-4.759	-4.780	-4.802	-4.823	-4.844	-4.865	-150
-140	-4.419	-4.443	-4.466	-4.489	-4.512	-4.535	-4.558	-4.581	-4.604	-4.626	-4.648	-140
-130	-4.177	-4.202	-4.226	-4.251	-4.275	-4.300	-4.324	-4.348	-4.372	-4.395	-4.419	-130
-120	-3.923	-3.949	-3.975	-4.000	-4.026	-4.052	-4.077	-4.102	-4.127	-4.152	-4.177	-120
-110	-3.657	-3.684	-3.711	-3.738	-3.765	-3.791	-3.818	-3.844	-3.871	-3.897	-3.923	-110
-100	-3.379	-3.407	-3.435	-3.463	-3.491	-3.519	-3.547	-3.574	-3.602	-3.629	-3.657	-100
-90	-3.089	-3.118	-3.148	-3.177	-3.206	-3.235	-3.264	-3.293	-3.322	-3.350	-3.379	-90
-80	-2.788	-2.818	-2.849	-2.879	-2.910	-2.940	-2.970	-3.000	-3.030	-3.059	-3.089	-80
-70	-2.476	-2.507	-2.539	-2.571	-2.602	-2.633	-2.664	-2.695	-2.726	-2.757	-2.788	-70
-60	-2.153	-2.186	-2.218	-2.251	-2.283	-2.316	-2.348	-2.380	-2.412	-2.444	-2.476	-60
-50	-1.819	-1.853	-1.887	-1.920	-1.954	-1.987	-2.021	-2.054	-2.087	-2.120	-2.153	-50
-40	-1.475	-1.510	-1.545	-1.579	-1.614	-1.648	-1.683	-1.717	-1.751	-1.785	-1.819	-40
-30	-1.121	-1.157	-1.192	-1.228	-1.264	-1.299	-1.335	-1.370	-1.405	-1.440	-1.475	-30
-20	-0.757	-0.794	-0.830	-0.867	-0.904	-0.940	-0.976	-1.013	-1.049	-1.085	-1.121	-20
-10	-0.383	-0.421	-0.459	-0.496	-0.534	-0.571	-0.608	-0.646	-0.683	-0.720	-0.757	-10
0	0.000	-0.039	-0.077	-0.116	-0.154	-0.193	-0.231	-0.269	-0.307	-0.345	-0.383	0
0	0.000	0.039	0.078	0.117	0.156	0.195	0.234	0.273	0.312	0.352	0.391	0
10	0.391	0.431	0.470	0.510	0.549	0.589	0.629	0.669	0.709	0.749	0.790	10
20	0.790	0.830	0.870	0.911	0.951	0.992	1.033	1.074	1.114	1.155	1.196	20
30	1.196	1.238	1.279	1.320	1.362	1.403	1.445	1.486	1.528	1.570	1.612	30
40	1.612	1.654	1.696	1.738	1.780	1.823	1.865	1.908	1.950	1.993	2.036	40
50	2.036	2.079	2.122	2.165	2.208	2.251	2.294	2.338	2.381	2.425	2.468	50
60	2.468	2.512	2.556	2.600	2.643	2.687	2.732	2.776	2.820	2.864	2.909	60
70	2.909	2.953	2.998	3.043	3.087	3.132	3.177	3.222	3.267	3.312	3.358	70
80	3.358	3.403	3.448	3.494	3.539	3.585	3.631	3.677	3.722	3.768	3.814	80
90	3.814	3.860	3.907	3.953	3.999	4.046	4.092	4.138	4.185	4.232	4.279	90
100	4.279	4.325	4.372	4.419	4.466	4.513	4.561	4.608	4.655	4.702	4.750	100
110	4.750	4.798	4.845	4.893	4.941	4.988	5.036	5.084	5.132	5.180	5.228	110
120	5.228	5.277	5.325	5.373	5.422	5.470	5.519	5.567	5.616	5.665	5.714	120
130	5.714	5.763	5.812	5.861	5.910	5.959	6.008	6.057	6.107	6.156	6.206	130
140	6.206	6.255	6.305	6.355	6.404	6.454	6.504	6.554	6.604	6.654	6.704	140
150	6.704	6.754	6.805	6.855	6.905	6.956	7.006	7.057	7.107	7.158	7.209	150
160	7.209	7.260	7.310	7.361	7.412	7.463	7.515	7.566	7.617	7.668	7.720	160
170	7.720	7.771	7.823	7.874	7.926	7.977	8.029	8.081	8.133	8.185	8.237	170
180	8.237	8.289	8.341	8.393	8.445	8.497	8.550	8.602	8.654	8.707	8.759	180
190	8.759	8.812	8.865	8.917	8.970	9.023	9.076	9.129	9.182	9.235	9.288	190