UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
JANUARY 2017 SEMESTER

COURSE : **ECB4223 – INDUSTRIAL AUTOMATION AND CONTROL SYSTEMS**

DATE : **29TH APRIL 2017 (SATURDAY)**

TIME : **2.30 PM – 5.30 PM (3 hours)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions from the Question Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Show clearly steps taken in arriving at the solutions and indicate **ALL** assumption.
5. Do not open this Question Booklet until instructed.

Note : There are **THIRTEEN (13)** pages in this Question Booklet including the cover page and appendix.

1. a. Discuss the terms accuracy and precision in the context of industrial instrumentation and measurement and how both can be determined.

[6 marks]

b. **TABLE Q1** shows the calibration data for a pressure transmitter after 3 years and subsequently after 5 years in service. Both data were recorded before any adjustments were made. The operating range for the pressure transmitter is 0 – 50 kPa.

TABLE Q1

Time	**3 years in service**			**5 years in service**		
Trial	**1**	**2**	**3**	**1**	**2**	**3**
0%	2	7	3	18	23	19
25%	19	24	20	30	36	24
50%	37	36	41	44	35	41
75%	58	53	54	49	43	58
100%	69	70	72	55	63	62

As an instrument engineer you are required to provide feedback and recommendation to your superior on the performance of this flow meter based on its accuracy, precision and type of errors.

[8 marks]

c. An instrument engineer has been given a task to select a level measuring instrument for a cylindrical tank. The tank contains a pure, foamy, turbulent petrochemical liquid with a specific gravity of 0.85. Compare the suitability of the measuring technique between capacitance and ultrasonic.

[6 marks]

2. a. A thermistor is placed in a 100 °C environment and its resistance measured as 22 kΩ. The material constant, β, for this thermistor is 3650 K. If the thermistor is then used to measure a particular temperature and its resistance is measured as 350 Ω, calculate the temperature of the thermistor.

[4 marks]

b. An RTD forms one arm of a Wheatstone bridge as shown in **FIGURE Q2b**. The RTD is used to measure a constant temperature, with the bridge operated in a balanced mode. The RTD has a resistance of 25 Ω at a temperature of 20 °C and the thermal coefficient of resistance, α is 0.003925 °C^{-1}. The value of resistance R_3 and R_2 is the same, while R_1 must be set to 45 Ω to balance the bridge circuit.

Determine the temperature of the RTD and discuss the limitations of this technique as compared to thermocouples in measuring temperature.

[8 marks]

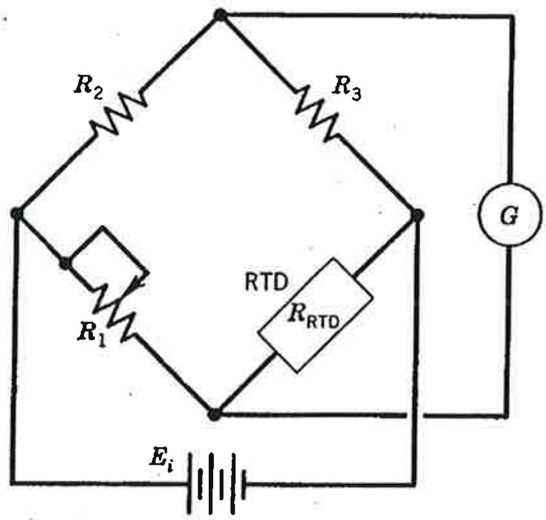


FIGURE Q2b

c. A digital voltmeter is being used to measure the output voltage, v_o from an iron-constantan thermocouple, as shown in **FIGURE Q2c.**

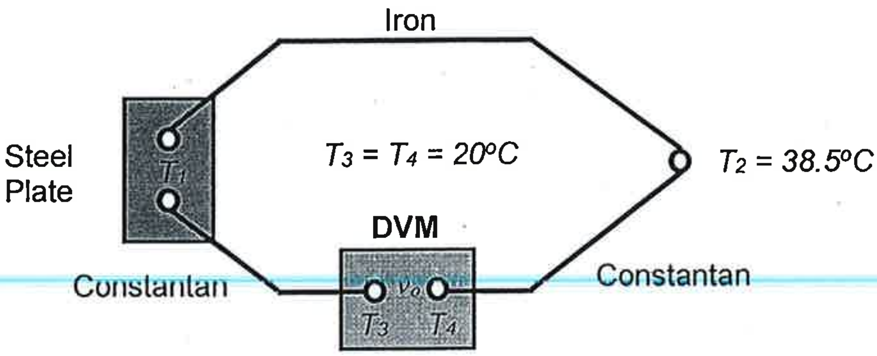


FIGURE Q2c

i. Determine the output voltage v_o indicated by the digital voltmeter, if the temperature at the measuring junction T_1 is 217.5 °C.

[3 marks]

ii. If the digital voltmeter reading changes to 11.758 mV, calculate the new temperature at T_1.

[3 marks]

iii. Does the separation of measuring point at the steel plate influence the measurement of T_1? State any assumptions made.

[2 marks]

3. a. **FIGURE Q3** shows piping and instrument diagram (P&ID) for a section of a process to control pressure of liquid in a closed tank.

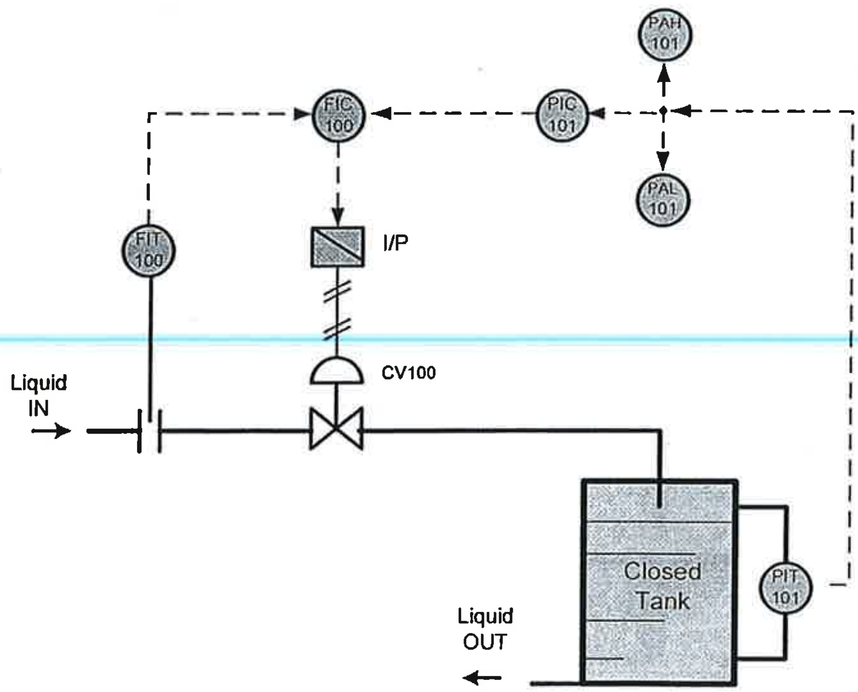


FIGURE Q3

i. Design a loop drawing for the system, assuming that the signals in the loops are 4 to 20 mA, and 3 to 15 psi. Include any appropriate instrument(s) if necessary.

[7 marks]

ii. If the control loops in **FIGURE Q3** are to be upgraded as part of a fieldbus system, propose the modification required at FIT100 and PIT101 that carry 4 to 20 mA signals.

[3 marks]

b. A fieldbus segment is to be powered by a power supply unit with a built-in power conditioner. A chicken foot topology is opted as its communication topology. The details below define the parameters of the equipment, devices and cable type.

- Fieldbus power supply/conditioner output is 24 V DC to the network.
- The cable used is 18 AWG and has a resistance of 22 ohms/km per conductor. The cable is 1.5 km long.
- Each device at the chicken foot draws 18 mA.
- Minimum voltage needed by a device is 9 V DC.

i. Analyze the total current that can be supplied at the chicken foot.

[3 marks]

ii. Evaluate the maximum number of devices that can be attached.

[2 marks]

iii. In another segment, a branch (bus to spur) topology with spur length of 20 m is connected 200 m away from the power conditioner. In addition to this segment, a chicken foot is connected 800 m away from the branch topology. If a total of seven devices is connected at the chicken foot with each having a spur length of 10 m, assess the voltage at the last device.

[5 marks]

4. a. Industrial automation is about the use of control systems, predominately computer based, to control industrial machinery and processes.

i. Evaluate how automatic control can be beneficial to large multinational production industries, as well as to small and medium scale industries (SMI).

[4 marks]

ii. Justify why Programmable logic controller (PLC) is an important element in modern industry.

[4 marks]

b. **FIGURE Q4b(i)** shows the actuators forming part of a production process used for bending sheet-metals into a specified shape. The double-acting-cylinder actuators A, B and D are to be energized individually by three different 5/2 way, electronic-actuated, spring-returned solenoid valves. The single-acting-cylinder actuator C is to be energized by a 3/2 way electronic-actuated, spring-returned solenoid valve. The sequence is to be initiated by a manual START pushbutton (PB) switch.

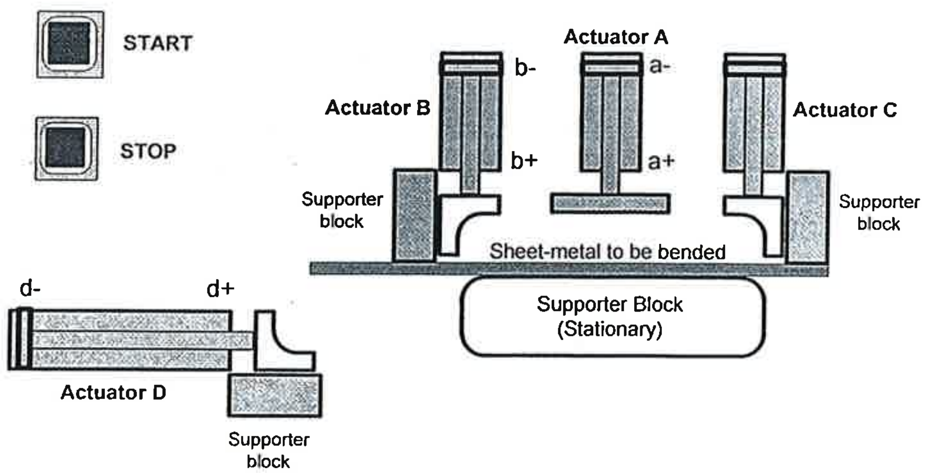


FIGURE Q4b(i)

The corresponding movement diagram for the operation is shown in **FIGURE Q4b(ii)** .

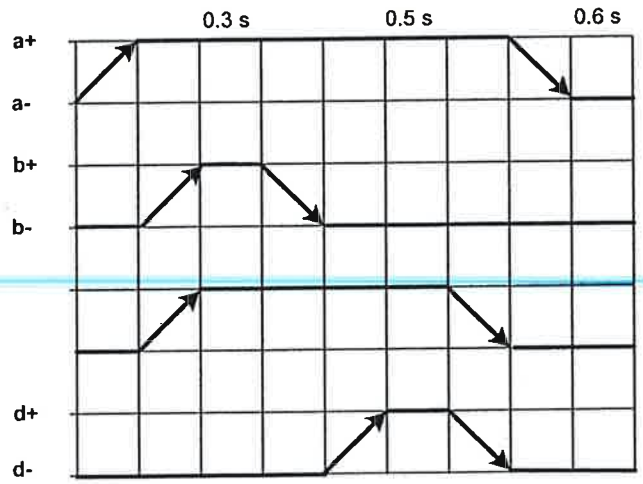


FIGURE Q4b(ii)

i. Derive the appropriate equations describing the SET and RESET functions of the sequence with the aid of the movement diagram.

[6 marks]

ii. Develop the corresponding ladder diagram for the required one-cycle working sequence.

[4 marks]

iii. Propose a ladder diagram for the working sequence to be repeated ten times. Assume that the sheet-metal to be bended is automatically loaded, and then released automatically at the end of each cycle.

[2 marks]

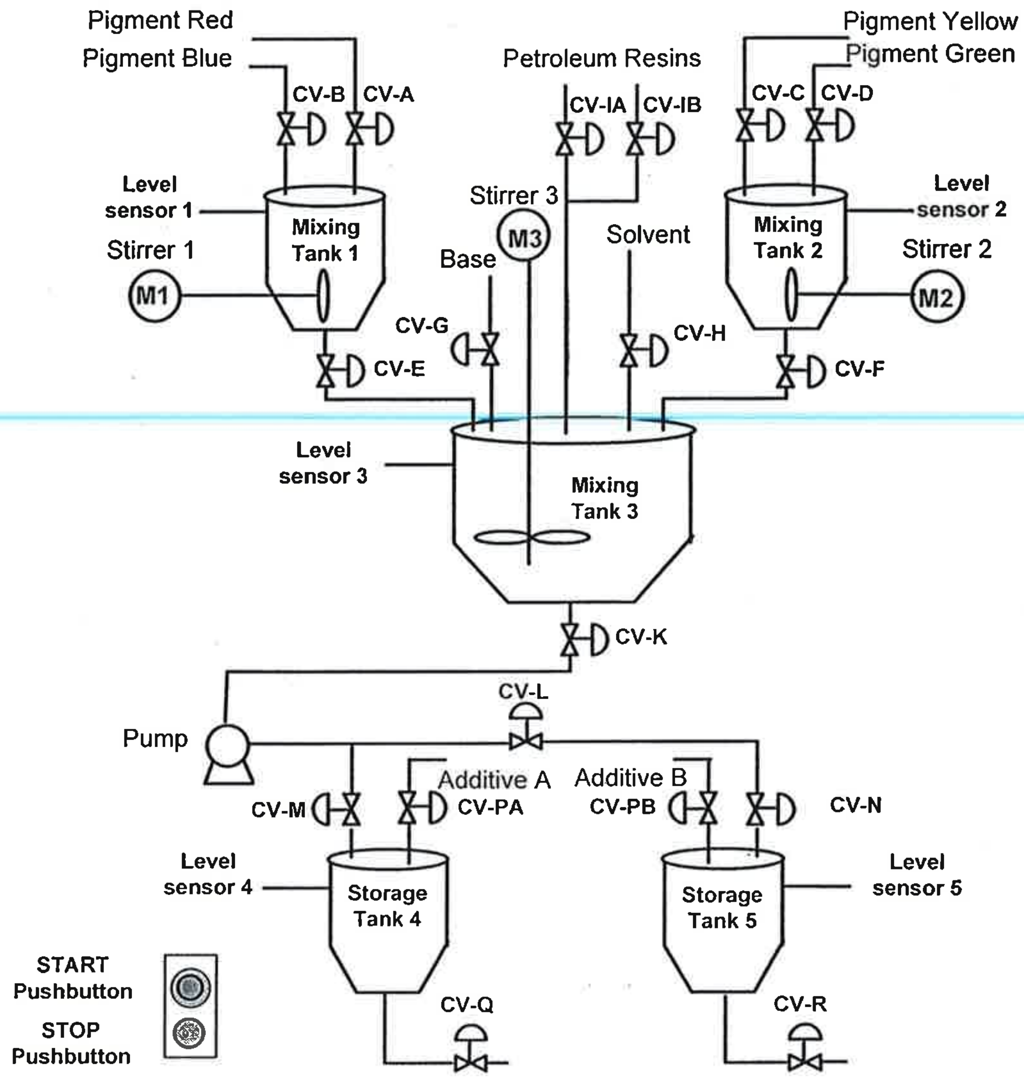
5. a. Sequential Function Chart (SFC) is one of the programming languages as specified in the IEC-1161-3 standard. Propose an SFC for an electro-pneumatic system with the following sequence: {(A+| delay 1.5 sec |A-) x 3}. The actuator is activated by a 5/2 way, electronic-actuated, electronic-returned solenoid valve. The sequence is to be initiated by a pushbutton (PB) switch.

[10 marks]

b. **FIGURE Q5b(i)** shows a paint product processing operation, which needs to be controlled by a Programmable logic controller (PLC). During the process, certain pigments, solvent, resins, paint-base and additives are mixed together in some appropriate quantities according to the following:

- The Stirrer 1, that mixes the Pigment Red and Pigment Blue, is set for 1 minute. Stirrer 1 is activated by Level sensor 1.
- The Stirrer 2, that mixes the Pigment Yellow and Pigment Green, is set for 1 minute. Stirrer 2 is activated by Level sensor 2.
- The Stirrer 3, that mixes the pigments, base, resins and solvent, is set for 3 minutes. Stirrer 3 is activated by Level sensor 3.
- The product will undergo an enhancement process (adding an additive (anti-fungal) based on type of surface materials) in tanks 4 and 5 for product classification. Both the level sensors 4 and 5 are set at 1 m.

The required sequence is to be initiated by a manual START pushbutton switch. The event diagram for the required sequence of events for the batch processing to be completed for one-cycle is shown in **FIGURE Q5b(ii)**.



Pigment Red
Pigment Blue
CV-B
CV-A
Petroleum Resins
CV-IA
CV-IB
Pigment Yellow
Pigment Green
CV-C
CV-D
Level sensor 1
Mixing Tank 1
Stirrer 1
M1
Stirrer 3
M3
Base
Solvent
Mixing Tank 2
Level sensor 2
Stirrer 2
M2
CV-G
CV-H
CV-E
CV-F
Level sensor 3
Mixing Tank 3
CV-K
CV-L
Pump
Additive A
Additive B
CV-M
CV-PA
CV-PB
CV-N
Level sensor 4
Storage Tank 4
Storage Tank 5
Level sensor 5
START Pushbutton
STOP Pushbutton
CV-Q
CV-R

FIGURE Q5b(i)

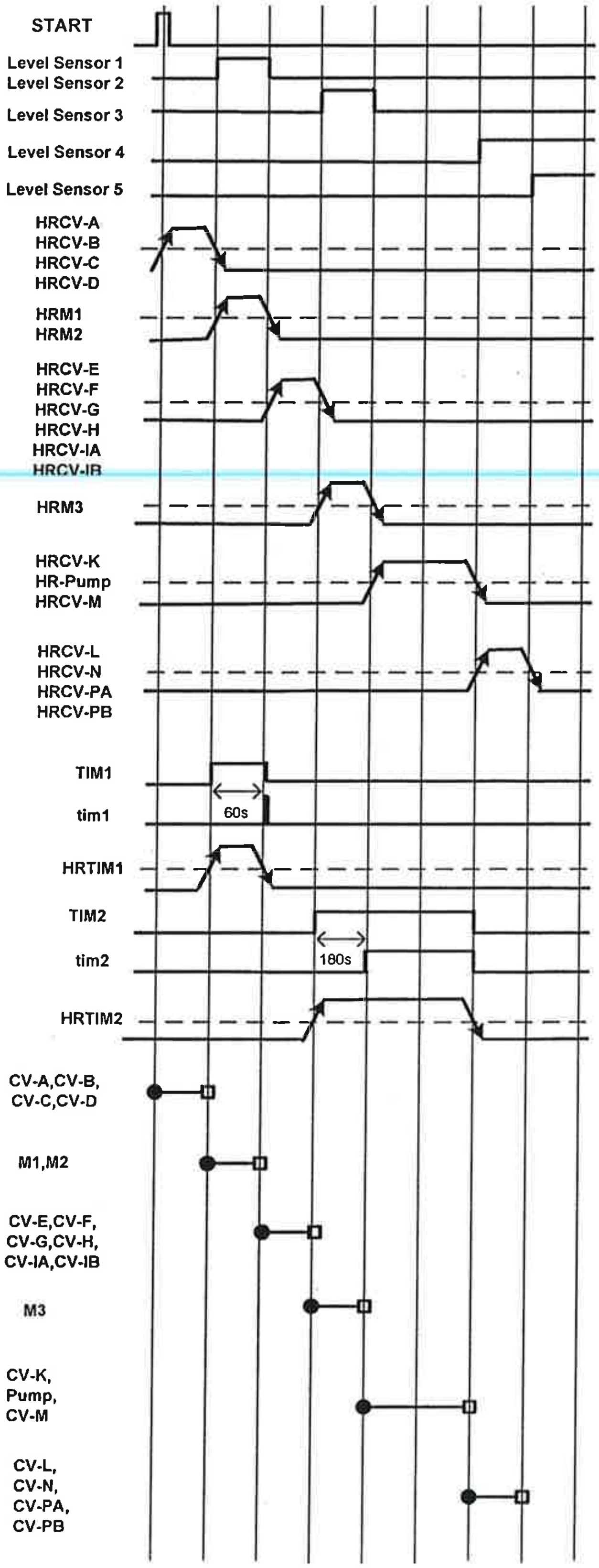


FIGURE Q5b(ii)

i. Referring to the events diagram depicted in **FIGURE Q5b(ii)**, design a ladder diagram to produce the required sequence of events for the system. The design should include the appropriate Boolean equations related to the events diagram.

[8 marks]

ii. The sequence is to be terminated automatically once both the storage tanks 4 and 5 have been filled with the final products. Propose the 'reset condition' for the START condition by incorporating this requirement.

[2 marks]

- END OF PAPER –

APPENDIX I

Type T Thermocouple (Copper-Constantan)
Reference Thermoelectromotive Force Table

Unit: μV

Temp. (°C)	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	Temp. (°C)
-200	-5 603	-5 753	-5 889	-6 007	-6 105	-6 181	-6 232	-6 258			-200
-100	-3 378	-3 656	-3 923	-4 177	-4 419	-4 648	-4 865	-5 069	-5 261	-5 439	-100
0	0	- 383	- 757	-1 121	-1 475	-1 819	-2 152	-2 475	-2 788	-3 089	0
Temp. (°C)	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**Temp. (°C)**
0	0	391	789	1 196	1 611	2 035	2 467	2 908	3 357	3 813	0
100	4 277	4 749	5 227	5 712	6 204	6 702	7 207	7 718	8 835	8 757	100
200	9 286	9 820	10 360	10 905	11 456	12 011	12 572	13 137	13 707	14 281	200
300	14 860	15 443	16 030	16 621	17 217	17 816	18 420	19 027	19 638	20 252	300
400	20 869										400

Remark: Temperature of reference junction is 0oC.
When temperature of reference junction is 20oC, substract 789 μV from the value given in the above table.

Type J Thermocouple (Iron-Constantan)
Reference Thermoelectromotive Force Table

Unit: μV

Temp. (oC)	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	Temp. (oC)
-200	-7 890	-8 096									-200
-100	-4 632	-5 036	-5 426	-5 801	-6 159	-6 499	-6 821	-7 122	-7 402	-7 659	-100
0	0	-501	-995	-1 481	-1960	-2 431	-2 892	-3 344	-3 785	-4 215	0
Temp. (oC)	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**Temp. (oC)**
0	0	507	1 019	1 536	2 058	2 585	3 115	3 649	4 186	4 725	0
100	5 268	5 812	6 359	6 907	7 457	8 008	8 560	9 113	9 667	10 222	100
200	10 777	11 332	11 887	12 42	12 998	13 553	14 108	14 663	15 217	15 771	200
300	16 325	16 879	17 432	17 985	18 537	19 089	19 640	20 192	20 743	21 295	300
400	21 846	22 397	22 949	23 501	24 054	24 607	25 161	25 716	26 272	26 829	400
500	27 388	27 949	28 511	29 075	29 642	30 210	30 782	31 356	31 933	32 513	500
600	33 096	33 683	34 273	34 867	35 464	36 066	36 671	37 280	37 893	38 510	600
700	39 130	39 754	40 382	41 013	41 647	42 283	42 922	43 563	44 207	44 852	700
800	45 498	46 144	46 790	47 434	48 076	48 716	49 354	49 989	50 621	51 249	800
900	51 875	52 496	53 115	53 729	54 341	54 948	55 553	56 155	56 753	57 349	900
1000	57 942	58 533	59 121	59 708	60 293	60 876	61 459	62 039	62 619	63 199	1000
1100	63 777	64 355	64 933	65 510	66 987	66 664	67 240	67 815	68 390	68 964	1100
1200	69 536										1200

Remark: Temperature of reference junction is 0°C.
When temperature of reference junction is 20°C, substract 1 019 μV from the value given in the above table.