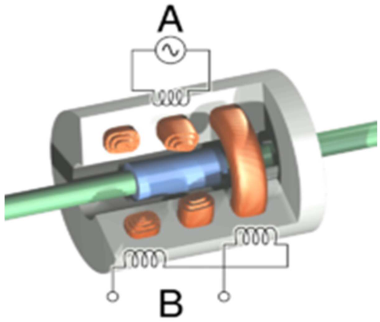
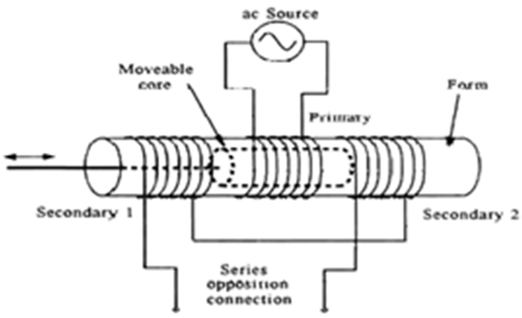
The University of Jordan

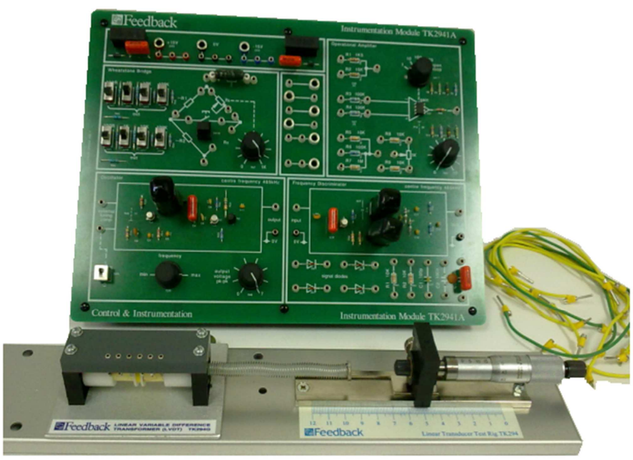
Mechatronics Engineering Department

Transducer Lab. (0908443)

Exp.2: Linear Variable Differential Transformer (LVDT)







Exp.1: Linear Variable Differential Transformer (LVDT)

Objectives

Know what is meant by the linearity and range of a mutual inductive type transformer.
Have studied how a dc voltage output may be obtained from a mutual inductance type transducer operated with an FM system

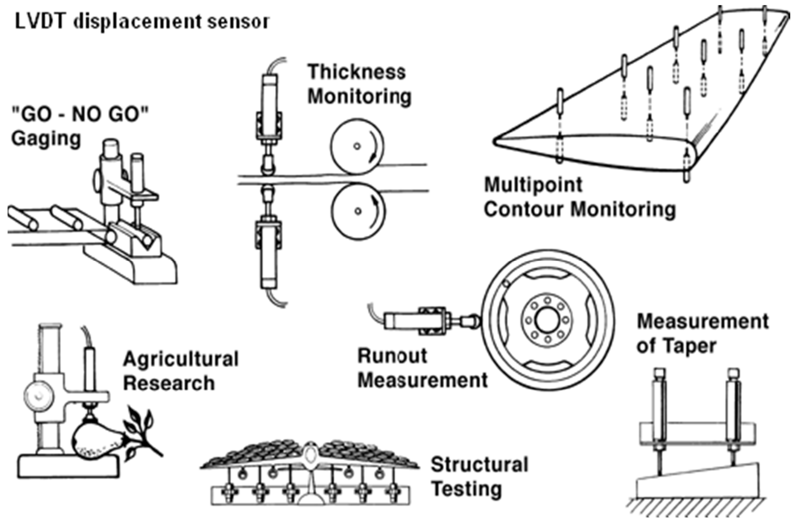
Introduction

The linear variable differential transformer (LVDT) is a type of electrical transformer used for measuring linear displacement. The transformer has three solenoidal coils placed end-to-end around a tube. The center coil is the primary, and the two outer coils are the secondaries. A cylindrical ferromagnetic core, attached to the object whose position is to be measured, slides along the axis of the tube.
On our position measurement LVDTs, the two transducer secondaries are connected in opposition.

As the core moves, these mutual inductances change, causing the voltages induced in the secondaries to change. The coils are connected in reverse series, so that the output voltage is the difference (hence "differential") between the two secondary voltages. When the core is in its central position, equidistant between the two secondaries, equal but opposite voltages are induced in these two coils, so the output voltage is zero.

When the core is displaced in one direction, the voltage in one coil increases as the other decreases, causing the output voltage to increase from zero to a maximum. This voltage is in phase with the primary voltage. When the core moves in the other direction, the output voltage also increases from zero to a maximum, but its phase is opposite to that of the primary. The magnitude of the output voltage is proportional to the distance moved by the core (up to its limit of travel), which is why the device is described as "linear". The phase of the voltage indicates the direction of the displacement.

Figure: 1.1 LVDT setup and wiring



Part1: LVDT AC output

Connect up the circuit of fig.2.1 as shown in fig.1.1 carefully check that the terminals of the transducer are wired up correctly

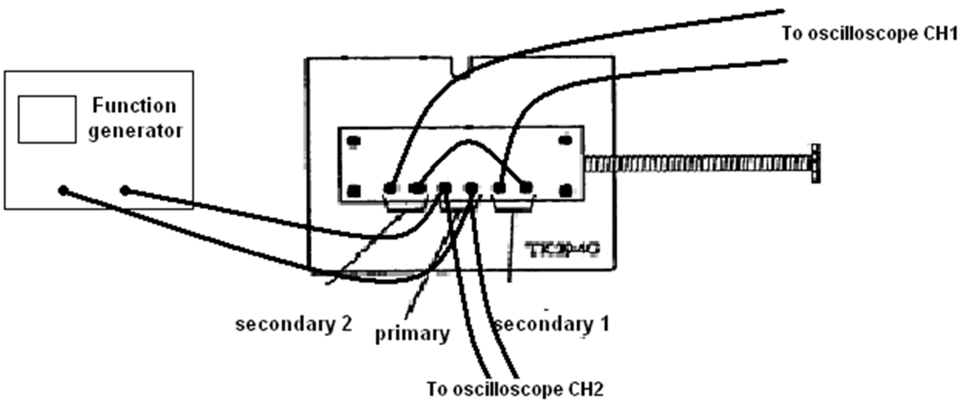


Figure 2.1: LVDT connections

Adjust the function generator to give output of 6 kHz and 1V pk-pk, adjust ch1 on the oscilloscope on 0.2 V/div and ch2 1 V/div. set the time base to 0.1ms/div .By pressing the rod against the return spring ,move the ferrite core through the body of the transducer. Observe the secondary output waveform on the oscilloscope .it should go through a maximum shifting phase and then a second maximum, reduce almost to zero, change phase and go through two further maximums again shifting phase. Observe particularly the phase change at the zero position. it should be 180^{o}.

Reduce the oscilloscope time base setting to say 100 µs/div so that it is easier to read the number of divisions peak-to-peak of the waveform. Using the micrometer move the core through the coils in 3mm steps, recording the output at each step, to fill the following table.

Record your readings in table ignore the third column .when the output passes through the null position, as you have noted ,there was an 180^o phase change. Record the position where this happens, and all subsequent readings as negative.

Using your results, plot a graph of the output against position for the whole range of movement.

Position(mm)	Output ac (volts pk-pk)	Output (dc volts)

Q1: Draw in what you consider to be the best straight line approximation to the central section . it will most likely pass through the zero null point.

Measure the maximum distance of your curve from this straight line, in the vertical (i.e. output voltage) direction. Express this as a percentage of the total output voltage range between the two peaks. Call this x%.

Q2: between which position is the output within this linearity figure? this presents the RANGE of the transducer. Express this as a figure of+- ymm about the null point. You now have two figures for the specification of this transducer. We can say that the output linearity is x% over a range of -+ ymm about the central position.

However, the output is an ac voltage which has to be measured on an oscilloscope.

Q4: Would a dc voltage output be more convenient?

What basic components do we need to convert the ac voltage in to a dc voltage?

Q5: How can we take account of the change in phase as the output voltage passes through zero?

Part 2: LVDT DC output

Switch off the power supply and connect up the circuit of fig 1.3. Carefully checks that the terminals on the transducer are wired up correctly.

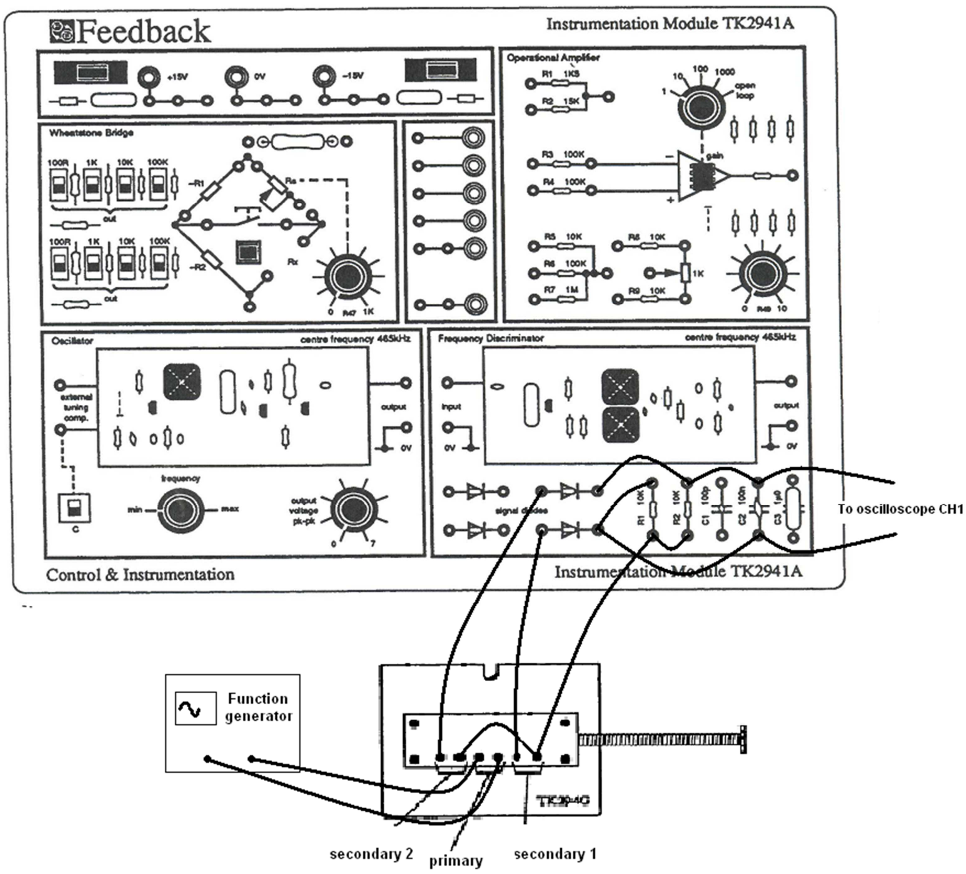


Figure 1.3: LVDT with rectifire

Connect your oscilloscope across the rectifier output terminals, set the time base as before to 1ms/div and the Y again to 50mV /div. Temporarily remove the two connections from each of the two 100Nf ,C2, sockets while still keeping the patching leads joined together i.e. remove the capacitor from the circuit. Note the rectification provided by the diodes alone.

Replace the connections, this time across the 100pF capacitor, C1.Note that this value of capacitance does not provide adequate smoothing and that the dc waveform has a large ripple.

Change the connections again to place the 1µF capacitor, C3 in circuit observe the waveform whilst very rapidly moving the core.

Q8: would this capacitor be suitable for smoothing the output voltage if the core were in continuous motion?

Replace the correct 100nF Capacitor and withdraw the core from the coils. Take a set of readings of dc output voltage and position at 3mm intervals as you move the core through the two secondary coils as before.

Record your readings in the third column in your table. Record the position where the output voltage is zero.

Using your results, plot a graph of output against position for the whole range of movement. Draw it on the same graph you did the ac graph. We are going to perform the same operations on it.

Q9: What shape is your graph, especially over the central section? Is it the same shape as the ac graph?

Q10: draw in what you consider to be the best straight line approximation to the central section. it will most likely pass through the zero null point.

http://www.sensorland.com/HowPage001.html

http://www.rdpe.com/displacement/lvdt/lvdt-principles.htm

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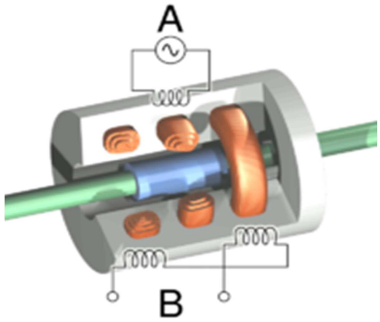

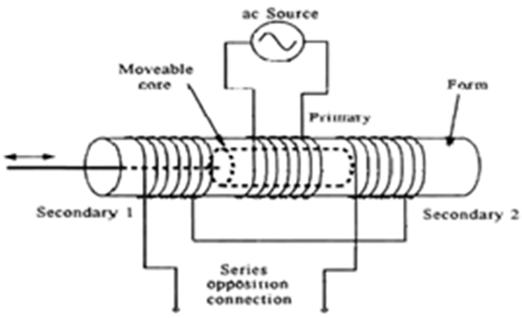

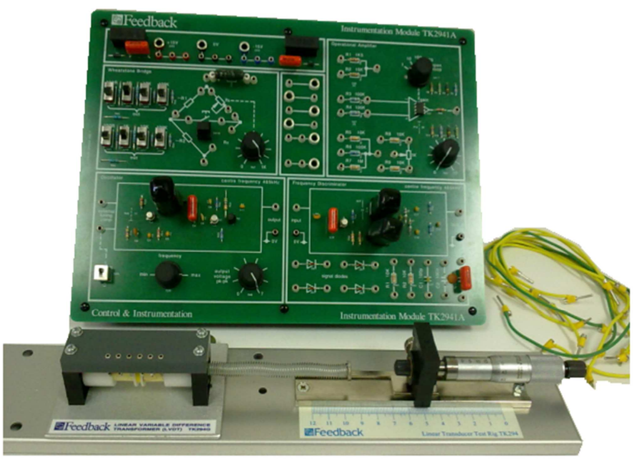

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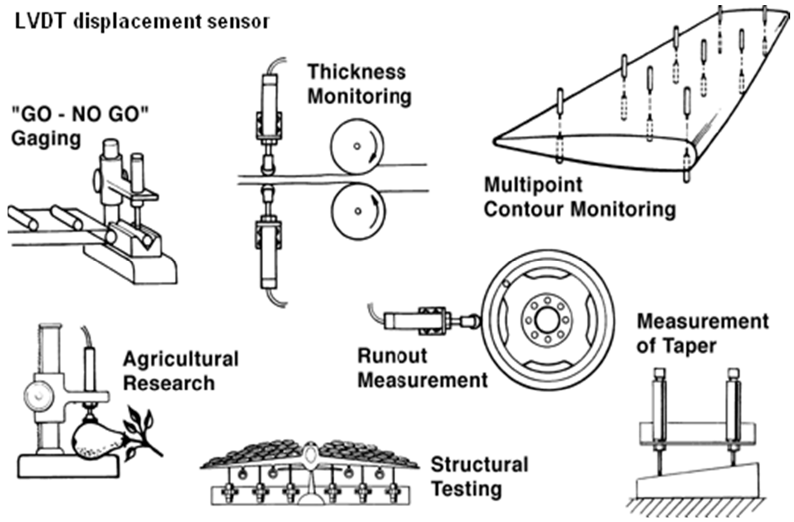

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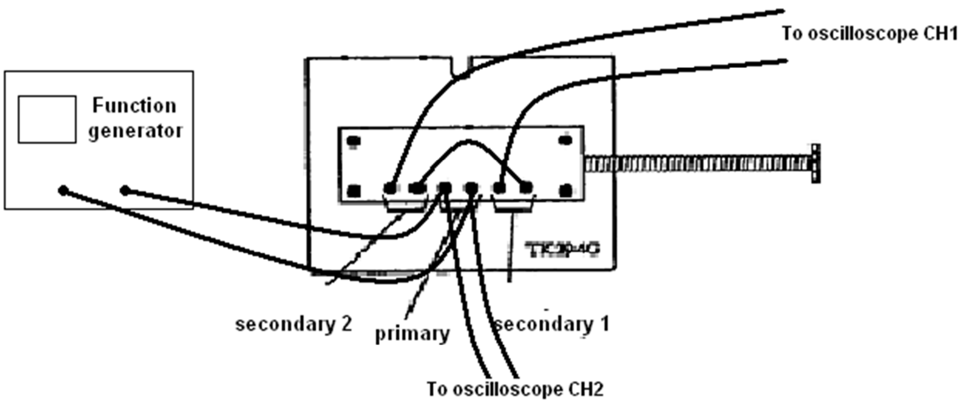

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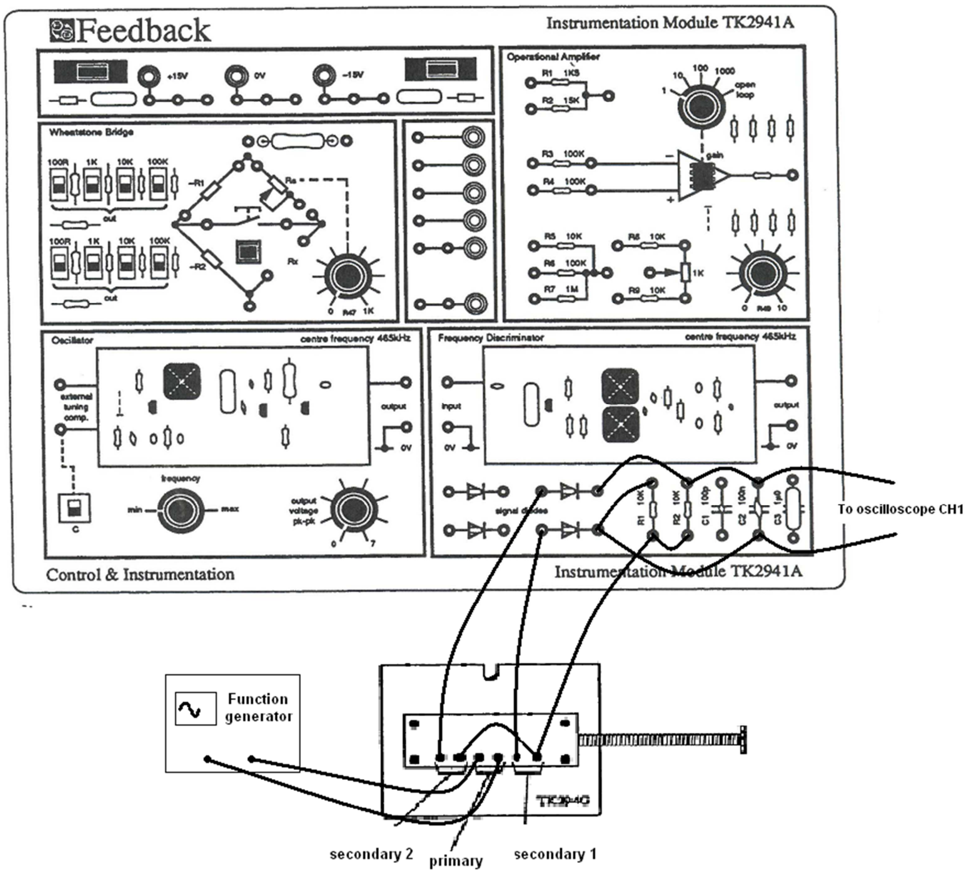

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Transducers lab.

Experiment 2: Strain Gauge

Objectives:

-Know how the change in resistance of a material, caused by a change in its physical dimension, can be used to measure the strain in the material

-Find the characteristics of the strain gauge

Pre-lab: read about dc bridges and strain gauges.

Introduction:

The strain gauge is the most common device used in mechanical testing and measurements. The most common type is the bonded resistance strain gauge, which consists of a grid of very fine foil or wire. The electrical resistance of the grid varies linearly with the strain applied to the device. When using a strain gauge, you bond the strain gauge to the device under test, apply force, and measure the strain by detecting changes in resistance. Strain gauges are also used in sensors that detect force or other derived quantities, such as acceleration, pressure, and vibration. These sensors generally contain a pressure sensitive diaphragm with strain gauges mounted to the diaphragm.

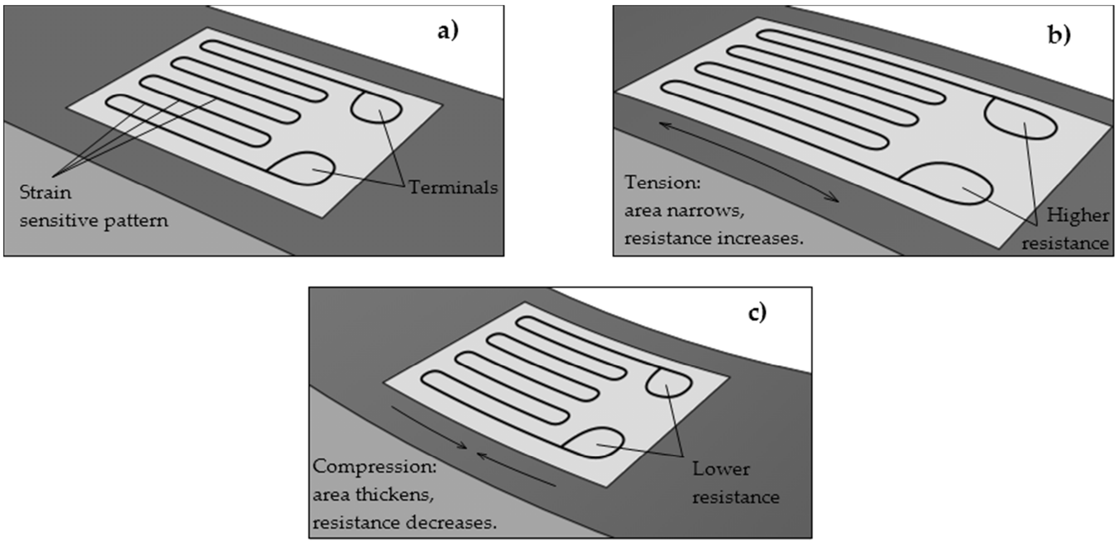


Figure 4.1: working concept behind the strain gauge on a beam under exaggerated bending.

Because strain measurement requires detecting relatively small changes in resistance, the Wheatstone bridge circuit is almost always used. The Wheatstone bridge circuit consists of four resistive elements with a voltage excitation supply applied to the ends of the bridge. Strain gauges can occupy one, two or four arms of the bridge, with any remaining positions filled with fixed resistors. Figure 4.2shows a configuration with a half-bridge strain gauge consisting of two strain gauge elements, R_{G1} and R_{G2}, combined with two fixed resistors, R_1 and R_2.

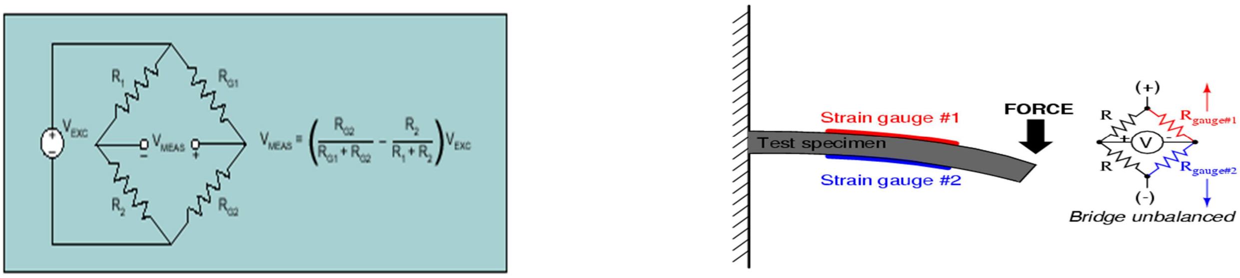


Figure 4.2: Half-Bridge Strain Gauge Configuration

$$V_O = \left(\frac{R_{G2}}{R_{G1}+R_{G2}} - \frac{R_2}{R_1+R_2}\right)\cdot V_{EXC}$$

When the ratio of R_{G1} to R_{G2} equals the ratio of R_1 to R_2, the measured voltage V_O is 0 V. This condition is referred to as a balanced bridge. As strain is applied to the gauge, their resistance values change, causing a change in the voltage at V_O. Full-bridge and half bridge strain gauges are designed to maximize sensitivity by arranging the strain gauge elements in opposing directions.

For example, the half-bridge strain gauge in Figure 5 includes an element R_{G1}, which is installed so that its resistance increases with positive strain, and an element R_{G2}, whose resistance decreases with positive strain. The resulting V_O responds with sensitivity that is twice that of a quarter-bridge configuration.

Some signal conditioning products have voltage excitation sources, as well as provisions for bridge-completion resistors. Bridge completion resistors should be very precise and stable. Because strain-gauge bridges are rarely perfectly balanced, some signal conditioning systems also perform nulling. Nulling is a process in which you adjust the resistance ratio of the unstrained bridge to balance the bridge and remove any initial DC offset voltage. Alternatively, you can measure this initial offset voltage and use this measurement in your conversion routines to compensate for unbalanced initial condition.

Part1: Basic Strain Gauge

Procedure:

- Connect the circuit shown in figure 4.3

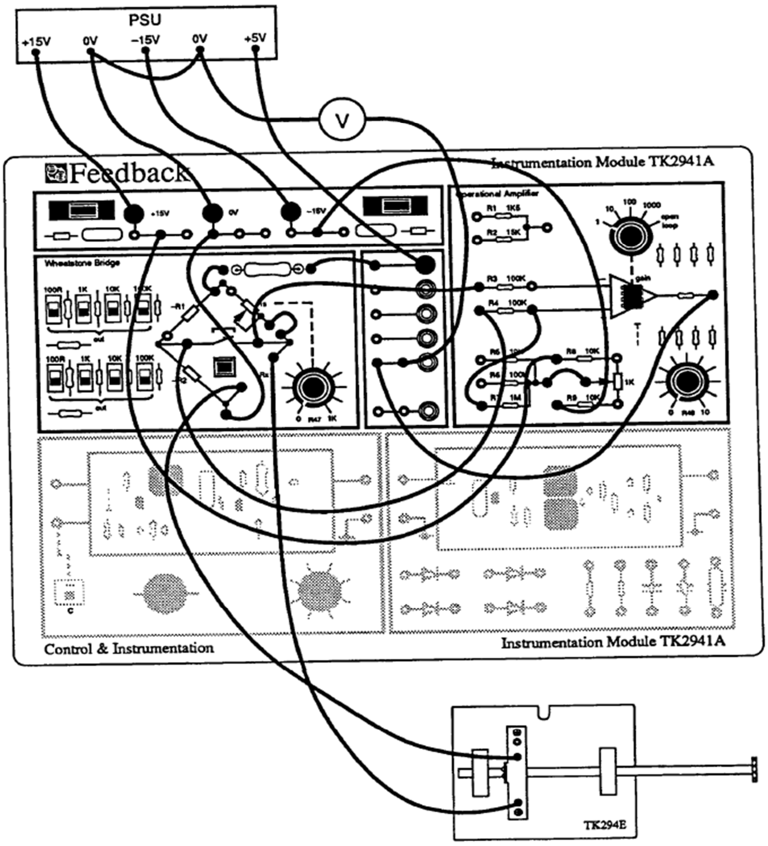


Figure 4.3: Strain Gauge

As shown in the figure there is 2 step before get the readings of the strain, first step is the wheatstone bridge

Q1: What is the advantages of using the Wheatstone bridge?

The second step is amplifying

Q2: why do we need this step?

Then you can read the output voltage from the signal

Q3: If we want to improve the output signal what type of conditioning can we add to the circuit, for pc processing as an example?

- Now we are going to use the previous circuit to measure the change in resistance of the gauge. When you bend the beam the actual changes in the transducer will be very small such that its resistance will change by only about 0.2Ω .this would be very difficult to measure this change by normal bridge methods as the contact resistances of any plugs, switches or potentiometers may change by a similar small amount. However, such a small change means that the bridge is only just out of balance voltage appearing across the detector and uses this to indicate on the meter.

  However, it will still be necessary to obtain an amplifier output of zero for the starting condition and to do this we shall use the variable resistor Rs on the Wheatstone bridge module to obtain a rough bridge balance; Rs is too coarse to give an accurate zero output through, so we use a different method for the fine control. This is to offset the amplifier deliberately so that it produces zero output for a small non-zero input, being the residual bridge unbalance. The potentiometer on the Operational amplifier,R49,is used for this purpose, as shown in fig 2 .

- Set the micrometer to 10mm,Use the slide to push the gauge operating rod against its left hand stop and note the slide scale reading (about 29 mm)
- Move the slide to the right until there is just no pressure on the operating rod and again note the scale reading (say 24 mm)
- Set the slide to the midway point of your two readings (26.5 mm typically) and lock the slide. The strain gauge should now be in about the middle of its operating range.
- On the Wheatstone bridge set R1=R1=1kΩ.
- Switch on the power supply
- Select a 10V range on the meter (or the nearest available) and set a gain of 100 on the operational amplifier. Set the potentiometer, R49, to mid-scale and adjust Rs on the Wheatstone bridge until the meter reads as near to zero as you can manage.
- Now adjust R49 to give an exact zero, increasing the meter sensitivity and re-adjusting R49 alternatively until you have a zero setting on the most sensitive range available. Wait five minutes for the system to settle and finally reset to zero with R49.
- Take a set of output readings for 0.5 mm steps of position, strain at 10.0mm ,increasing to 12.5 mm, reducing to 7.5mm and finally increasing again to 10.0 mm. Record your results in the table below.

Micrometer setting (mm)	Output Voltage(mV)
10	
10.5	
11	
11.5	
12	
12.5	
12	
11.5	
11.0	
10.5	
10	
9.5	
9	
8.5	
8	
7.5	
8	
8.5	
9	
9.5	
10	

Plot your results of micrometer settings against output voltage.

Q4: Is the plot linear? If so, what is its slope in volts/mm?

Q5: Find the maximum hysteresis, non-linearity and the sensitivity as a percentage of f.s.d?

Part2: Dual Gauge System

Connect up the circuit of figure 4.4. Although the tow gauges are nominally of equal resistance there could still be a small unbalance remaining so the offset potentiometer R49 is retained in this circuit.

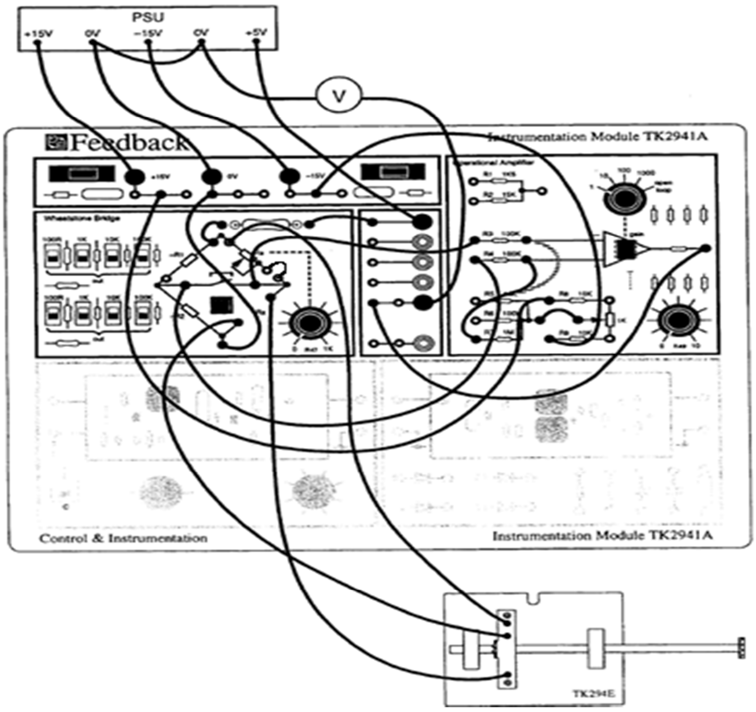


Figure4.4: Dual Strain Gauge

On the Wheatstone bridge set R1=R2=1 kΩ, Set the operating rod to the same mid-position as was used in part1 and then adjust R49 to give an exact zero as before . If you find balance cannot be obtained move the lead from R7 to the other input to the amplifier as shown dotted in fig and try again.

Now take a set of readings of output voltage against micrometer setting as before (10.0 up to 12.5, down to 7.5 and back up to 10.0 mm) and record them in the following table.

Micrometer setting (mm)	Output Voltage(mV)
10	
10.5	
11	
11.5	
12	
12.5	
12	
11.5	
11.0	
10.5	
10	
9.5	
9	
8.5	
8	
7.5	

8	
8.5	
9	
9.5	
10	

Plot your results of micrometer settings against output voltage.

Q6: Are the new results free from thermal effects?

Q7: What is the slope of your new plot?

Q8: Find the maximum hysteresis, non-linearity and the sensitivity as a percentage of f.s.d?

Q9: Discuss the results you obtained in part one and two.

Useful links:

http://www.rdpe.com/ex/hiw-sglc.htm

http://www.sensorland.com/HowPage002.html

http://en.wikipedia.org/wiki/Strain_gauge

University of Jordan
Transducer Lab.
Exp.2:Thermocouple

1.Introduction

A thermocouple transducer is formed by a junction of two dissimilar metals. The junction, when heated, will produce a small voltage and associated current flow. The voltage developed is directly proportional to the temperature of the junction.

2. Objectives

In this experiment you will:

- Calibrate J-type thermocouple
- You will measure the time constant of the thermocouple in air and in water.

3. Background

Thermocouple Type:

-Type J (Iron-Constantan)– cheap because one wire is iron; high sensitivity but also high uncertainty (iron impurities cause inaccuracy)

-Type K (<u>chromel</u>{90 percent nickel and 10 percent chromium}–<u>alumel</u>)(Alumel consisting of 95% nickel, 2% manganese, 2% aluminium and 1% silicon) popular type since it has decent accuracy and a wide temperature range; some instability (drift) over time If the thermocouple is connecting direct to a voltmeter as shown in figure 2.1, problems will occur:

-The measured voltage depends not only upon the unknown temperature but room temperature as well. This is undesirable because room temperature can fluctuate, causing apparent fluctuations in the measured temperature.

-The second problem is that the contacts between metal Cu and the voltmeter and metal C and the voltmeter will both set up small “contact” voltages which will be different from each other because metals Cu and C are different. The differences between these two voltages set up an additional voltage that gives rise to error in the measurement.

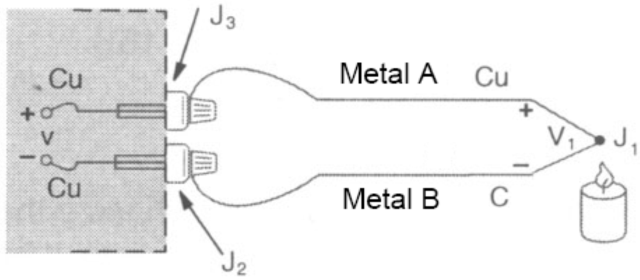


Figure 2.1: Thermocouple

This as created another junction! Displayed voltage will be proportional to the difference between J1 and J2 (and hence T1 and T2).see figure 2.2

A solution is to put J2 in an ice-bath; then you know T2, and your output voltage will be proportional to T1-T2.

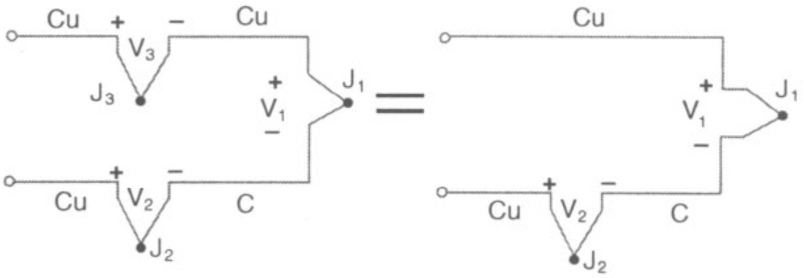


Figure 2.2: Equivalent circuit

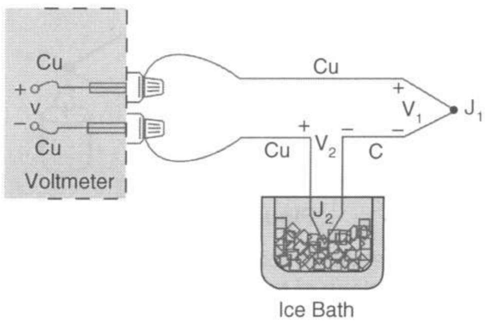


Figure 2.3: Solution circuit

Law of Intermediate Materials

This law states that when a third metal is connected between the two dissimilar metals this will not affect the output voltage as the two junction at the same temperature.

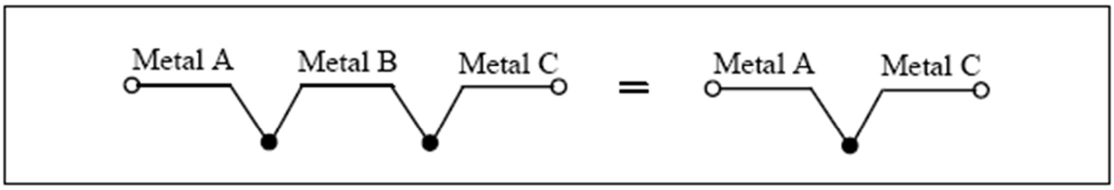


Figure 2.4:law of intermediate metals

When a thermocouple is heated, it is required a certain period of time for the output voltage of the junction to be follow temperature change. The difference between the temperature change and the output voltage is referred to as the time constant (tc) of the devise. The time constant (tc) is defined as the time required for the output to reach 63.2% of its final output voltage value at the new temperature, in response to a step function change in temperature. As shown in figure 2.5.

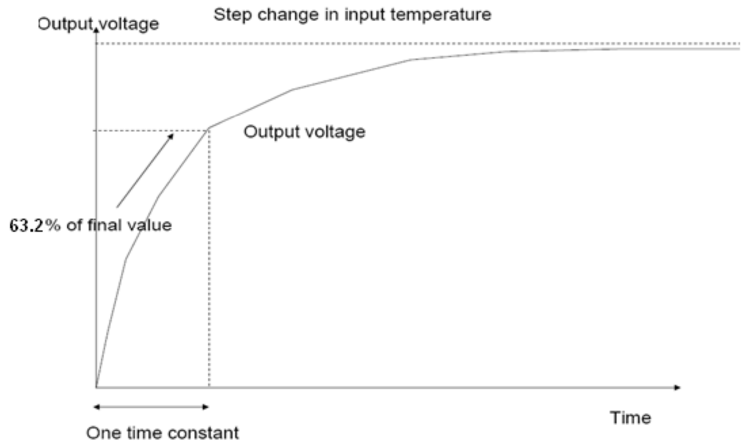
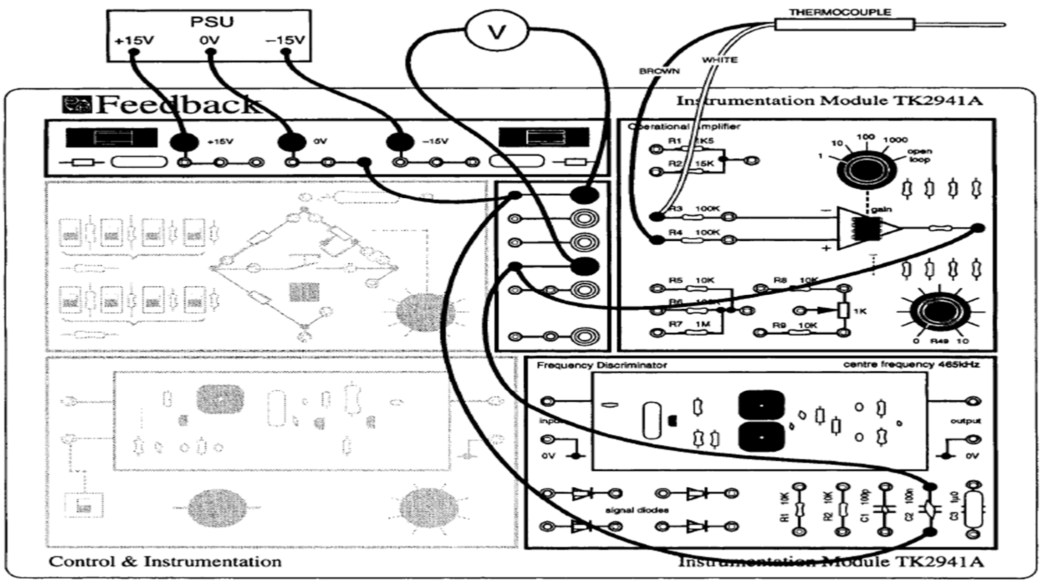


Figure2.5: Time constant

4. Procedure

Part 1: Calibrating the Thermocouple

Connect the circuit shown in figure 1.5 ,switch on the power supply and place the probe near to the amplifier input so that all points are at the same temperature. To avoid possible ‘pick up’ of signal, due to the proximity of the thermocouple lead to the TK2941A oscillator, the positive input to the operational amplifier is decoupled to 0with a 100 µF capacitor. Read the room temperature near the amplifier .this will be the cold junction temperature and should ideally be constant during the experiment. Switch the gain of the operational amplifier to 1000,disconnect the prope,note the meter reading in table 5.1and place it and a thermometer in the watter tank and clip this on the heat bar at notch 20.



When the temperature is steady (about 15 minutes) note the thermometer reading and the meter reading. Repeat for notches 18,16,..etc every 2 minutes up to the point 100^oC is reached. Fill the following table.

Notch no.	Room temp. (^oC)	Tank temp.(^oC) (thermometer)	Meter (V)	Thermocouple emf (mV)	Temperature From J type reference table
20					
18					
16					
14					
12					
10					
8					
6					
4					
2					

Calculate the temperature difference and the thermocouple emf,which will be the meter reading divided by 1000 expressed in mV.
Plot the emf against temperature difference.
Q1: Is the graph a straight line within the accuracy of your observation and plotting?
Q2: If so,what is the slope in µV/^oC?
Q3: What source of error could contribute to uncertainty about this figure?

Part 2: Measuring time constants
i. Time constant for J-type thermocouple in water:
1) Place the thermocouple in the cold water. Record the final voltage value at which it settles.
2) Remove the thermocouple and place it in the hot water mug and keep it. Record the voltage that it shows.
3) The difference between the two voltages will be the step function it is exposed to when moving from one to the other. The time constant will be the time takes it to drop to the 37% of the difference between the two values.
4) Prepare a stopwatch to measure the time.
5) At the same time, start the stopwatch and move the thermocouple from the hot water to the cold water.
6) Note when the voltage drops to 37% of the difference and check the time.
7) This is the time constant for the thermocouple in water.

ii. Time constant for J-type thermocouple in air:
1) Place the thermocouple in air. Wait long enough for it to settle.
2) Record the final voltage value at which it settles.
3) Remove the thermocouple and place it in the hot water mug and keep it. Record the voltage that it shows.

4) The difference between the two voltages will be the step function it is exposed to when moving from one to the other. The time constant will be the time takes it to drop to the 37% of the difference between the two values.
5) Prepare a stopwatch to measure the time.
6) At the same time, start the stopwatch and move the thermocouple from the hot water to the air. Note when the voltage drops to 37% of the difference and check the time. This is the time constant for the thermocouple in air.

5. Discussion:

- Discuss the main problems with this experiment and how you can improve it.
- Comment on the accuracy of the method, the number of point obtained and the number of significant figures you are getting from the multimeter.

The University of Jordan

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Experiment 8: OP AMP applications (Integrator and precise rectifier)

Objectives:

To use study some OP AMP applications

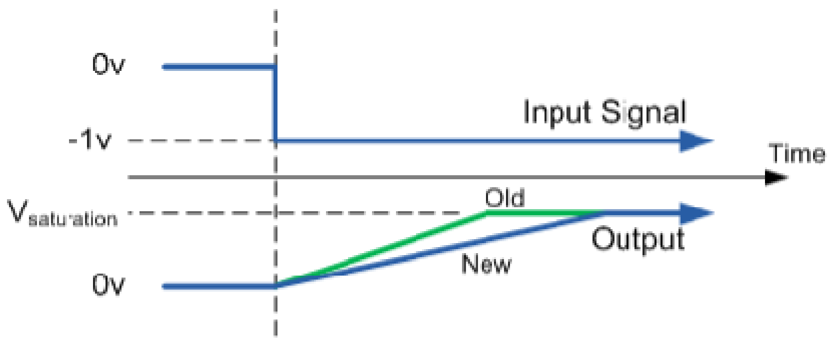
1- To use OPAMP as an integrator

2-To build a precise rectifier circuit

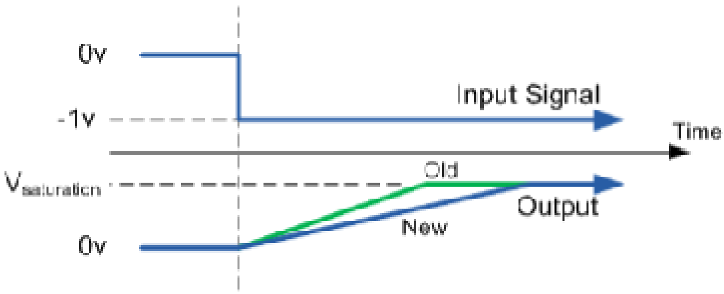
Introduction:

An operational amplifier (op-amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.[1]
Operational amplifiers can be connected using external resistors or capacitors in a number of different ways to form basic "Building Block" circuits such as, Inverting, Non-Inverting, Voltage Follower, Summing, Differential, Integrator and Differentiator type amplifiers. There are a very large number of operational amplifier IC's available to suit every possible application.

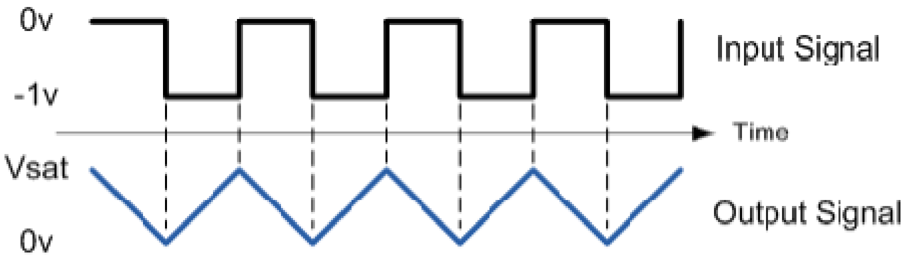
The integrator amplifier performs the mathematical operation of integration, that is, we can cause the output to respond to changes in the input voltage over time and the integrator amplifier produces a voltage output which is proportional to that of its input voltage with respect to time. In other words the magnitude of the output signal is determined by the length of time avoltage is present at its input as the current through the feedback loop charges or discharges the capacitor.



When a voltage, V in is firstly applied to the input of an integrating amplifier, the uncharged capacitor C has very little resistance and acts a bit like a short circuit (voltage follower circuit) giving an overall gain of less than 1, thus resulting in zero output. As the feedback capacitor C begins to charge up, the ratio of Z f /R in increases producing an output voltage that continues to increase until the capacitor is fully charged. At this point the ratio of feedback capacitor to input resistor (Z f /R in) is infinite resulting in infinite gain and the output of the amplifier goes into saturation as shown in the diagram. (Saturation is when the output voltage of the amplifier swings heavily to one voltage supply rail or the other with no control in between).
The rate at which the output voltage increases (the rate of change) is determined by the value of the resistor and the capacitor, "RC time constant". By changing this RC time constant value, either by changing the value of the Capacitor, C or the Resistor, R, the time in which it takes the output voltage to reach saturation can also be changed.



If we apply a constantly changing input signal such as a square wave to the input of an Integrator Amplifier then the capacitor will charge and discharge in response to changes in the input signal. This results in an output signal with a sawtooth waveform and its frequency is dependent upon the time constant (RC) of the circuit.



This type of circuit is also known as a Ramp Generator and the transfer function is given below.

Since the node voltage of the integrating op-amp at its inverting input terminal is zero, the current I in flowing through the input resistor is given as:

$$I_{in} = \frac{V_{in}}{R}$$

The current flowing through the feedback capacitor C is given as:

$$I_{in} = C\frac{dV_{out}}{dt}$$

Assuming that the input impedance of the op-amp is infinite (ideal op-amp), no current flows into the op-amp terminal. Therefore, the nodal equation at the inverting input terminal is given as:

$$\frac{V_{in}}{R} = C\frac{dV_{out}}{dt} = 0$$

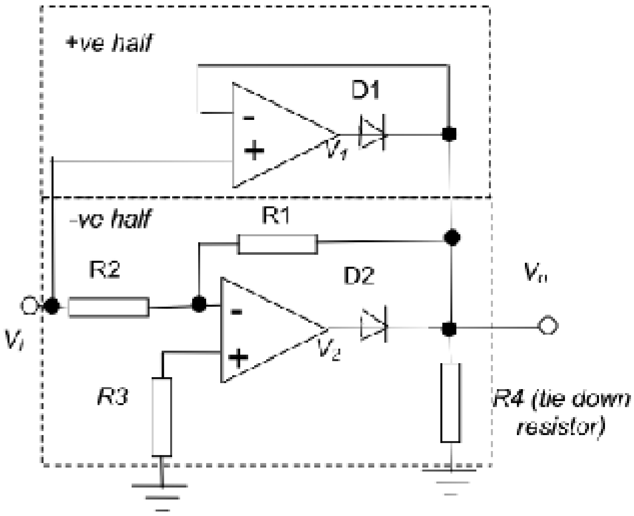
From which we have an ideal voltage output for the Integrator Amplifier as:

$$V_{out} = -\frac{1}{RC}\int V_{in}dt = -\frac{1}{j\omega RC}V_{in}$$

Where $j\omega = 2\pi f$ and the output voltage V out is a constant 1/RC times the integral of the input voltage V in with respect to time. The minus sign (-) indicates a 180^{0} phase shift because the input signal is connected directly to the inverting input terminal of the op-amp.

Precise rectifier:

When dealing with very small signals, it is not possible to use the conventional approach of rectification using diodes or full wave bridges, as this take away 0.7 V of the signal (and if the signal has amplitude less than 0.7 V, it would not appear at the output). In such cases, it is important to use a precise rectifier. A precise rectifier uses an operational amplifier with a diode in order to rectify the signal with no loss. An example of a precise rectifier is shown in the Figure below. It is built in two halves: one half deals with the positive part and the other deals with the negative half. Note that the diodes are fitted between the output of the operational amplifier and the output signal. Thus the point V 1 is 0.7 V higher than the output signal, but the output signal is equal to the input signal (via the virtual connection between the inverting and non-inverting inputs of the operational amplifier (0.7 V assumes a silicon diode). The same argument applies to the V 2 .



Procedure:

1.Integrator:

Assemble the circuit as shown in figure 8.3 choosing R 1 , R 2 = 10KΩ each, R f = 100KΩ, and C f = 0.1µF. Use 0- ±15V terminal output to provide supply to the IC. Feed a square wave input of required amplitude from the function generator, which is set at 1kHz
frequency.

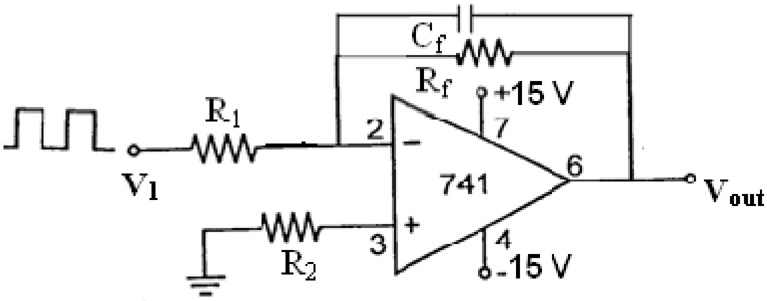


Figure8.5: integrator

Feed both the input and output signals to an oscilloscope.
-Compare the output signal with the input one.

2. Precise rectifier:
Connect the following circuit:

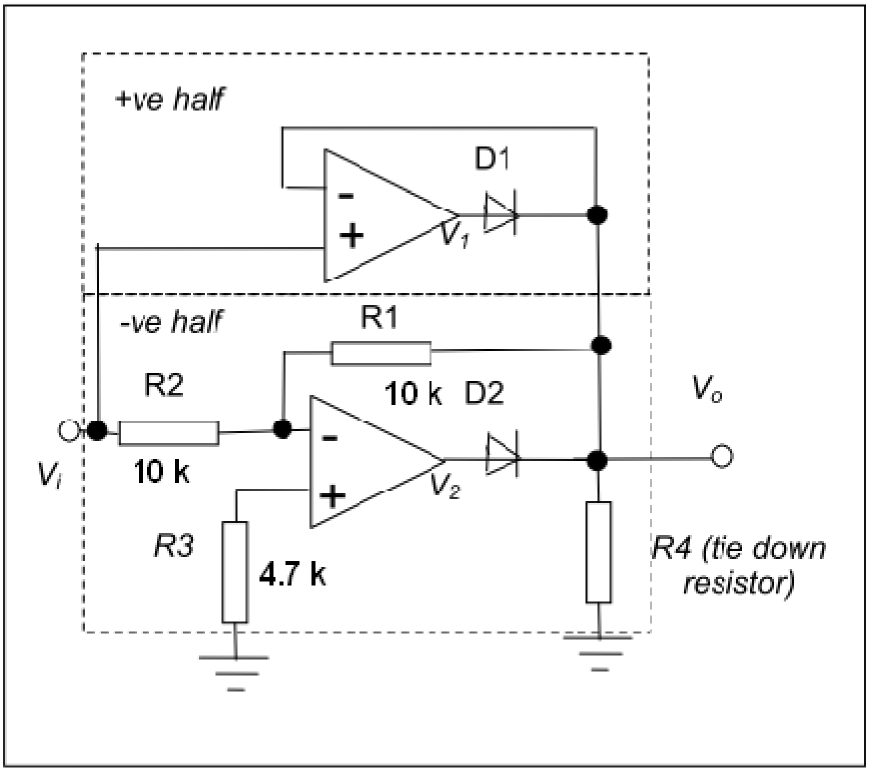


Figure 8.6: precise rectifier

Now input signal is 200 mV pk-pk
-Compare the output signal with the input one.

References:
http://en.wikipedia.org/wiki/Operational_amplifier

http://eacademic.ju.edu.jo/l.sharif/Material/Forms/AllItems.aspx?RootFolder=%2fl.sharif%2fMaterial%2f0908443%20Transducers%2f2%20Signal%20Conditioning%20and%20Processing&FolderCTID=&View={A0E71073-59AD-4A99-ACC6-800786A5413C}&InitialTabId=Ribbon.Document&VisibilityContext=WSSTabPersistence

http://physics.niser.ac.in/labmanuals/sem4/Advanced_Electronics_Lab_Manual.pdf

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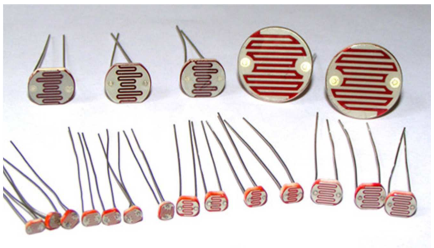
Exp.5: Find illumenance using LDR(Light Dependent Resistor)

Objectives:

Make a transducer that finds the illuminance depending on the vary in resistance of the LDR.

Introduction:

A photoresistor or light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. It can also be referred to as a photoconductor or CdS device, from "cadmium sulfide," which is the material from which the device is made and that actually exhibits the variation in resistance with light level. Note that CdS is not a semiconductor in the usual sense of the word (not doped silicon). A photoresistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.



Light Level – Illuminance:

Light Level or Illuminance, is the total luminous flux incident on a surface, per unit area, Illumenance is measured in foot candles (ftcd, fc, fcd) (or lux in the metric SI system). A foot candle is actually one lumen of light density per square foot, one lux is one lumen per square meter.[1]

Wheatstone bridge:[2]

A bridge is one of the most widely used forms of VCE/SCE's. Bridges can have either a.c. or d.c. excitation voltages. D.C. voltages are needed for resistance measurements while a.c. voltages are needed for capacitance and inductance measurements. The bridge can be used either in null type mode or deflection type mode. The Wheatstone bridge is a type of d.c. bridge that is used for precision measurement of resistance from approximately 1 ohm to the low mega-ohm range.

A typical Wheatstone null type bridge is shown in Figure 1 below. An excitation voltage source is used to operate the bridge (*Vi*).
A galvanometer is used to connect the mid-points of the right hand side voltage divider (made up of *R2* and *R4*) and the left hand side voltage divider (made up of *R1* and *R3*). The galvanometer connection between the two mid-points form a bridge between the two sides, hence the name of the device. When used as a null type device, it can produce an accurate measurement of resistance. When used in the deflection type mode, it can produce a change in an output voltage that is proportional to a change in the sensor under question (a resistor). The change in the resistance of the sensor is representative of a change in the value of an external variable (e.g., stress, force, temperature). The null type mode is more accurate than the deflection type mode, as the error in the former case will be in the mV or μV compared to fraction of a volt in the latter case.

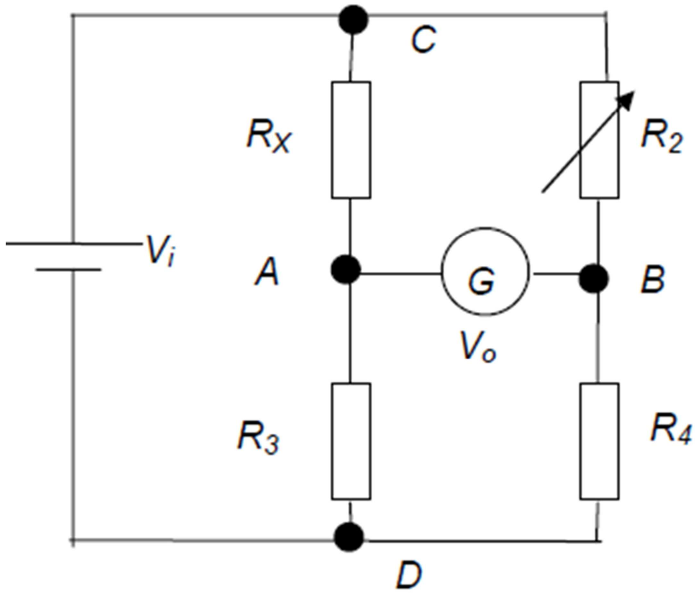


Figure5.1: Null Type Wheatstone bridge[2].

When used as a null type device, the unknown resistor *Rx* is placed in one limb of the bridge, a calibrated resistor *R2* is placed in the adjacent limb. Another two fixed resistors of known value *R3* and *R4* are placed on the other two limbs. The value of *R2* is gradually changed until a zero deflection on the Galvanometer (G) is achieved (a Galvanometer is an extremely sensitive current detector). The null type bridge obviously needs human intervention to adjust the value of *R2* until perfect balance conditions are achieved. Thus the null type bridge would not be suitable for measuring dynamic signals (a voltage that is changing quickly in value). The output voltage can be derived as follows:

$$v_o = V_{AC} - V_{BC} = V_i \cdot \left(\frac{R_x}{R_x + R_3} - \frac{R_2}{R_2 + R_4} \right)$$

$$0 = \left(\frac{R_x}{R_x + R_3} - \frac{R_2}{R_2 + R_4} \right)$$

$$\frac{R_x}{R_x + R_3} = \frac{R_2}{R_2 + R_4}$$

$$R_x \cdot R_2 + R_x \cdot R_4 = R_x \cdot R_2 + R_3 \cdot R_2$$

$$R_x = \frac{R_3}{R_4} \cdot R_2$$

In cases where *R3=R4*, then *Rx=R2*.
So to summarise, equation (1) below is used for the deflection type bridge and equation (2) below for the null type bridge.

$$v_o = V_i \cdot \left(\frac{R_x}{R_x + R_3} - \frac{R_2}{R_2 + R_4} \right) \ldots\ldots\ldots.(1)$$

$$R_x = \frac{R_3}{R_4} \cdot R_2 \ldots\ldots\ldots.(2)$$

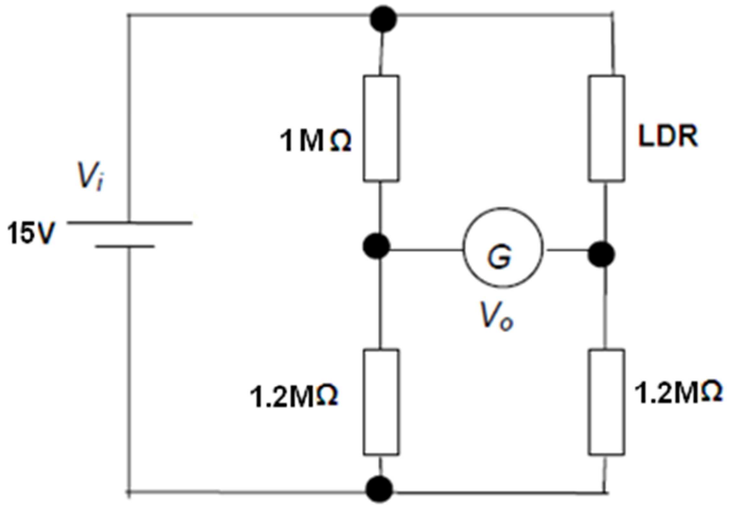
Procedure:
in this experiment you are going to find the illuminance using an LDR sensor and display the value of illuminance on pc using DAQ system, the DAQ used in this experiment is usb-6008 from ni see the manual (http://www.ni.com/pdf/manuals/371303l.pdf) notice the input and output range of the DAQ. Now you're going to find the range of the resistance and the relation between the resistance and illuminance.

Now you are going to make a transducer that finds the illumenance using LDR, to do that you need a lux meter and variable illumenance source, Vary the illumenance and measure the LDR resistance and fill the following table.

LDR resistance	Illuminance
	10
	20
	. .
	1000

Try to collect as many readings as you can so you find more accurate relation
Now find the relation between the resistance and the illumination, use any program excel for example.

Now connect the following circuit:

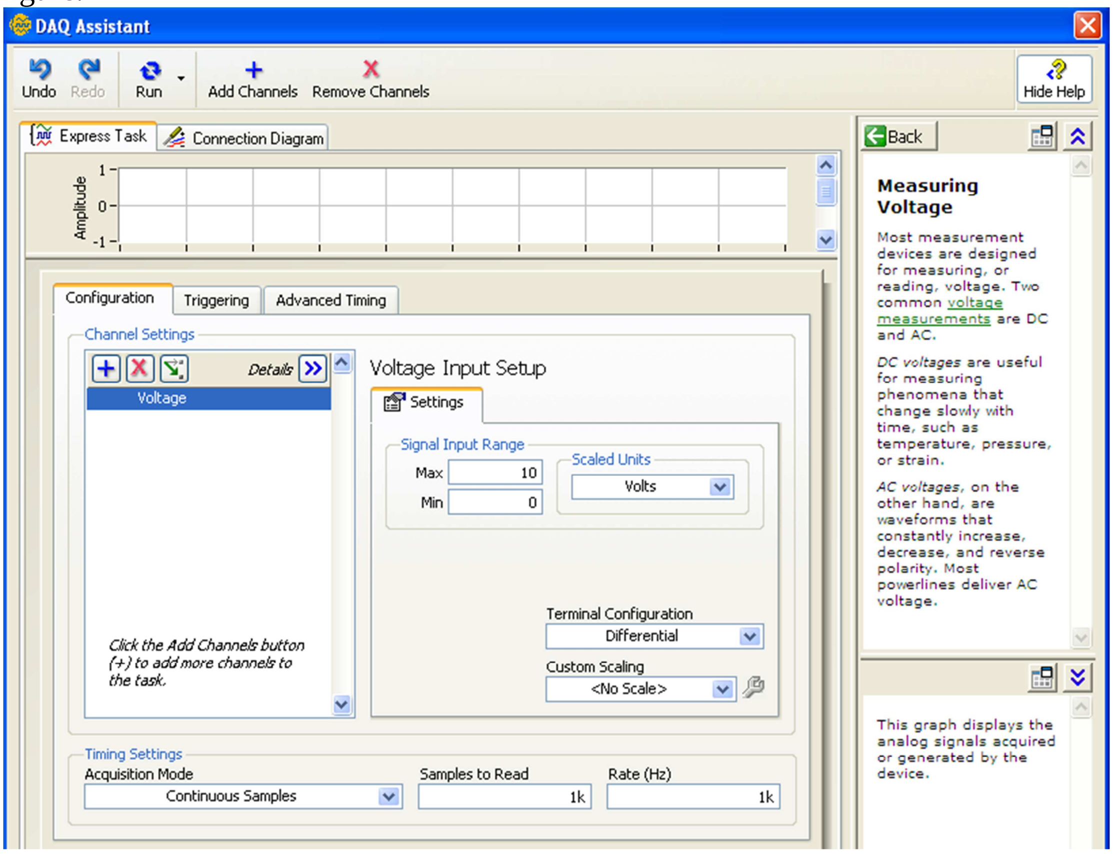


The range of the LDR resistance is 100 Ω-1MΩ

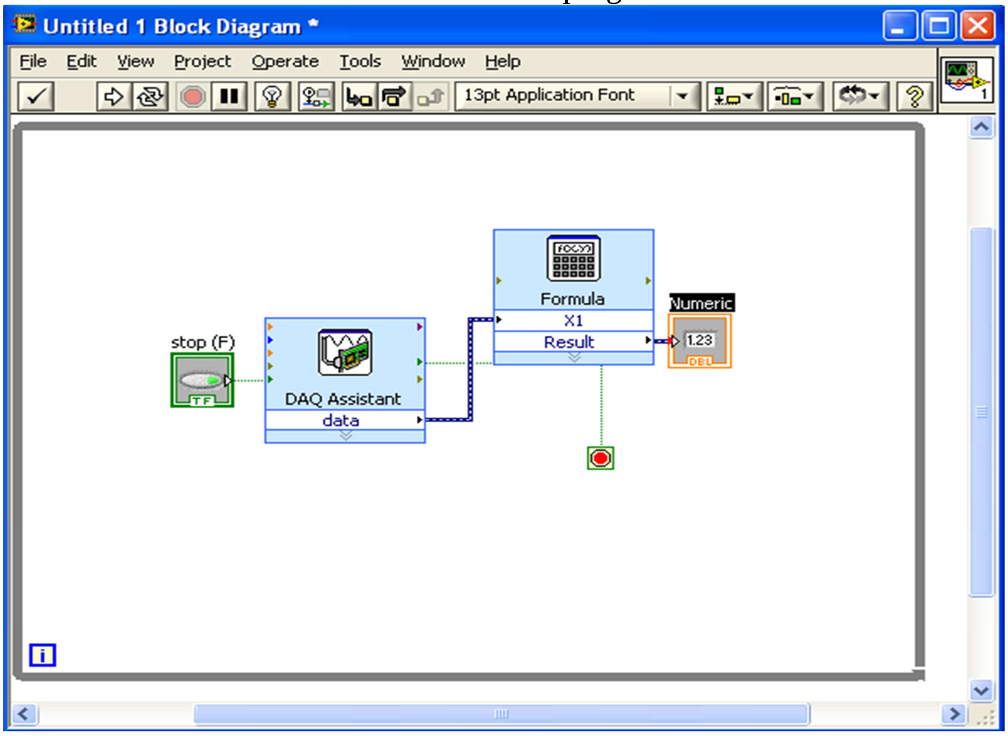
Q1: What is the maximum output voltage? Find the maximum output voltage you can get from the bridge.Is it suitable as input to the DAQ? Why?

take the output from the bridge as a differential input to the DAQ card see the manual for the DAQ, Open labview program in the block diagram window from view menu choose functions palette>inputs> DAQ assist. in the window that appears choose Acquire signals >analog input > voltage.

Select ai2 (analog input2) then click finish Then fill the values as in the following figure.



Now right click in the block diagram window select arithmetic and comparison>formula. Then right the equation then press ok.
Connect the signal out from DAQ to the input of the formula then right click on results select creat>numeric indicator as in the following figure
Right he furmula that represent the relation between the lux value and the voltage value then run the program.



References:

[1]http://www.engineeringtoolbox.com/light-level-rooms-d_708.html

[2]http://fetweb.ju.edu.jo/staff/Mechatronics/LShareef/MandI_files/11%20DC%20 Bridges/11%20DC%20%20bridges%20rev%203%20080425.pdf

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Experiment 5-2 : Signal analysis and processing using labview

Objectives:

To be familiar with signal processing toolkit in labview.

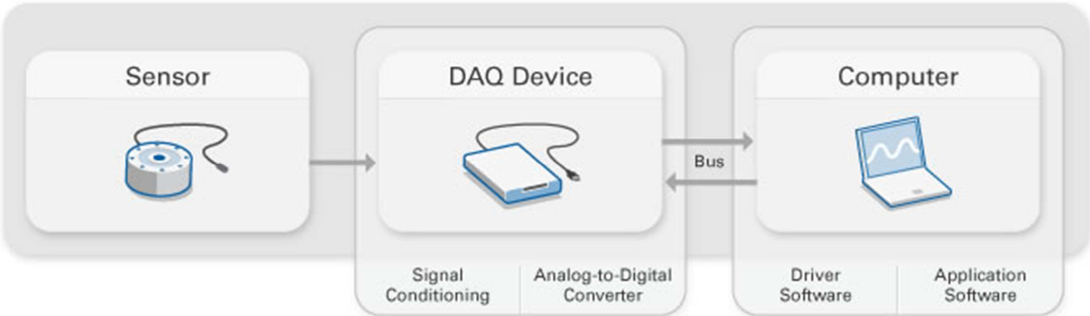
Be familiar with data acquisition system.

About labview:

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming language that uses icons instead of lines of text to create applications. In LabVIEW, you build a user interface by using a set of tools and objects. The user interface is known as the front panel. You then add code using graphical representations of functions to control the front panel objects. This graphical source code is also known as G code or block diagram code. The block diagram contains this code. In some ways, the block diagram resembles a flowchart.

What Is Data Acquisition?

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display, and connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution.

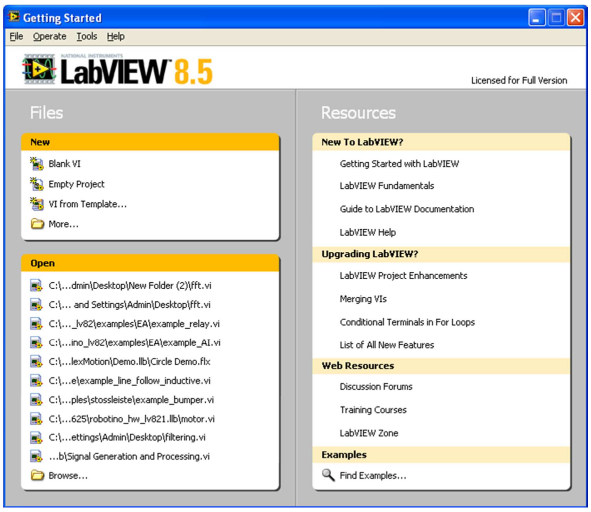


To read more see the following site:

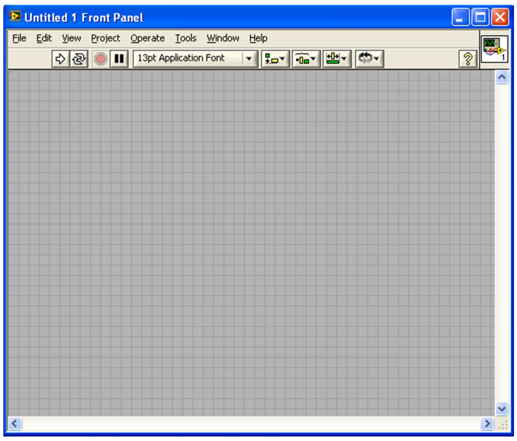
http://www.ni.com/dataacquisition/whatis/

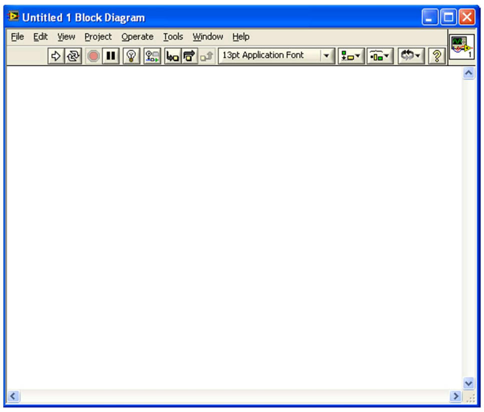
1. LabVIEW Fundamentals Manual, National Instruments.
   http://www.ni.com/pdf/manuals/374029a.pdf
2. Getting Started with labVIEW Manual, National Instruments.
   http://www.ni.com/pdf/manuals/373427c.pdf

Open the labview program then open a blank VI.

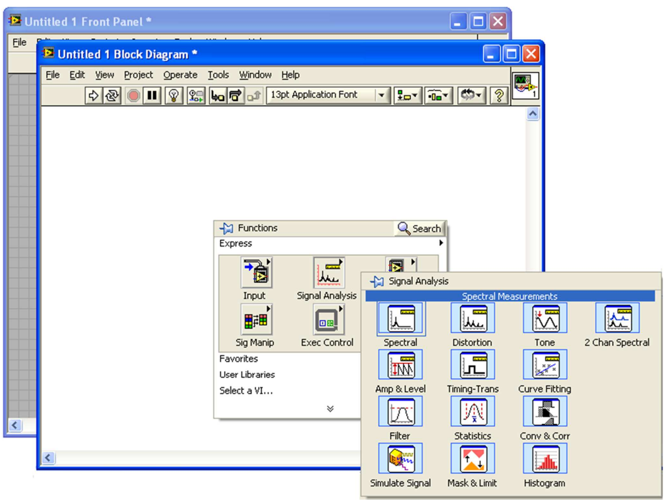


The following windows will be opened

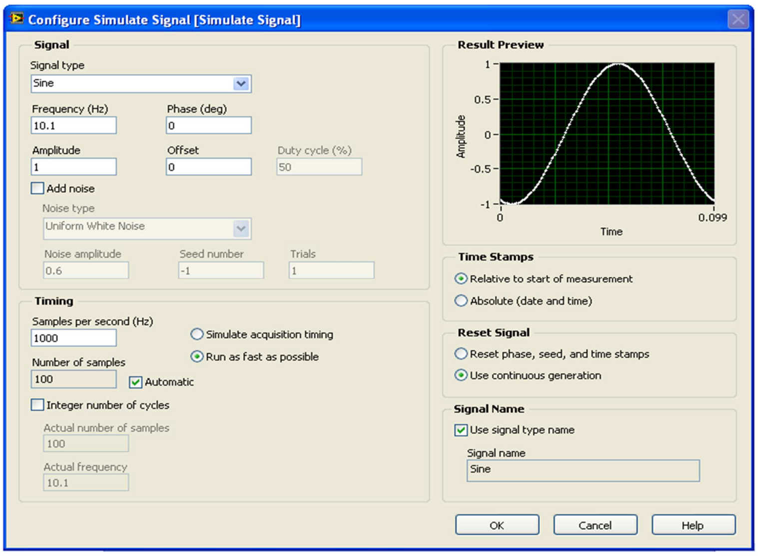




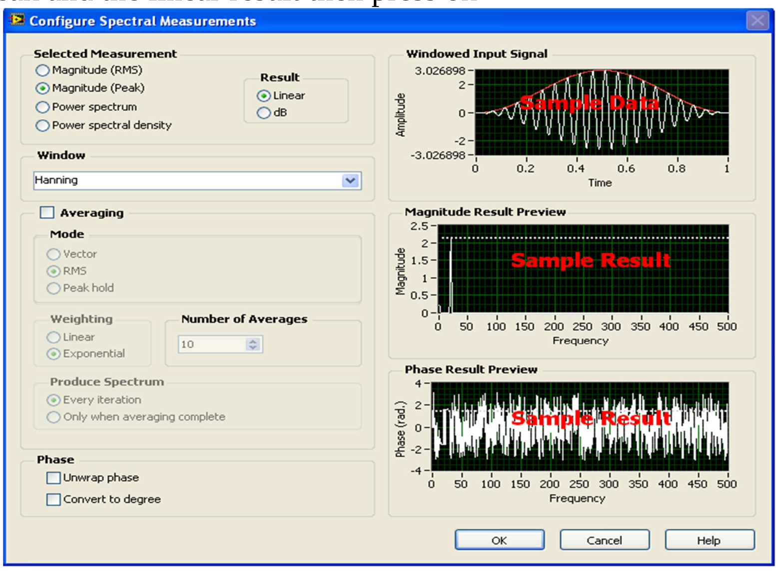
Right click in the block diagram window choose signal analysis>simulate signal.



The following window will appear choose sin wave with 400 Hz and amplitude 1V

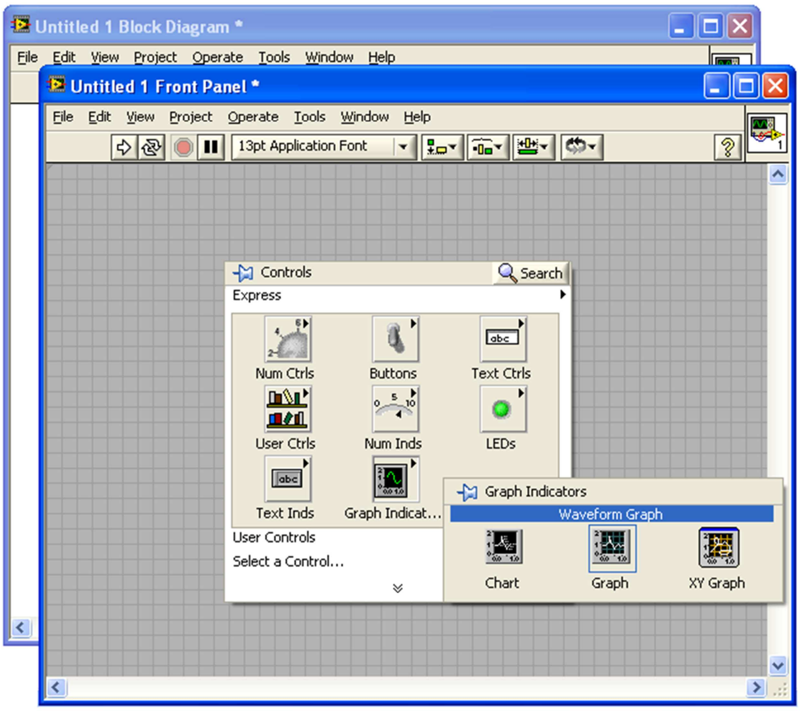


Again add another block but now let the amplitude be 2V and the frequency 50 Hz
At the same way from signal analysis choose spectral measurement block, select magnitude peak and the linear result then press ok

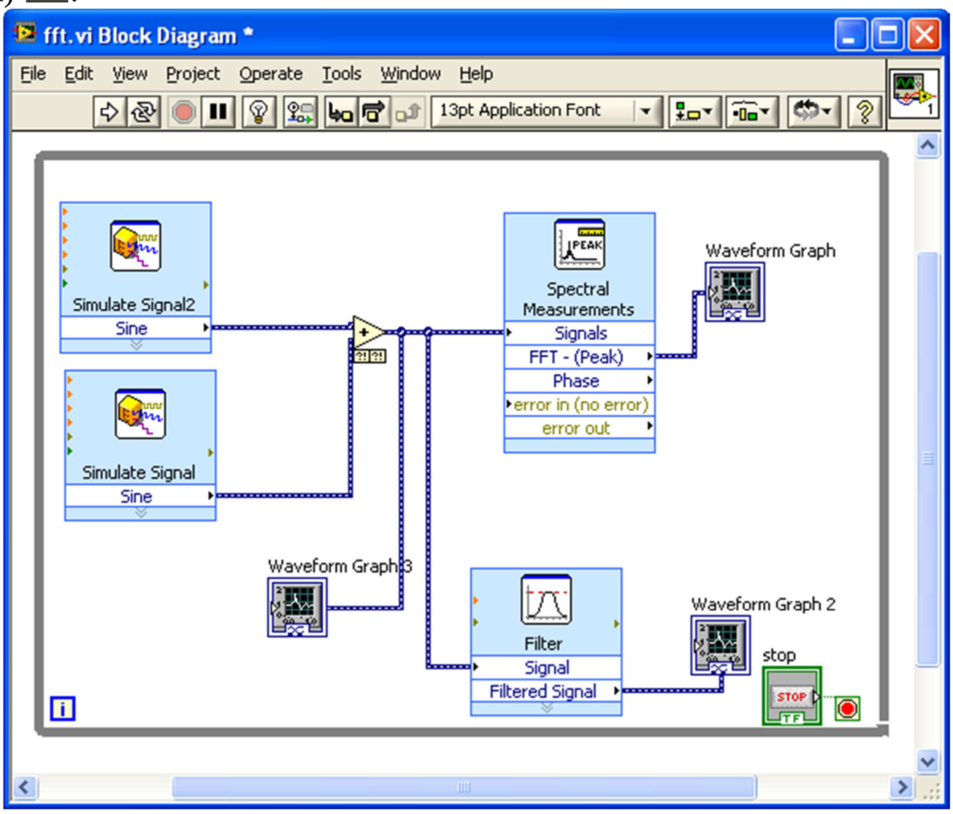


Now select filter block Use the suitable values for the filter sitting to remove the signal of 400 Hz. From arithmetic and comparison block select add.

From the front panel window right click and select graph indicators>graph, select three graphs.



Connect the blocks as shown in the following figure and click on (run continuously button) .



Comment on the graphs.

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Experiment 6: Filtering

Objectives:

-To be familiar with twin t-notch filter and low pass filter.

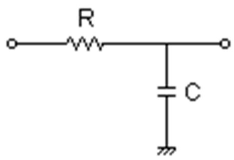
-To design low pass filter and twin t-notch filter with the suitable values to remove a noise signal of known frequency.

-To be familiar with signal processing toolkit in labview.

Introduction:

A filter is a device or process that removes from a signal some unwanted component or feature.

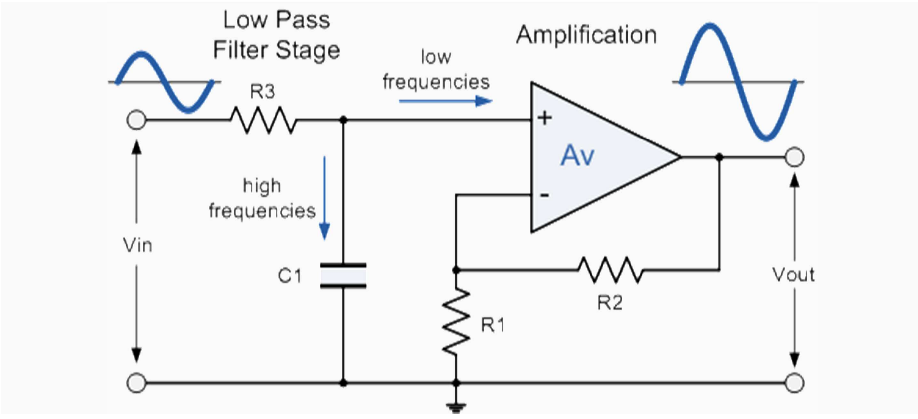
A low-pass filter is a filter that passes low-frequency signals but attenuates (reduces the amplitude of) signals with frequencies higher than the cutoff frequency.



RC low pass filters

$F_O=1/(2\pi RC)$

Active filter: is a type of analog electronic filter that uses active components such as an amplifier. Amplifiers included in a filter design can be used to improve the performance and predictability of a filter,[1] while avoiding the need for inductors (which are typically expensive compared to other components). An amplifier prevents the load impedance of the following stage from affecting the characteristics of the filter.Active Low Pass Filter with Amplification



The frequency response of the circuit will be the same as that for the passive RC filter, except that the amplitude of the output is increased by the pass band gain, A_F of the amplifier. For a non-inverting amplifier circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R_2) divided by its corresponding input resistor (R_1) value and is given as:

DC gain=$(1 + \frac{R2}{R1})$

Therefore, the gain of an active low pass filter as a function of frequency will be:

Gain of a first-order low pass filter:

Voltage Gain Av=$\frac{Vout}{Vin}=\frac{Af}{\sqrt{1+(\frac{f}{fc})^2}}$

- Where:
- A_F = the pass band gain of the filter, (1 + R2/R1)
- f = the frequency of the input signal in Hertz, (Hz)
- fc = the cut-off frequency in Hertz, (Hz)

Thus, the operation of a low pass active filter can be verified from the frequency gain equation above as:

1. At very low frequencies, $f < f$c, $\frac{Vout}{Vin} \cong A_F$

2. At the cut-off frequency, $f = f$c, $\frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707\,A_F$

3. At very high frequencies, $f > f$c, $\frac{Vout}{Vin} < A_F$

Thus, the **Active Low Pass Filter** has a constant gain A_F from 0Hz to the high frequency cut-off point, f_C. At f_C the gain is $0.707A_F$, and after f_C it decreases at a constant rate as the frequency increases. That is, when the frequency is increased tenfold (one decade), the voltage gain is divided by 10. In other words, the gain decreases 20dB (= 20log 10) each time the frequency is increased by 10. When dealing with filter circuits the magnitude of the pass band gain of the circuit is generally expressed in *decibels* or *dB* as a function of the voltage gain, and this is defined as:

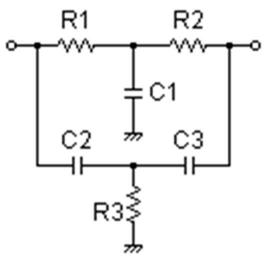
Magnitude of Voltage Gain in (dB):

$$\mathbf{Av(dB)=20log_{10}(\frac{Vout}{Vin})}$$

$$\mathbf{-3dB=20log_{10}(\frac{Vout}{Vin})}$$

A Twin t notch filter:

is a filter that removes unwanted frequency signals



Twin t notch filter

Where R1=R2,R3=R1/2

C2=C3,C1=2*C2

F_O=1/ (2πRC), R=R1=R2, C=C2=C3

Prelab.1:

Design a twin t notch filter that attenuates (reduces the amplitude of) signals with frequency 150 Hz, let C2=C3=1µF, C1=2 µF, Find R1,R2, R3.

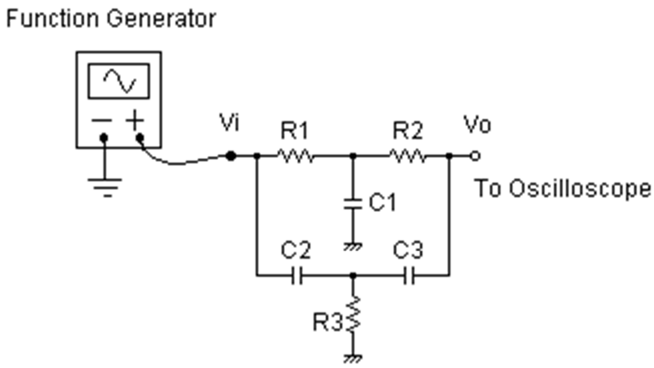
Prelab.2:

Design a non-inverting active low pass filter circuit that has a gain of two at low frequencies, a high frequency cut-off or corner frequency of 500Hz and an input impedance of 330Ω.

Part 1:

Connect the following circuit on the breadboard you have in the lab.

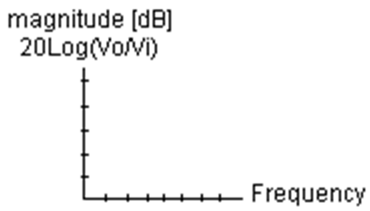
Vi=5V pk-pk, R1=R2=1.12 kΩ, R3=560 Ω, C2=C3=1 µF, C1=2 µF



Now vary the frequency starting from 10 Hz to 3KHz and complete the following table:

Frequency	Amplitude pk-pk	20Log(Vo/Vi)	Frequency	Amplitude pk-pk	20Log(Vo/Vi)
10			250		
20			300		
40			350		
60			400		
120			450		
130			500		
140			600		
150			700		
160			800		
170			1000		
180			1100		
190			1200		
200			1500		
210			2000		
220			3000		

Q1: Plot the gain magnitude versus frequency, using a *logarithmic* frequency axis

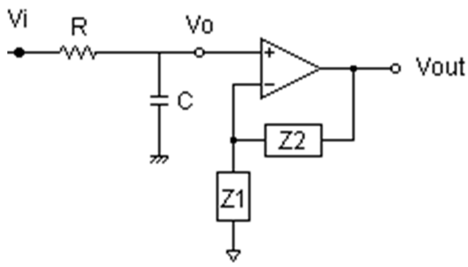


Q2: What is the center rejection frequency you got from the graph? Are the theoretical and the practical values are the same? If not, why?

Part 2:

In this part you will filter unwanted frequency using low pass filter.

Connect the following circuit with the filters element values as you found in prelab2.



Q3: Plot Plot the gain magnitude versus frequency, using a *logarithmic* frequency axis

Frequency	Amplitude pk-pk(Vout)	Vout/Vi (experimentally)	Vout/Vi (theoretically)	20Log(Vo/Vi)
50				
100				
150				
200				
250				
300				
350				
450				
500				
550				
600				
650				
700				
750				
800				
850				
900				
1000				

University of Jordan

Transducer Lab.

Exp.7: Thermistor

Objectives:

- Know that a thermistor has a negative temperature coefficient of resistance.
- Have noted the practical implications of the self-heating effect.
- Have produced a calibration curve for the thermistor.
- Recognize the term dissipation constant.

Introduction:

All electrical conductors possess resistance and in every case the resistance is to some degree dependent upon temperature.in most cases resistance increases with temperature rise and the change is usually an undesirable effect to be made as small as possible.

It is possible, however, to take advantage of this effect to enable temperature changes to be detected by it .in in this experiment, through,you shall study a device called thermistor (from Thermal Resistor)which has a very large and nearly always negative temperature coefficient. The applications for such a device extend beyond simple temperature measurements and are very numerous indeed.

There are two types: PTC (positive temperature coefficient) and NTC (negative temperature coefficient).
PTC: If the resistance increases with increasing temperature, the device is called PTC thermistor. PTC thermistors can be used as heating elements in small temperature controlled ovens.
NTC: If the resistance decreases with increasing temperature, the device is called NTC thermistor. NTC thermistors are used as resistance thermometers in low temperature measurements of the order of 10 K.
Thermistors are also commonly used in modern digital thermostats and to monitor the temperature of battery packs while charging

Steinhart-Hart equation

The Steinhart-Hart equation is a widely used for accurate temperature measurements:

$$\frac{1}{T} = a + b\ln(R) + c\ln^3(R)$$

where a, b and c are called the Steinhart-Hart parameters

B **parameter equation**

Resistance of the thermistor can also be characterized with the exponential function of temperature

$$R = R_o e^{B\left(\frac{1}{T}-\frac{1}{T_o}\right)}$$

Or

$$R = Ae^{\frac{B}{T}}$$

where **R** is the resistance of thermistor at the temperature**T** (in **k**), $\mathbf{R_O}$ is the resistance at given temperature and **B** is the material constant.

B parameter equation is essentially the Steinhart Hart equation with

$$a = \frac{1}{T_o} - \frac{1}{B}\ln(R_o)\ , b = \frac{1}{B}, \text{and } c = 0.$$

If we arrange the Eq. 7.3 into a logarithmic form, we get a linear function of

$$\ln(R) = \ln(A) + \frac{B}{T}$$

The temperature dependence of the resistance of a thermistor is shown in the following Figure. Ln(R) vs. 1/T is also given in the Figure As it is clearly seen, Ln(R) is linearly dependent on 1/T The slope of the straight line is B

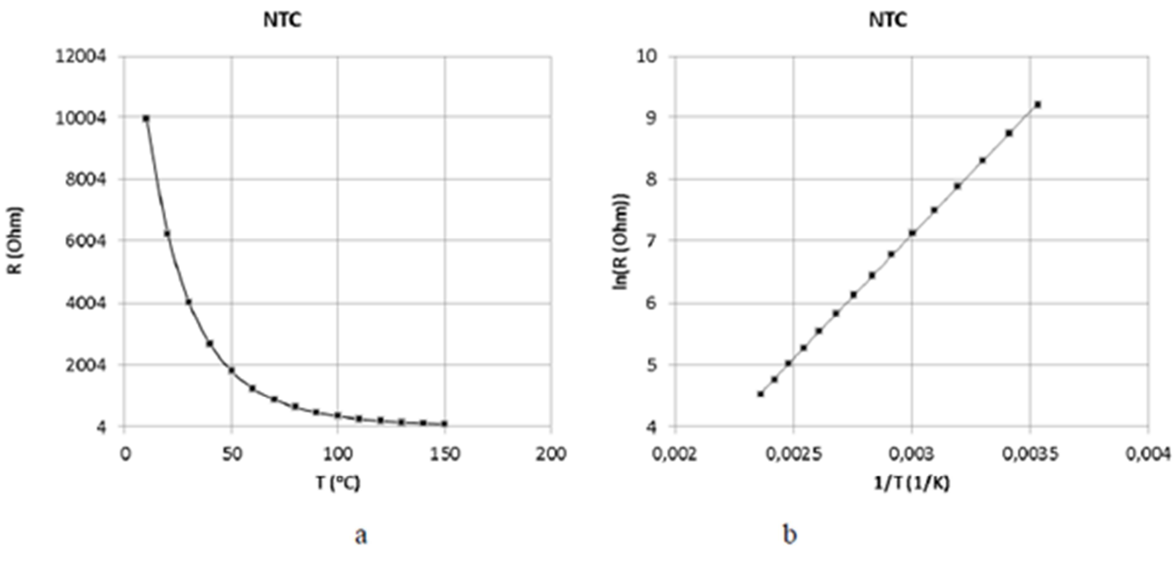
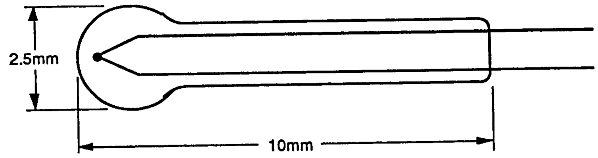


Figure 3.1 The temperature dependence of the resistance of a thermistor.

Q1: Mention some applications for the thermistor.

Thermistors are made from various metal oxide materials fired at a high temperature and appear in many different physical forms. the one used in this experiment although not visible inside its protective probe ,is a glass encapsulated bead of material supported on its connecting wires as shown in the following figure.



The resistance of a thermistor is dependent upon its temperature

The shape of the curve relating resistance to temperature is governed by an equation of the type

$$R = A_e^{\,b/T}$$

Where R : resistance in ohms

T :absolute temperatures

E:base of natural logarithms

A and b are constants

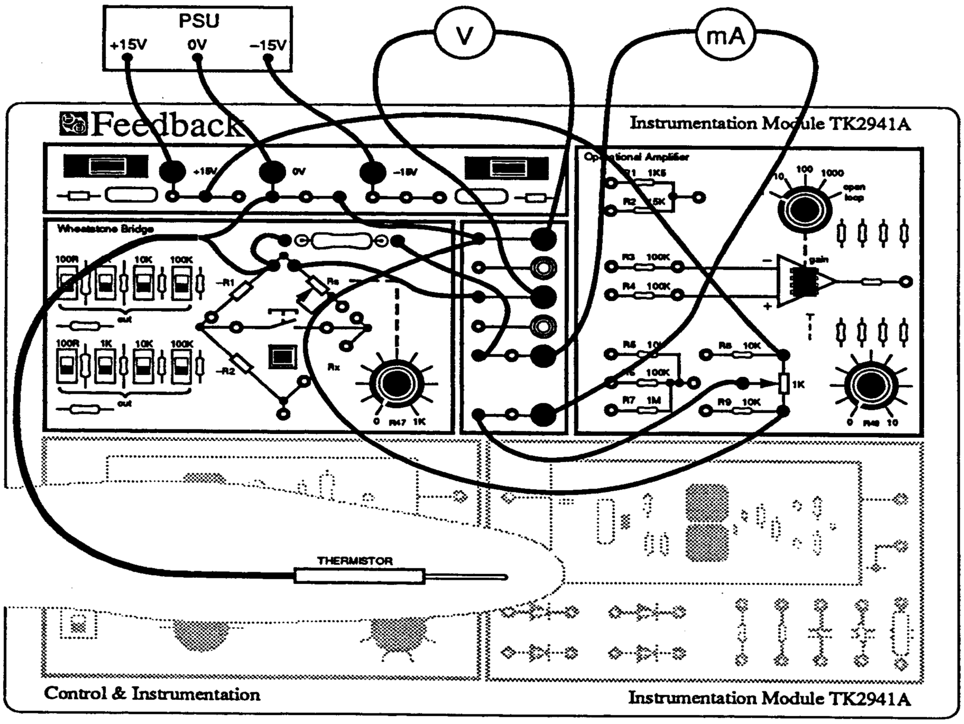
For the thermistor in this kit the value of R at 20C is about 2000 ohm and it varies with temperature as sketched in the following figure, shortly you will plot such a curve experimentally .

We must ensure that whatever measuring circuit we use does not appreciably heat up the thermistor, thus giving an artificially high temperature not representative of its surroundings.

This effect is called 'self heating', in some applications it is deliberately used but in most it must be kept small. But how small? This question should be answered before calibration .so first we will determine how the resistance changes when power is dissipated in it by a current.

Part1:self heating

connect the circuit shown in the next figure.



Note that the potentiometer set to zero and switch on the power supply.

Note: the current taken by the voltmeter, although small may need to be taken in to account to obtain accurate results as follows:

I: measured current

V : measured voltage

Ifs: voltmeter full scale current

Vfs: voltmeter full scale voltage

The thermistor current:

$$I' = I - \frac{V}{V_{FS}} \times I_{FS}$$

And the thermistor resistance

$$R = \frac{V}{I'}$$

The power dissipated in the thermistor is $V \times I'$.

For this experiment it is referable that the ambient temperature is fairly constant over the period of the readings. Use a mercury thermometer to read room temperature.

Now increase the variable dc supply using the potentiometer to set the current to the values shown in the following table after each change of the current wait at least 1 minute before recording the voltage.you have to be careful at the higher currents because having changed the voltage the current will go on increasing for a while as the thermistor heats up and reduces in resistance.

Note: do not allow the current to exceed 20 mA.

Q2: Why the 220 ohm resistor is used in series with the probe?

I(mA)	V (V)	R=V/I (kΩ)	P=VXI
Air			
1			
2			
4			
10			
15			
20			
Water			
1			
2			
4			
10			
15			
20			

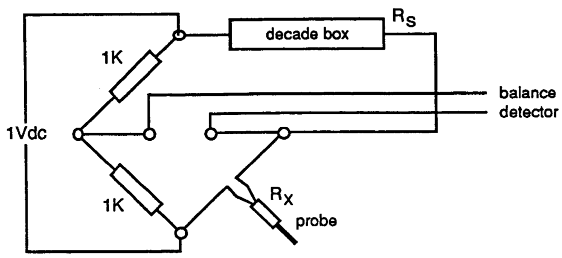
Q3: Plot a graph R versus P for both sets of readings .

Q4: Discuss the differences between the curves obtained for air and for water.

Q5: How many mW of power can safely be dissipated in the thermistor without lowering its resistance by more than 1% of its starting value for air and for water?

Part 2: calibration-zero power measurement

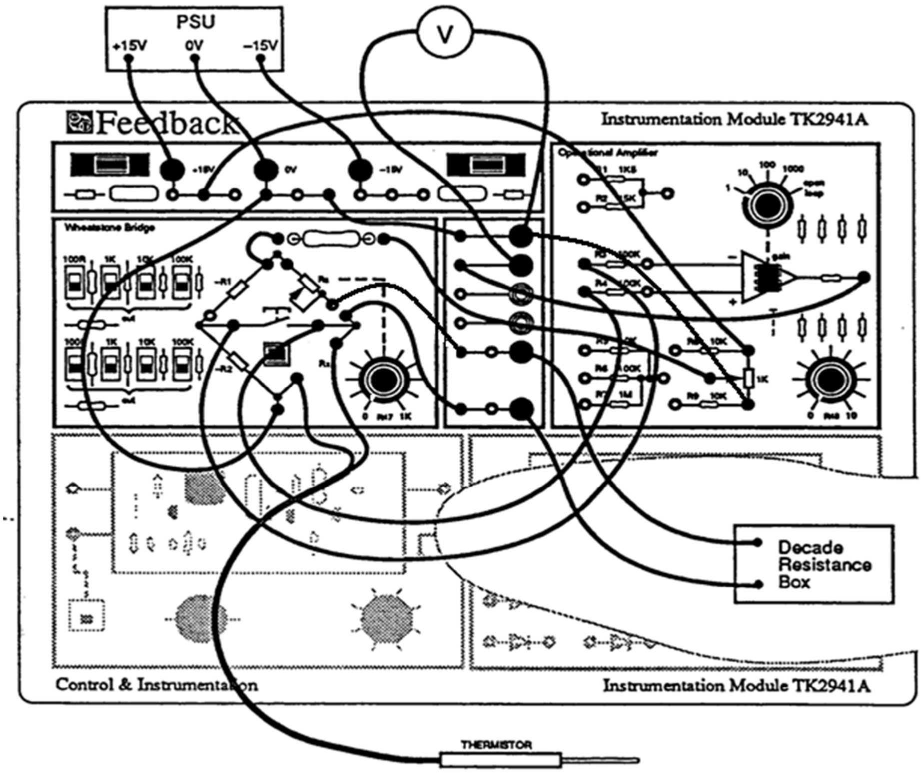
To calibrate the thermistor we wish to place it in the calibration tank with a mercury thermometer and heat the water to various temperatures, measuring the thermistor resistance at each point by means of a Wheatstone bridge. Suppose we used an equal ratio bridge excited by about 1 V as follows:



At balance the voltage across Rx will always be half the supply that is 0.5 V . if Rx should fall to say 100 ohm when heated externally the power dissipated would be 0.5^2/100=2.5 mW.

Q6: Is this more or less than your upper limit allowed in answer to Q5?

Connect the following circuit:



Q7: What is the maximum power is now dissipated in the thermistor at balance?

In the wheatstone bridge set switch SW3 and SW6 ‘in’ and all other switches ‘out’.

Switch on the power supply and set the potentiometer to give 1 volt dc across the bridge circuit.

We are now in a position to make measurements of the thermistor resistance at different temperatures with negligible self-heating . this is often called zero power measurement.

Insert the thermometer and the thermistor in the water tank and and fill the following table, when the thermometer is steady at room temperature balance the bridge and note the temperature and resistance. Clip the tank to the heat bar at notch 20 ,wait until the temperature stabilized and rebalance the bridge to read the thermistor resistance.

Notch no.	Temperature C	Resistance(ohm)	Temperature(K)	1/T	Ln(R)
20					

18					
16					
14					
12					
10					
8					
6					
4					
2					

Q8: Plot a graph for R versus temperature.

Q9: Is the curve linear?

Dissipation constant

When a thermistor is to be used in a temperature measurement or control system there will be two conflicting requirements.

Greatest possible sensitivity from the detector circuit requiring as large an energizing current as possible.

Limited error, implying a limit to the self heating effect.

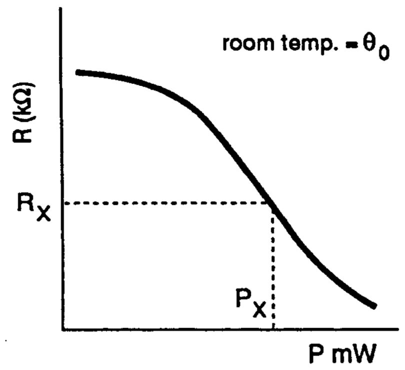
The dissipation constant is a parameter which helps to resolve this conflict by specifying how much power can be dissipated by the energizing current without causing more than the permitted amount of self heating.

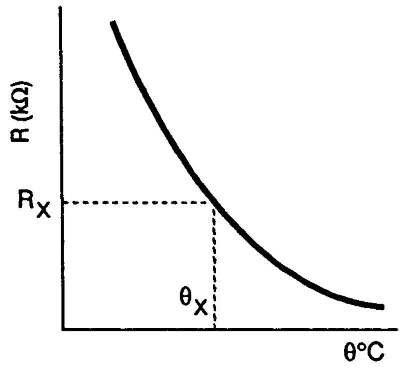
It is defined as:

Dissipation constant= mW of power dissipation which will cause a temperature rise of 1 C.

Obviously the value of the constant will depend upon the thermal conduction characteristics of the medium in which the thermistor is situated because if this is high more power will be needed to rise the temperature by 1 C than if it is low. That is why you obtained different curves in part 1 q4..

Those curves show how resistance varied with power dissipation whilst the curve you have just obtained in part 2 showed how resistance varied with temperature. We can thus combine the information from these two graphs to show how the thermistor temperature is affected by its power dissipation the following figure shows typical graphs

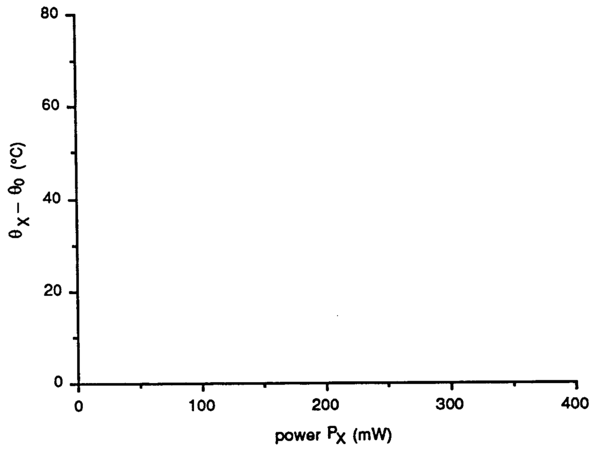




By taking a number of values of Rx at arbitrary intervals you can find corresponding values of Px and Θx

Θx is the actual temperature of the thermistor when ambient temperature is Θo and it is dissipating a power Px. Thus Px causes an increase in temperature above ambient of (Θx- Θo) C

Q9: Find Px, Θx and (Θx- Θo) for About 8 values of Rx noting in each case for each of the two graphs (in air and in water)from part 1. Now plot Px(air)and Px water against (Θx- Θo) as follows:



From the graph work out the slopes in terms of mW per C for air and water. These slopes are the dissipation constants for the two conditions.