Contestant number: Submission time:

Number of points of the complex project:

Task 1 (5b): Task 2 (2b): Task 3 (10b): Task 4 (3b): Task 5 (20b): Bonus:

Achieved parameters: Input voltage at 0°C 100°C

A complex project in the field of electronics

In this part, your task is to analyze the electronic circuit that you will build this year at the ZENIT in Electronics nationwide round as part of the practical part. The aim is to test the ability to understand the task, the ability of theoretical and practical knowledge and the creativity of the contestants.

Do all sketches and calculations directly in the assignment text. Results without calculation, justification and without correct physical units will not be recognized.

The use of external assistance is prohibited for the competition. Violation of the regulation will be penalized by disqualification.

Task 1: Platinum Resistance Temperature Sensor (5 points)

Resistive temperature sensors (RTD) based on platinum resistors are widely used from measurements in industrial processes to the most precise metrology applications. It is a resistor made of ultrapure platinum or a platinum alloy, which has a precisely known temperature resistance characteristic. The most common type of model is the PT100 type, with a nominal value of R(0°C) = 100 Ω at a temperature of 0°C. Platinum sensors can be used in the temperature range of -200 to +850 °C, the most common applications of conventional sensors are in the range from -50 to +250 °C.

For the needs of this task, let's consider the case where the resistance of the sensor will be a simplified linear function (directly proportional to) the temperature.

$$(t) = (0°\mathrm{C})\ [1 + A\ t] \quad (1)$$

Where A = 3.850x10-3 1/°C is the sensitivity sensor, it is the temperature expressed in °C.
Calculate the resistance value of the PT100 sensor for the following temperatures

Temperature (°C)	Resistance	Value (Ω)
-50	$R_{-50°C}$	
0	$R_{0°C}$	
22	$R_{22°C}$	
100	$R_{100°C}$	
250	$R_{250°C}$	

Task 2: Self-heating sensor (2 bodies)

Electrically, a resistive temperature sensor is nothing more than a resistor component. With the correct design of the measuring circuit and a high-quality sensor, it can measure the temperature with an accuracy of 0.01 °C. But during use, the designer can completely destroy its inaccuracies. For the purposes of this task, let's consider a PT100 sensor, in the version for surface mounting, chip size 1206. The sensor is placed in an environment with a temperature of 0 °C.

An inexperienced designer uses an excitation current of I = 5.0 mA.
Calculate the magnitude of the power loss that will be delivered to the sensor

$P_{STRATOV}$ =

Calculate the temperature rise of the chip, due to self-heating of this resistor, if the datasheet indicates the thermal resistance of the 1206 case Rth1206 = 700 K/W. Self-heating will cause temperature measurement error and we need to minimize it.

Δt =

Task 3: Exciting the PT100 sensor (10 points)

One of the ways to measure with the PT100 sensor is to excite it with a constant current of a known value and measure the voltage drop. Ohm's law is then used to calculate the resistance of the sensor.

Realization of the constant current source operating network is shown in Figure 1. The non-inverting input OZ is connected to the reference voltage source UREF. OZ excites the transistor, which controls the amount of current flowing from the source, through the load (R1) and the reference resistor v RREF.

The basic function of an operational amplifier with built-in feedback is that the amplifier will always maintain a zero difference between the non-inverting and inverting inputs, U+ = U-. Ideally, both voltages will be exactly the same. When calculating, mark important facts in the diagram.

Calculate the magnitude of the current I in Figure 1 if the magnitude of the reference voltage is U_{REF} = 0.5 V

I =

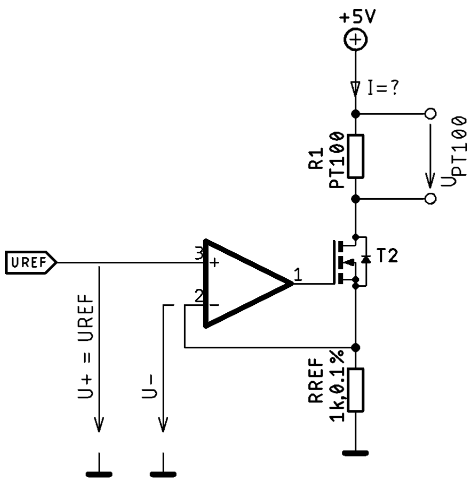


Figure 1: Realization of a constant current source using an operational amplifier.

Task 4: Temperature measurement using a resistance temperature sensor (3 points)

We want to construct a thermometer with a PT100 sensor that will measure the temperature in the range of 0 to +100 °C with a resolution of 0.01 °C. What will be the technical requirements for the resistance measurement circuit?

The minimum value of the measured resistance

R_{MIN} =

The maximum value of the measured resistance

R_{MAX} =

Required resistance measurement resolution (in Ohms)

resolution =

Task 5: Design and implement a thermometer with a PT100 sensor (20 points)

Design and implement a thermometer with a PT100 sensor and analog voltage output on the contact field. Design the connection, calculate the values of the elements, document it in detail and implement it on the contact field. Suggest how to set up and test the circuit.

You will submit the project to the expert evaluation committee, and together you will verify the accuracy.

The technical requirements for the circuit are as follows:

1. Used sensor: RTD type PT100
2. Guaranteed temperature measurement range of 0 to +100 °C
3. Sensor current 500 μA to 1 mA

Category B

4. The measured value is read/displayed on a needle voltmeter with a range of 1 V, or a digital multimeter set to measure voltage on a range of 1 V. The output voltage must be as directly proportional as possible to the measured temperature. The value before 0 °C must be 0 V, before +100 °C 1.00 V.
5. Supply voltage +/-2.5 V (it is defined by the operational amplifier used)
6. **Bonus:** The circuit will have the ability to set and reset the offset of the temperature measurement (and op amps) so that the 100,000 Ω (0°C) test resistor connection is as close to 0V as possible.

Category A

4. The measured value is read/displayed on a needle voltmeter with a measurement range of 10 V, or a digital multimeter set to a voltage range of 10 V. The output voltage must be directly proportional to the measured temperature as much as possible. The value before 0 °C must be 0 V, before +100 °C 10.00 V.
5. Supply voltage +/-15 V (it is used with operational amplifier).
6. The circuit must have the ability to set and reset the offset of the temperature measurement (and op amps) so that when the 100,000 Ω (0°C) test resistor is connected, the output voltage is as close to 0V as possible.

List of material available to you:

Integrated circuits:

Category A:

MCP6002-E/P Dual , rail to rail operational amplifier, offset ±4.5 mV, supply 1.8 to 5.5V, GBW 1 MHz
NE5532P Dual operational amplifier, offset ±4 mV, supply ±5 to ±15 V, GBW 10 MHz

Category B:

MCP619-I/P Quad, rail to rail operational amplifier, offset ±150 μV, supply 2.3 to 5.5 V, GBW 190 kHz
MCP617-I/P Dual, rail to rail operational amplifier, offset ±150 μV , power supply 2.3 to 5.5 V, GBW 190 kHz

Discrete components (category A, category B):

BC557A Transistor PNP bipolar. 50V/100mA/500mW
BC547A Transistor NPN bipolar. 50V/100mA/500mW
1N4148-TAP LED diode 100V/300mA
LTL2R3KRD-EM LED 5mm red. Operating current 2mA
LTL2R3KGD-EM LED 5mm green. Operating current 2mA

Passive components (category A, category B):

Reference resistor 100 Ω, tolerance 0.1%, very low temperature coefficient 10 ppm/°C
E12 series resistors, standard tolerance 1%, values 10Ω to 10 MΩ

Ceramic capacitors: 1n, 2n2, 4n7, 10n, 22n, 47n, 100n, tolerance typically ±10%
ceramic: 220n, 470n, tolerance typically -80...+22%
electrolytic: 1μF, 2.2μF, 4.7μF, 10μF, 22μF, 47μF, tolerance typically ±20%
electrolytic: 100μF, 220μF, tolerance typically ±20%

Instructions

Temperature measurement using resistive sensors is a low to medium value resistance measurement task. From electrical engineering, you know different methods of measuring resistance, for example Volt-Ampere, comparison, using bridges and others.

From the point of view of a very simple theoretical analysis and easy implementation, we recommend using the Wheatstone bridge measurement. But you can also use another method. You have at your disposal a known resistor of exact value, with a low temperature coefficient, which can serve as a reference R_{ref}. The temperature sensor is represented by the resistor R_{rtd}.

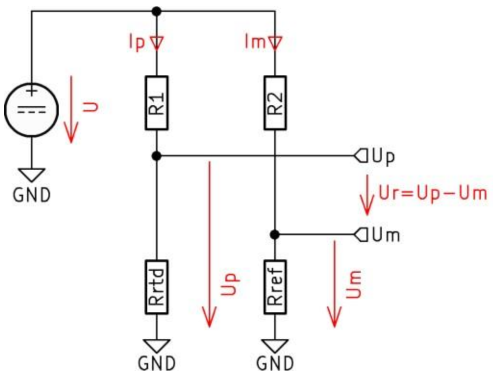
The voltage on the diagonal of the Ur bridge will somehow depend on the resistance of the resistive temperature sensor, and therefore on the temperature. Write/derive relations for currents Ip, Im, voltages Up, Um, Ur.

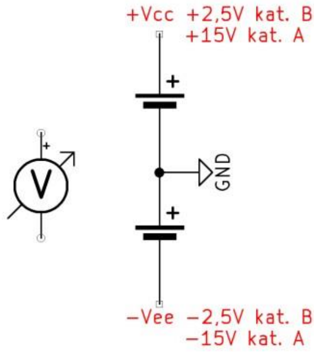
Numerically express their values for the two extreme temperatures of 0°C and 100°C. You will get an idea of the magnitude of the voltage that will need to be processed for the resulting indication. It is likely that the Ur obtained directly will not be good enough for a direct voltmeter indication as specified and you will need to use an amplifier. Several useful connections with operational amplifiers and their most important parameters can be found in the aids at the end of the assignment.

Figure 2: Wheatstone bridge with unknown resistor Rrtd and reference resistor Rref

Calculations (continue on the back if necessary):

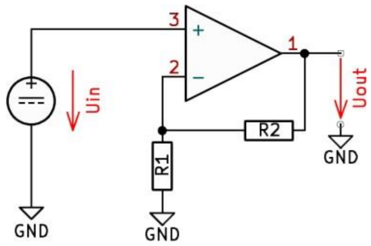
Full wiring diagram and detailed bill of materials
(number the integrated circuit factories)





Utilities

Amplifier type 1:



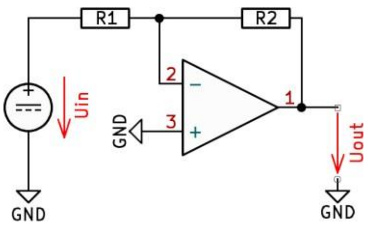
Input voltage: $U_{OUT} = U_{IN}\left(1 + \frac{R_2}{R_1}\right)$

Input resistance: $R_{IN}\,\infty$

Notes:

The maximum output current of the operational amplifier is hundreds of microamps Required active when selecting feedback resistors.

Amplifier type 2:



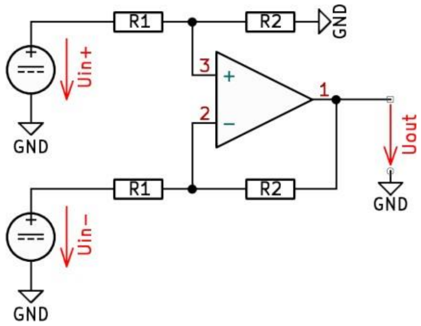
Input voltage: $U_{OUT} = -U_{IN}\frac{R_2}{R_1}$

Input resistance: $R_{IN} = R_1$

Notes:

The maximum output current of the operational amplifier is hundreds of microamps Required active when selecting feedback resistors.. The input resistance is not infinite.

Amplifier type 3:



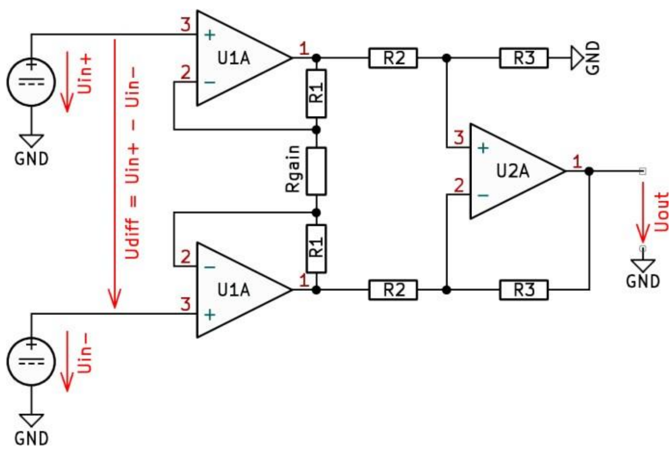
Input voltage: $U_{OUT} = (U_{IN+} - U_{IN-})\frac{R_2}{R_1}$

Input resistance: $R_{IN+} = R_1 + R_2$ $R_{IN-} = R_1$

Notes:

The maximum output current of the operational amplifier is hundreds of microamps Required active when selecting feedback resistors.. The input resistance is not infinite. For proper function, it is important that the values of both resistors R1 are as equal as possible. The same applies to resistor R2.

Amplifier type 4:



Input voltage:

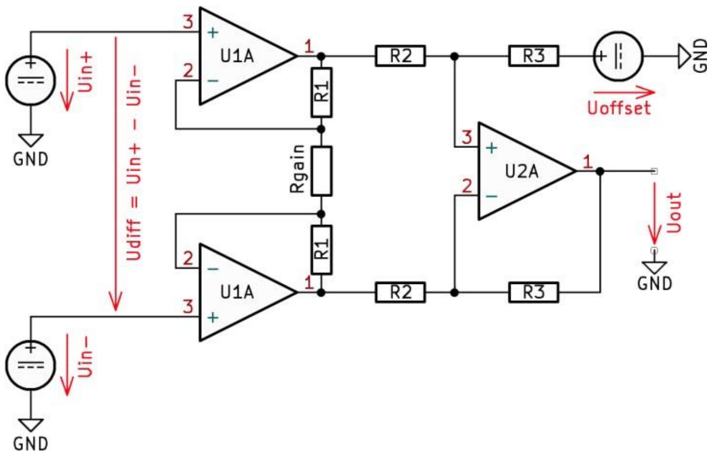
$U_{OUT} = (U_{IN+} - U_{IN-})\left(1 + \frac{2R_1}{R_{gain}}\right)\frac{R_3}{R_2}$

Input resistance: $R_{IN+} \approx \infty$ $R_{IN-} \approx \infty$

The maximum output current of the operational amplifier is hundreds of microamps Required active when selecting feedback resistors.. The input resistance is not infinite. For proper function, it is important that the values of both resistors within the pair of R1, R2 and R3 are as equal as possible. The standard 1% tolerance may not be enough.

In practice, it is reasonable to divide the required amplification between both stages – i.e. amplifier U1A/U1B which contributes a gain of $(1 + \frac{2R_1}{})$ and amplifier U2A which contributes a gain of $\frac{R3}{}$. Final delivery $Rgain$ $R2$ gain to the same value as can be achieved by keeping a single element R_{gain}.

Amplifier type 5, extension to add an offset:



Input voltage:

$$U_{OUT} = (U_{IN+} - U_{IN-})\left(1 + \frac{2R_1}{R_{gain}}\right)\frac{R_3}{R_2} + U_{OFFSET}$$

Input resistance: $R_{IN+} \approx \infty$ $R_{IN-} \approx \infty$

The connection has the same properties as the previous version (connection 4), but it allows adding the voltage UOFFSET to the v step. The function can be used, for example, to shift the zero or compensate the offset of the operational amplifiers used. The UOFFSET voltage source must have a low output impedance. If you use a resistance trimmer, it is advisable to include a tracker with an operational amplifier behind it.

TEXAS INSTRUMENTS

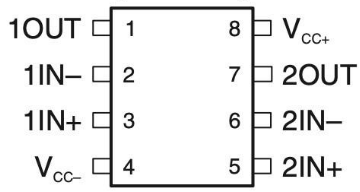
www.ti.com

NE5532, NE5532A, SA5532, SA5532A

SLOS075J – NOVEMBER 1979 – REVISED JANUARY 2015

6 Pin Configuration and Functions

NE5532, NE5532A . . . D, P, OR PS PACKAGE
SA5532, SA5532A . . . D OR P PACKAGE
(TOP VIEW)



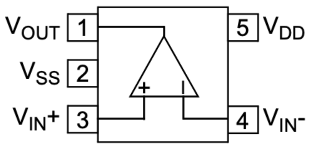
Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
1IN+	3	I	Noninverting input
1IN-	2	I	Inverting Input
OUT1	1	O	Output
2IN+	5	I	Noninverting input
2IN-	6	I	Inverting Input
2OUT	7	O	Output
VCC+	8	—	Positive Supply
VCC-	4	—	Negative Supply

Package Types

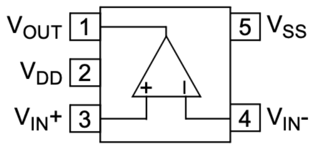
MCP6001

5-Lead SC70, SOT-23



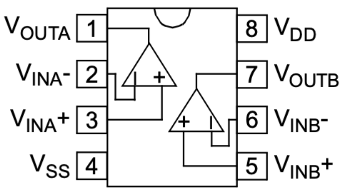
MCP6001R

5-Lead SOT-23



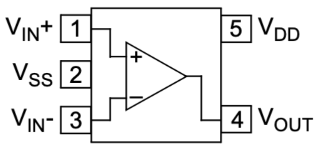
MCP6002

8-Lead PDIP, SOIC, MSOP



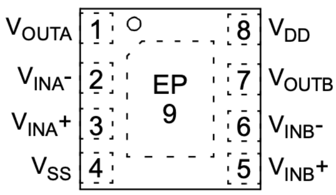
MCP6001U

5-Lead SOT-23



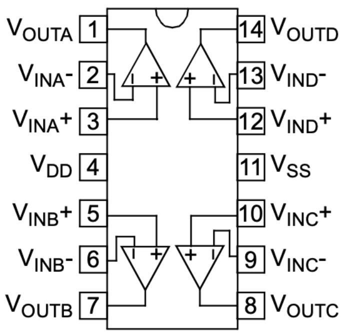
MCP6002

8-Lead 2x3 DFN*



MCP6004

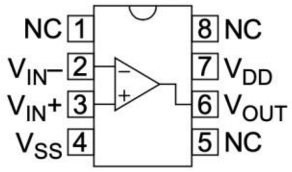
14-Lead PDIP, SOIC, TSSOP



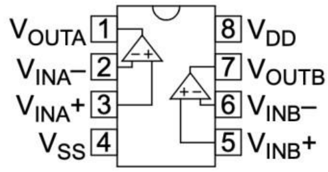
*Includes Exposed Thermal Pad (EP); see Table 3-1.

Package Types

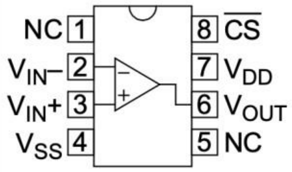
MCP616
PDIP, SOIC, MSOP



MCP617
PDIP, SOIC, MSOP



MCP618
PDIP, SOIC, MSOP



MCP619
PDIP, SOIC, TSSOP