LJ Technical Systems

An Introduction To Transducers And Instrumentation

Curriculum Manual IT02

Volume 1

DIGIAC

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The three wire resistance measuring circuit.

With some resistance transducer circuits, the transducer may be situated a relatively large distance from the bridge circuit, and hence the resistance of the connecting leads may be significant and could affect the results. For these situations the three wire connection arrangement is used.

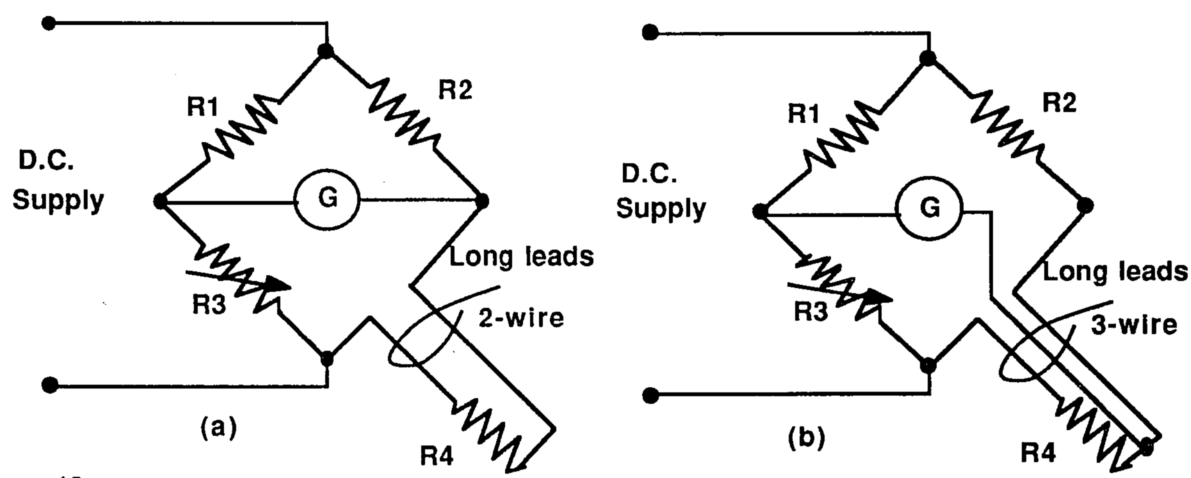


Figure 18

Fig 18 (a) shows the circuit with the transducer R4 situated remote from the bridge and connected via two wires. The resistance of these wires will be included in the measurement of R4.

Fig 18 (b) shows the three wire arangement. One of the wires to the transducer is now included in the R2 circuit and the other is in the R4 circuit. Both circuits will therefore be affected equally and the balance condition will not be affected.

The extra wire in the galvanometer circuit will have no effect at balance ,since there is no current flowing in it under this condition.

The DIGIAC 1750 Temperature Transducer Facilities.

Fig 25 shows the layout of the temperature transducer facilities of the DIGIAC 1750 unit.
The active transducers are contained within a clear plastic container which includes a heater.
In the case of the N.T.C. thermistors and the thermocouples, a separate unit is mounted outside the heated enclosure.

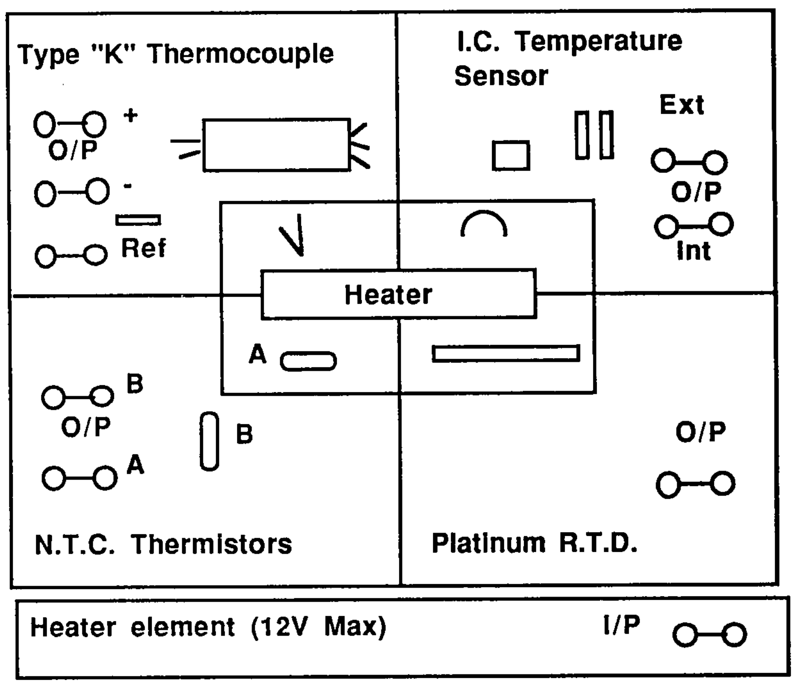


Figure 25

The I.C. Temperature Transducer.

This is an integrated circuit containing 16 transistors,9 resistors and 2 capacitors contained in a transistor type package.

The device reference number is LM 335 and it provides an output of 10mV/^{o}K. A measurement of the output voltage therefore indicates the temperature directly in ^{o}K.
e.g. At a temperature of 20^{o}C (293^{o}K) the output voltage will be 2.93V.

The circuit arangement provided with the DIGIAC 1750 unit is shown in Fig 26.

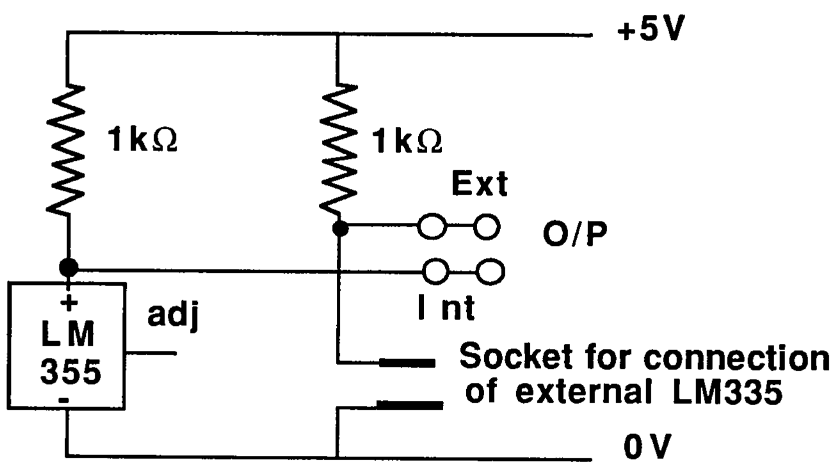


Figure 26

A 2-pin socket is provided for the connection of an external LM 335 unit if desired.
Note:- An LM 335 unit is mounted external to the heated enclosure and fitted in a heat sink with a type "K" thermocouple, its output being obtained from the "Ref" socket.

The output from this can be used as an indication of the ambient temperature outside the heated enclosure and that from the "Int" socket in Fig 26 indicates the temperature within the heated enclosure.

The output from the "Ref" socket does not give an accurate value of the room ambient temperature when the heater is in use, due mainly to heat passing along the baseboard by conduction from the heater. An LM 335 remotely mounted or some other method is necessary for accurate values of ambient temperature.

Exercise 8. The Characteristics of an LM 335 I.C. Temperature Transducer.

Equipment:-

1 LM 335 I.C. Temperature transducer
1 20V Digital voltmeter
Connecting leads.

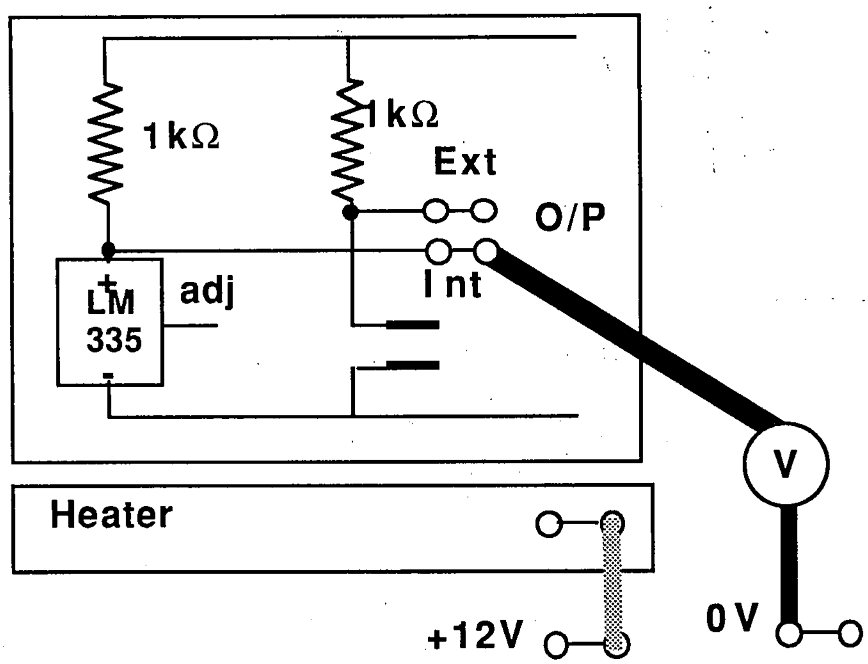


Figure 27

- Connect the voltmeter to the circuit as shown in Fig 27, switch the power supply ON and note the output voltage, this representing the temperature in °K.

- Now connect the +12V supply to the heater input socket and note the voltage reading every minute until the value stabilizes. Enter the values in Table 12.

Time (Mins)		0	1	2	3	4	5	6	7	8	9	10
Voltage (Volts)												
Temperature	°K											
	°C											

Table 12.

This exercise illustrates the characteristics of the LM 335 transducer, indicates the maximum temperature rise possible using the heater supplied at 12V and also indicates the time scale required for the unit to reach stable conditions.

Notes:

Exercise 9. Construction of a Digital Thermometer using the Facilities of the DIGIAC 1750

Equipment:-

1 LM 335 I.C. Temperature transducer
1 Buffer amplifier
1 10kΩ Carbon slider resistor
1 Amplifier #1
1 V/F Converter
1 Differentiator
1 3-Digit Counter/Timer

General considerations.

The output voltage of the LM 335 is of the order of 2.93V.
The V/F converter gives a frequency output of 1kHz/V
The digital display has 3 digits and is capable of counting a maximum of 600 counts/s.

Reducing the LM 335 output by a factor of 10 will give an output voltage of the order of 0.293V which will result in a frequency of 293Hz being obtained from the V/F converter and this value is within the counting capability of the counter. The buffer amplifier is used to minimise the loading on the LM 335.

The 10kΩ resistor and amplifier #1 are used to set the voltage amplification during the calibration of the assembly. The differentiator is used to modify the output waveform from the V/F converter and make it more suitable for the input to the counter/timer.

- The offset control of amplifier #1 must be set correctly first. You should be familiar with the procedure by now but ,to refresh your memory , the procedure is given again.

  With the power supply switched ON, connect amplifier #1 input to 0V and connect the output to the M.C.meter + and connect the meter - socket to 0V.

  With amplifier #1 fine gain set 1.0 and coarse gain set 10 adjust the offset control for approximate zero output and then set the coarse gain to 100 and adjust for zero output.

  Set amplifier coarse and fine gain controls to 1 and 0.1 respectively.

- Connect the circuit as shown in Fig 28, set the 10kΩ slider fully to the right, the differentiator time constant to 1s and the counter controls to "count" and 1s.

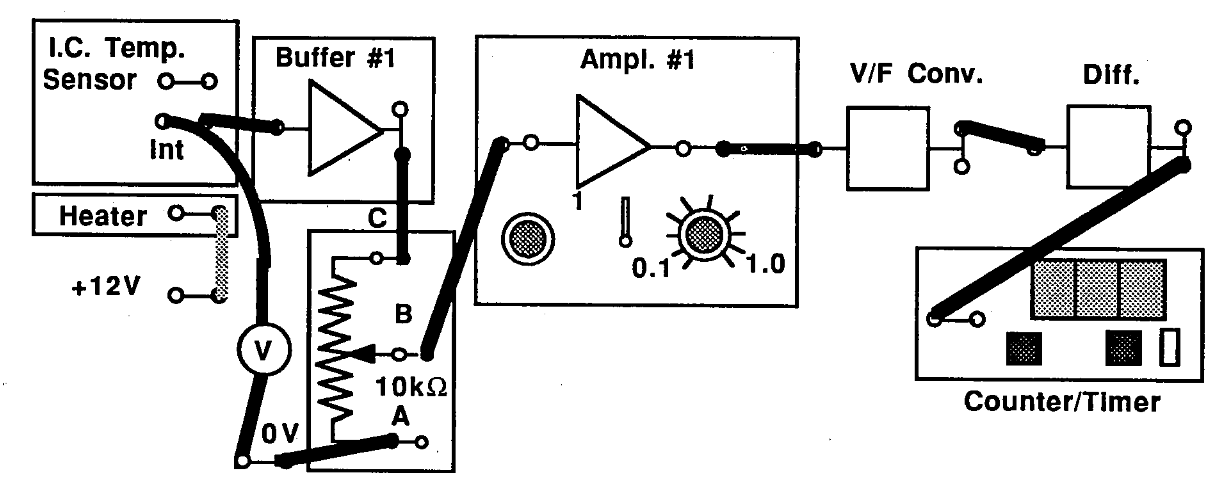


Figure 28

- Note the voltmeter reading and then press the "Reset" button of the counter and note the final displayed value.Compare this with the voltmeter reading.

    (a) If the displayed value exceeds the voltmeter reading,reduce the setting of the 10kΩ slider slightly and then press the reset button of the counter again and note the revised display. Compare this with the voltmeter reading. Repeat the process if necessary until the display and voltmeter readings are the same.

    (b) If the displayed value is less than the voltmeter reading, increase the "Fine" gain setting of amplifier #1 slightly and then press the "reset" button of the counter and note the revised display. Repeat the procedure as necesary until the display and voltmeter readings are the same.

The assembly should now be calibrated so that the 3-digit counter displays the temperature at the instant the reset button is pressed.

- Connect the 12V supply to the heater input, note the voltage indicated by the voltmeter, press the counter "reset" button and note the displayed value. Enter the values in Table 13.

- Repeat the process, noting the values of the voltmeter and counter displayed readings for comparison at intervals as the temperature increases. Enter the values in Table 13.

Voltmeter Reading									
Counter Display									

Table 13.

This exercise has illustrated the use of some of the other facilities available with the DIGIAC 1750 unit.

Do the readings compare ?

The readings may not be identical over the full range, but they will be sufficiently accurate to illustrate the basic principle. The accuracy depends on the accurate setting of the V/F converter.

The Platinum R.T.D. (Resistance Temperature Dependent) Transducer.

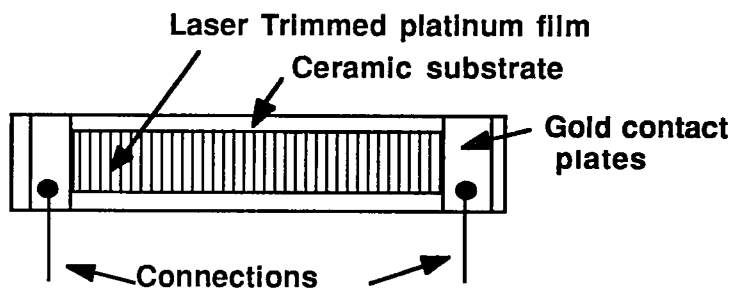


Figure 29

The construction of the platinum R.T.D. transducer is shown in Fig 29, consisting basically of a thin film of platinum deposited on a ceramic substrate and having gold contact plates at each end that make contact with the film.

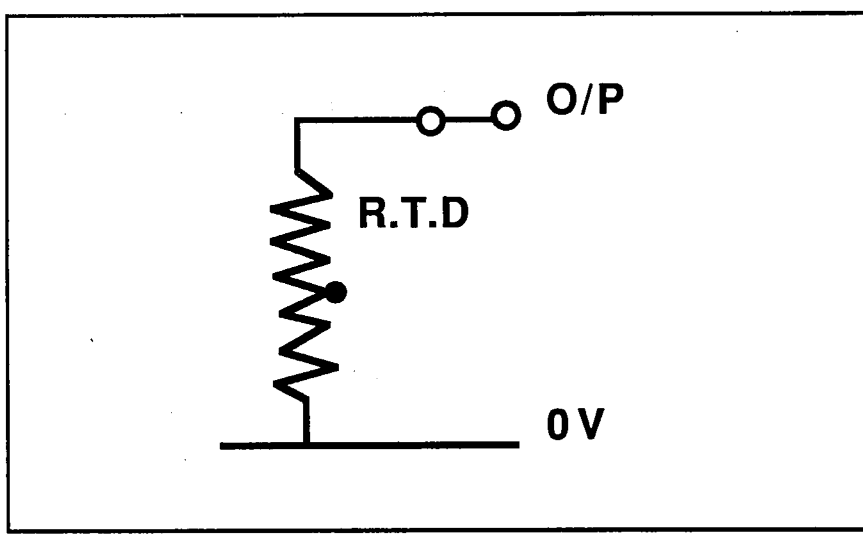
The platinum film is trimmed with a laser beam so that the resistance is 100Ω at 0°C.

The resistance of the film increases as the temperature increases, i.e. it has a positive temperature coefficient. The increase in resistance is linear, the relationship between resistance change and temperature rise being 0.385Ω/°C for the unit.

Rt = Ro + 0.385t
Where Rt = Resistance at temperature t°C
Ro= Resistance at 0°C = 100Ω

Normally, the unit would be connected to a D.C. supply via a series resistor and the voltage developed across the transducer is measured. The current flow through the transducer will then cause some self heating, the temperature rise due to this being of the order of 0.2°C /mW dissipated in the transducer.

The electrical circuit arrangement of the DIGIAC 1750 unit is as follows:-



Notes:

Exercise 10. The Characteristics of a Platinum R.T.D. Transducer.

Equipment:-

1 Platinum R.T.D. transducer
1 10kΩ Wirewound resistor
1 2/20V range Digital voltmeter
1 LM 335 I.C. temperature transducer .
Connecting leads.

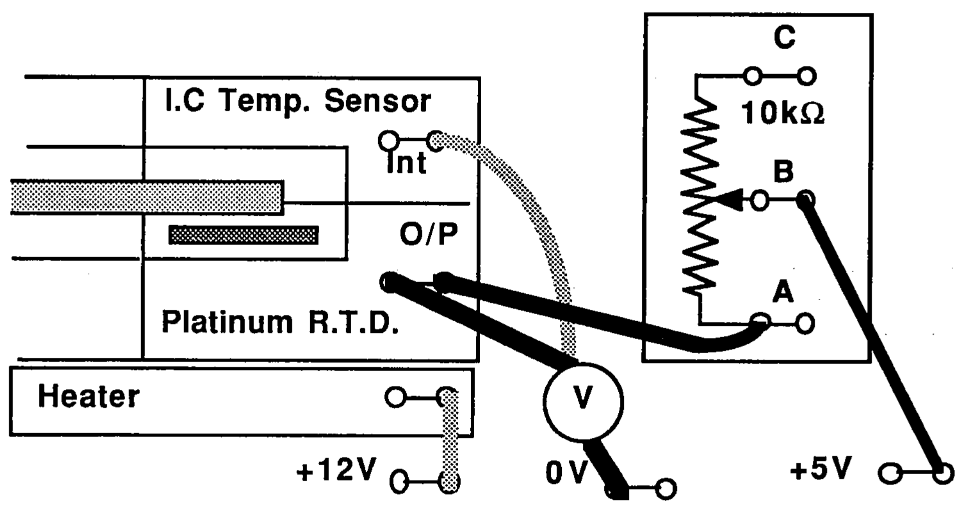


Figure 30

In this exercise we will connect the platinum R.T.D. in series with a high resistance to a D.C. supply and measure the voltage drop across it. Due to the small variation of resistance, the curr
ent change will be negligible and the voltage drop across the transducer will be directly proportional to its resistance.

- Connect the circuit as shown in Fig 30, with the voltmeter set to its 2V D.C. range.

- With the power supply switched ON, adjust the control of the 10kΩ resistor so that the voltage drop across the platinum R.T.D. is 0.108V as indicated by the digital voltmeter. This calibrates the platinum R.T.D. for an ambient temperature of 20°C, since the resistance of the R.T.D. at 20°C will be 108Ω.

  Note:- If the ambient temperature differs from 20°C, the voltage can be set to the correct value for this ambient temperature if desired.
  (1) Set the voltmeter to its 20V range and measure the output from the I.C. temperature transducer to obtain the ambient temperature in °K. Then °C = (°K - 273)
  (2) R.T.D. resistance = 100 + 0.385 x °C. Set the voltage drop across the R.T.D for this value.

- Now connect the +12V supply to the heater input and note the values of the voltage across the R.T.D.with the voltmeter set to its 2V range,(this representing the R.T.D. resistance) and the output voltage from the temperature transducer with the voltmeter set to its 20V range, (this representing the temperature of the R.T.D.).

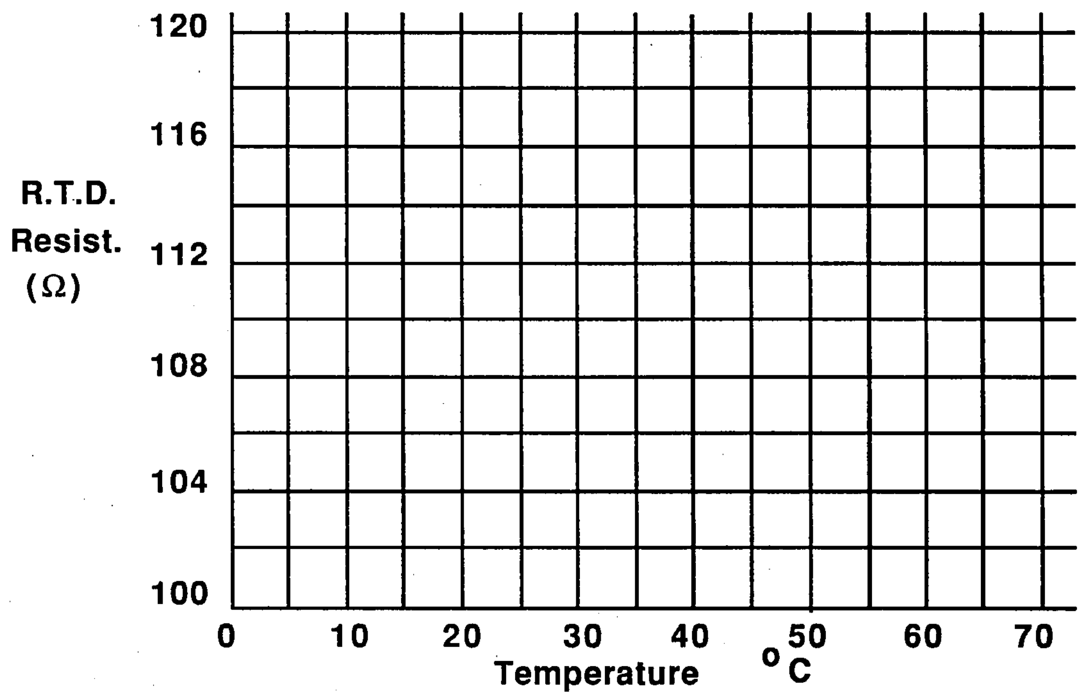
  Enter the values in Table 14.

- Repeat the readings at 1 minute intervals and enter the values in Table 14.

Time (minute)		0	1	2	3	4	5	6	7	8	9	10
R.T.D. Temperature	°K											
	°C											
R.T.D. Resistance												

Table 14.

Plot the graph of R.T.D. resistance against temperature on the axes provided.



Is the resistance/temperature characteristic linear ?

Is the resistance 100Ω at 0°C ?

During the exercise, the current flowing was of the order of1mA and the total circuit resistance was of the order of 5kΩ. The variation of 12Ω approx. in the R.T.D. transducer therefore had little effect on the circuit current and hence the voltage drop across it represented the resistance value reasonably accurately.

The current of 1mA in the R.T.D. represents a power of the order of 0.1mW dissipated in the R.T.D. so that the self heating effect would produce a temperature rise of 0.02°C which is negligible.

The N.T.C. (Negative Temperature Coefficient) Thermistor.

The construction of the N.T.C. thermistor is shown in Fig 31, consisting basically of an element made from sintered oxides of metals such as nickel, manganese and cobalt and with contacts made to each side of the element.

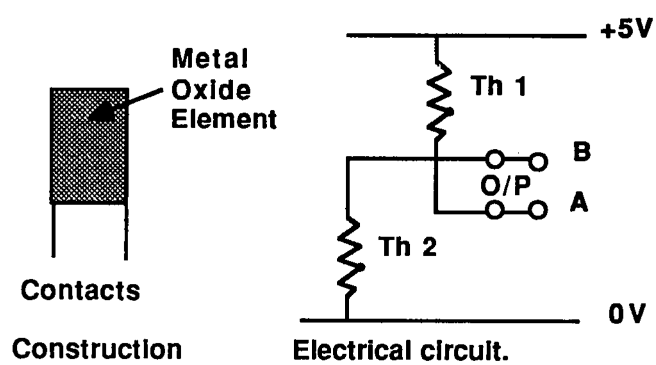


Figure 31

As the temperature of the element increases, its resistance falls, the resistance/temperature characteristic being non-linear.

The resistance of the thermistors provided with theDIGIAC 1750 unit is of the order of 5kΩ at an ambient temperature of 20°C (293°K).

The relationship between resistance and temperature is given by the formula:-

$$R2 = R1e^{\left(\frac{B}{T2} - \frac{B}{T1}\right)}$$

Where R1 = Resistance at temperature T1°K

R2 = Resistance at temperature T2°K

e = 2.718

B = Characteristic temperature = 4350°K

Two similar units are provided, one being mounted inside the heated enclosure, this being connected to the +5V supply and designated A. The other is mounted outside the heated enclosure, is connected to the 0V connection and is designated B. The circuit arrangement is shown in Fig 31.

Notes:

Notes:

Exercise 11. The Characteristics of an N.T.C. Thermistor.

Equipment:-

2 Thermistors A & B
1 10kΩ 10 turn resistor (From the Wheatstone Bridge circuit)
1 20V Digital voltmeter
1 LM 335 I.C. Temperature transducer (To indicate the temperature)
Connecting leads.

Resistance measurement method.

The resistance of the N.T.C thermistor varies over the range 5k to 1.5kΩ approximately for the temperature range available within the heated enclosure for an ambient temperature of 20°C. For this large range we cannot use the method we used in exercise 10 to measure the resistance. Also, if readings are to be taken at regular intervals of 1 minute, the readings of resistance must be obtained with the minimum of time.

The method used connects the thermistor in series with a calibrated resistor to the +5V supply. For each reading, the variable resistor is adjusted until the voltage at the junction of the thermistor and resistor is half the supply value. For this setting there will be the same voltage drop across the thermistor and the resistor and their resistances will be equal, and hence the value of the resistance read from the calibrated resistor scale represents the resistance of the thermistor.

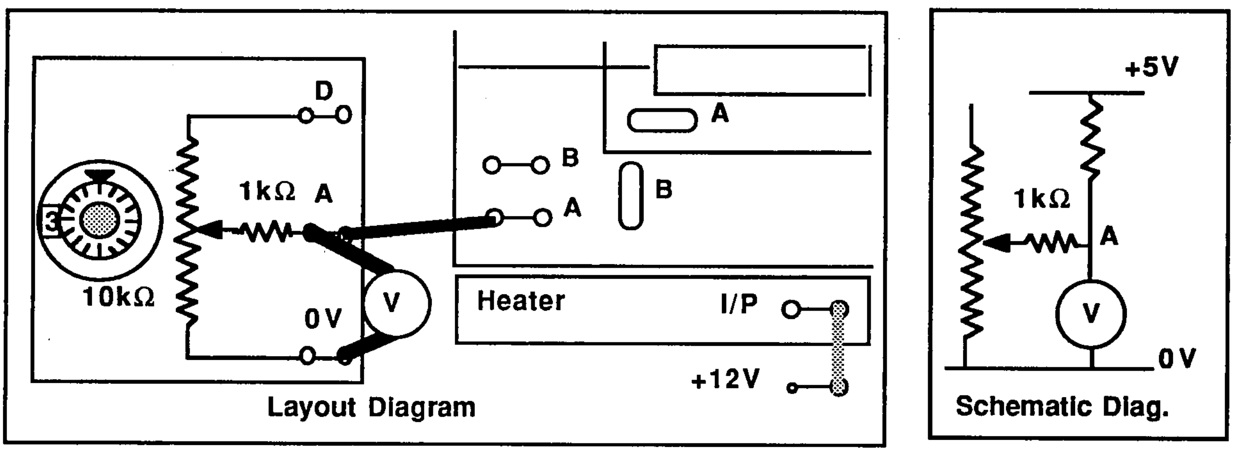


Figure 32

- Connect the circuit as shown in Fig 32, set the switch on the Wheatstone bridge circuit to OUT to disconnect the 12kΩ and Rx resistors from the circuit and set the resistor dial reading to 500 approximately.

- Switch the power supply ON, adjust the resistor control until the voltage indicated by the voltmeter is 2.5V and then note the dial reading and the temperature, by connecting the voltmeter temporarily to the "Int" socket of the I.C. temperature transducer.

Note:- Since there is a 1kΩ resistor in the output lead of the resistance, the total resistance in the resistance circuit will be of value (10 x Dial reading + 1kΩ)

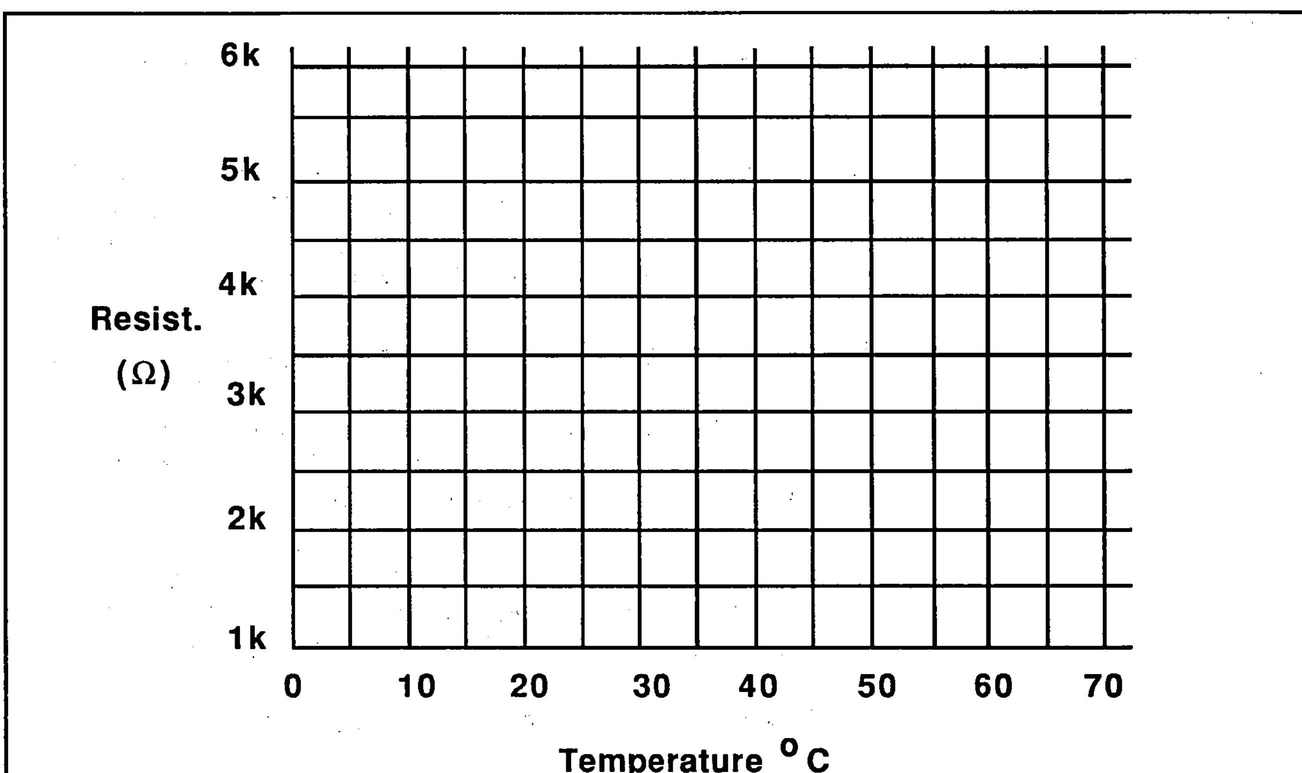
Enter the values of dial reading and temperature in Table 15.

■ Now connect the 12V supply to the heater input socket and, at 1 minute intervals, note the values of the dial reading to produce 2.5V across the resistance and also the temperature. Enter the values in Table 15.

Time (Minutes)		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Temperature	**°K**											
	°C											
Dial reading for 2.5V												
Thermistor resistance												

Table 15.

Plot the graph of thermistor resistance against temperature on the axes provided.



Note that the graph is non-linear, with the resistance falling as the temperature increases.

The unit is not suitable for applications where an accurate indication of temperature is required, but is more suitable for applications in protection and alarm circuits where an indication of temperature exceeding a certain safe value is required.

Units are available having a rapid change of resistance when the temperature exceeds a certain value.

The resistance of the N.T.C. thermistor B which is mounted outside the heated enclosure does not remain constant, due mainly to conduction of heat from the heater along the baseboard and this reduces its resistance.

We cannot use the same procedure as for thermistor A to measure its resistance because the 10 turn resistor and thermistor B are both connected to the 0V supply connection. We can measure its resistance using the Wheatstone Bridge method but we will have no means of measuring the temperature of the unit.

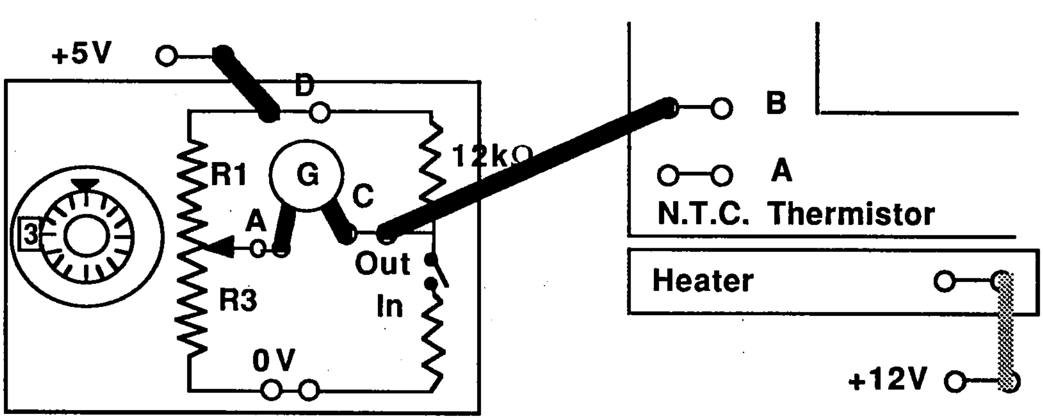


Figure 33

- Connect the circuit as shown in Fig 33 and set the switch on the Wheatstone bridge circuit to OUT.Use either the digital voltmeter or the combination of differential amplifier, amplifier #1 and moving coil meter as the galvanometer.

- Balance the bridge for conditions with the thermistor B (a) cold and (b) hot and calculate its resistance for each condition.

N.T.C. Thermistor cold:-

R3 at balance =
R1 at balance = 10,000 - R3 =

Thermistor B resistance = $\frac{R3}{R1} \times 12k\Omega =$

N.T.C. Thermistor Hot::-

R3 at balance =
R1 at balance = 10,000 - R3

Thermistor B resistance = $\frac{R3}{R1} \times 12k\Omega =$

When used for alarm or protection circuits, two thermistors would normally be used, these being connected in a bridge circuit as shown in Fig 34.

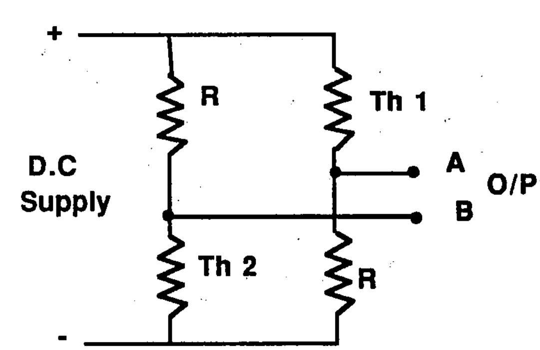


Figure 34

The two thermistors and two equal value resistors R having the same value resistance as the "cold" resistance of the thermistors are connected in the bridge circuit shown in Fig 34.

When cold, there will be no output at the connections AB because the bridge will be balanced under this condition.

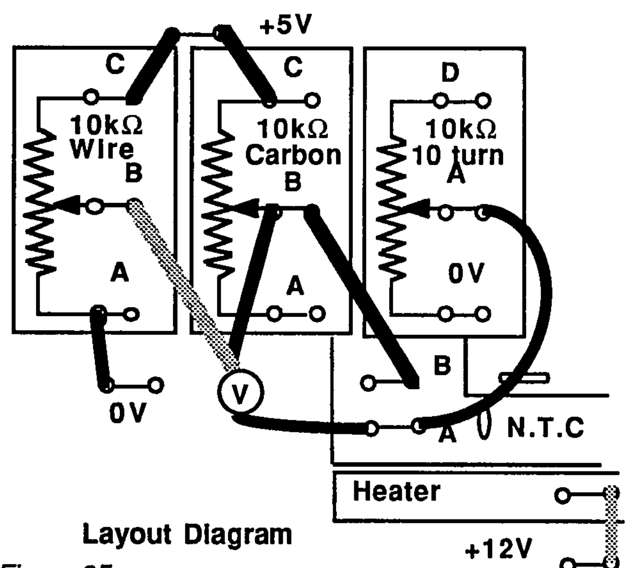
As the temperature rises, the thermistor resistance will decrease and the potential of connection A will rise and that of connection B will fall, thus giving a larger output than would be obtained with a circuit using only one thermistor.

Notes:

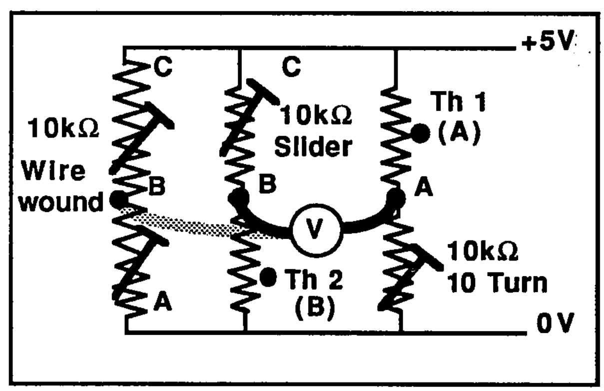
Exercise 12. The Characteristics of N.T.C. Bridge Circuits with (a) one & (b) two active Thermistors.

Equipment:-

2 N.T.C. Thermistors
1 10kΩ 10 turn resistor
1 10kΩ Carbon slider resistor
1 10kΩ Wirewound resistor
1 20V Digital voltmeter
Connecting leads



Layout Diagram



Schematic Diagram

Figure 35

Th1, the 10kΩ 10 turn resistor and the 10kΩ wirewound resistor form the bridge circuit with one active thermistor.

Th1, the 10kΩ 10 turn resistor, Th2 and the 10kΩ carbon resistor form the bridge with two active thermistors.

- Connect the circuit as shown in Fig 35 and set the switch on the Wheatstone Bridge circuit to OUT.

- Connect the voltmeter between the N.T.C. "A" socket and 0V. Switch the power supply ON and adjust the 10kΩ 10 turn resistor so that the voltmeter reading is 2.5V. The 10kΩ resistor and thermistor Th1 are now set for the same resistance.

- Now connect the voltmeter between the N.T.C. "A" socket and the "B" socket of the 10kΩ wirewound resistor and adjust the control of the wirewound resistor for a voltage reading of zero.

- Connect the voltmeter between the N.T.C. "A" socket and the "B" socket of the 10kΩ carbon slider resistor and adjust the slider position for an output voltage of zero.

Both bridges are now set for zero output with the thermistors at ambient temperature.

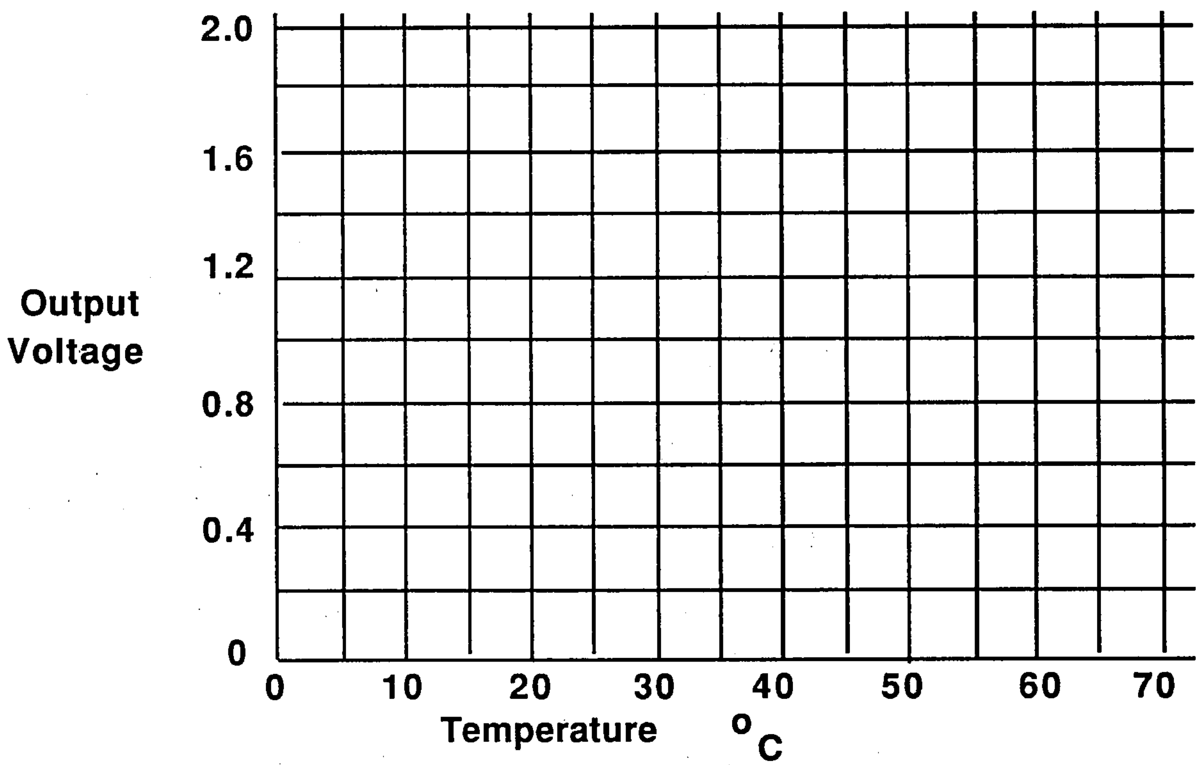
Note the temperature by measuring the voltage output from the "Int" socket of the I.C. temperature transducer and enter the value in Table 16.

- Now connect the 12V supply to the heater input and at 1 minute intervals, note the temperature and the output voltages from each bridge circuit. The output voltages are measured between the N.T.C. socket "A" and the "B" sockets of the 10kΩ wirewound and 10kΩ carbon slider resistors. Enter the values in Table 16.

Time (Minutes			0	1	2	3	4	5	6	7	8	9	10
Temperature		°K											
		°C											
Bridge Output	1Active N.T.C												
	2Active N.T.C												

Table 16

Draw graphs of output voltage against temperature for the two bridge circuits on the same axes provided as follows.



Note that the output with two active thermistors exceeds that with only one thermistor. If both active thermistors were at the same temperature, the output would be twice that for one active thermistor.

Is the relationship linear ?