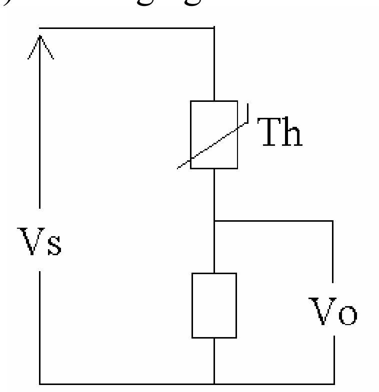
INVESTIGATING A THERMISTOR

After deciding to investigate the properties of a thermistor, I chose to be more specific, and to look at repeatability, accuracy, and sensitivity. I also thought of many different ideas as to what the experiment could be used for: for fridge…??? controlled???. The proceeded by looking at different circuits suitable for exploring sensitivity. I looked into the 'whetstone bridge' circuit:

The wheatstone bridge circuit enables more accurate readings,

However, I decided on another circuit that acted as a potential divider only using one fixed resistor, which seemed equally suitable for detecting small changes of volts. The reason for this being that I thought it would be interesting to see the effect(s) of changing the fixed resistor (R):



After recognizing the importance of (R), I decided on the equipment I was going to use, and then tried using some algebra to tackle the problem of finding the value of R that would give me the biggest change DV_o.

Equipment:

1 power generator set at 2volts

1 thermistor (RS 0.47Kohms 232-4538)
an assortment of fixed resistors
some leads
some crocodile clips
a digital voltmeter

Here are my jottings:

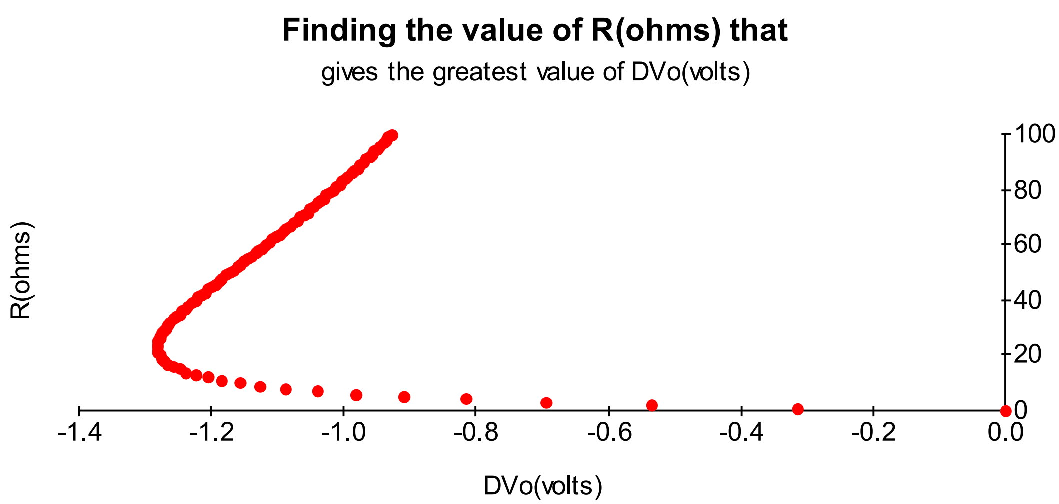
$V_o/V_s=R/R+R_{Th}$

$V_o=V_s(R/R+R_{Th})$

$\triangle V_o=V_{o\ t2} - V_{o\ t1}$

$\triangle V_o=V_sR[1/ R+R_{Th\ t2} - 1/ R+R_{Th\ t1}]$

At this point I thought it appropriate to take a numerical approach, and use Excel to plot a graph of the equation as I was having difficulty simplifying or manipulating it further. For $R_{Th\ t1\ and\ 2}$ I put in 5 and 105, as an RS data sheet showed these to be the values at 100 and 0 degrees.



This graph suggests to me that using a fixed resistance of about 25ohms would produce the highest value of DV_o, and therefore would produce the most sensitive readings. However, I suspected that the resistance of the fixed resistor should be roughly equal to the thermistors resistance (0.47Kohms), so I used the internet, and found that the ???? website stated:??????????????????. Due to these conflicting ideas, I decided to perform the experiment using a range of thermistors.

The problem of self heating then occurred to me, which is extremely important as the thermistor responds to temperature. So to address the problem I used some more algebra:

$V=IR$

Which can be written as $I=V/R$

$P=I^2R$

Therefore $P=(V/R)^2R$,

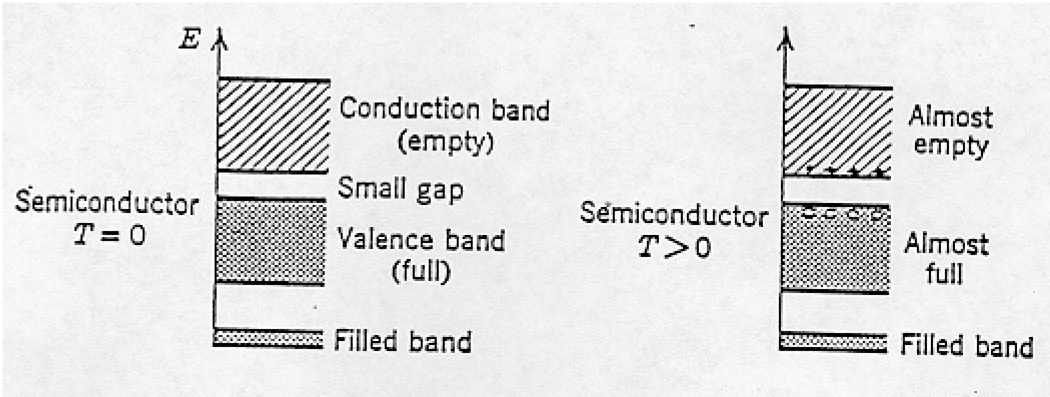
so subbing in V and R (or R_{th}) I get $P=(2/470)^2x470=8.51E-3W$

Because the power is in micro watts, there is no reason why my experiments should be noticeably effected by the thermistor's self heating.

I thought of any other ways that may lead to an unreliable experiment, which lead me to thinking how I was going to accurately control the temperature for the thermistor. At first I thought the logical solution was to use a water bath, however these are cumbersome and slow, so my next idea was to use a hairdryer, and to place a thermometer by the side of the thermistor. I then could have positioned the hairdryer at different distances from the thermistor (creating different temperatures). However, due to the fact that the air is a poor thermal conductor I decided to small beaker of use distilled water (as it is a poor electrical conductor and as explained below the temperature can easily be kept constant throughout the beaker). I also decided to boil the water to increase the temperatures.

After looking at aspects that may effect the reliability, I thought about any safety precautions I may have to take. However, due to the fact that I am only using 2volts, I thought that there are few precautions I must take, except to be careful with the boiling water, and to make sure that there is no chance any of the water may spill into the power supply.

I then decided to investigate the reasons for the resistance changing which temperature, and looked at the band gap theory to get an idea of what was happening at the atomic level. The band gap theory suggests that electrons can be moved between 'bands' when heat is applied, with the band of highest energy states being called the conduction band, and the energy band just below is being called the valence band:



This theory suggests that the absorption of energy by the semiconductor (thermistor) can boost electrons from the valence band to the conduction band (if the energy is at least as large as the energy gap). In the ideal situation of T=0 K, the conduction band is completely empty. As the temperature is raised, some electrons get enough thermal energy to ‘pop up’ into the conduction band. Therefore, due to the fact that electrical current consists of the movement of electrical charge, electrons in the conduction band are able to move from atom to atom and so contribute to electrical currents.

However, not only does the conduction band contribute to these currents,- as an unoccupied state in the valence band is called a hole, an to compensate for this, electrons in the valence band move to fill the ‘hole states’. Bellow are a few diagrams to illustrate this:

Experiment:

After gaining my background knowledge, and after doing my planning, I felt I was ready to start my experiments. I decided to produce more accurate results, that I would take two sets of results, which would also help to test for repeatability. I started by testing the 470ohm resistor, and the results are as follows:

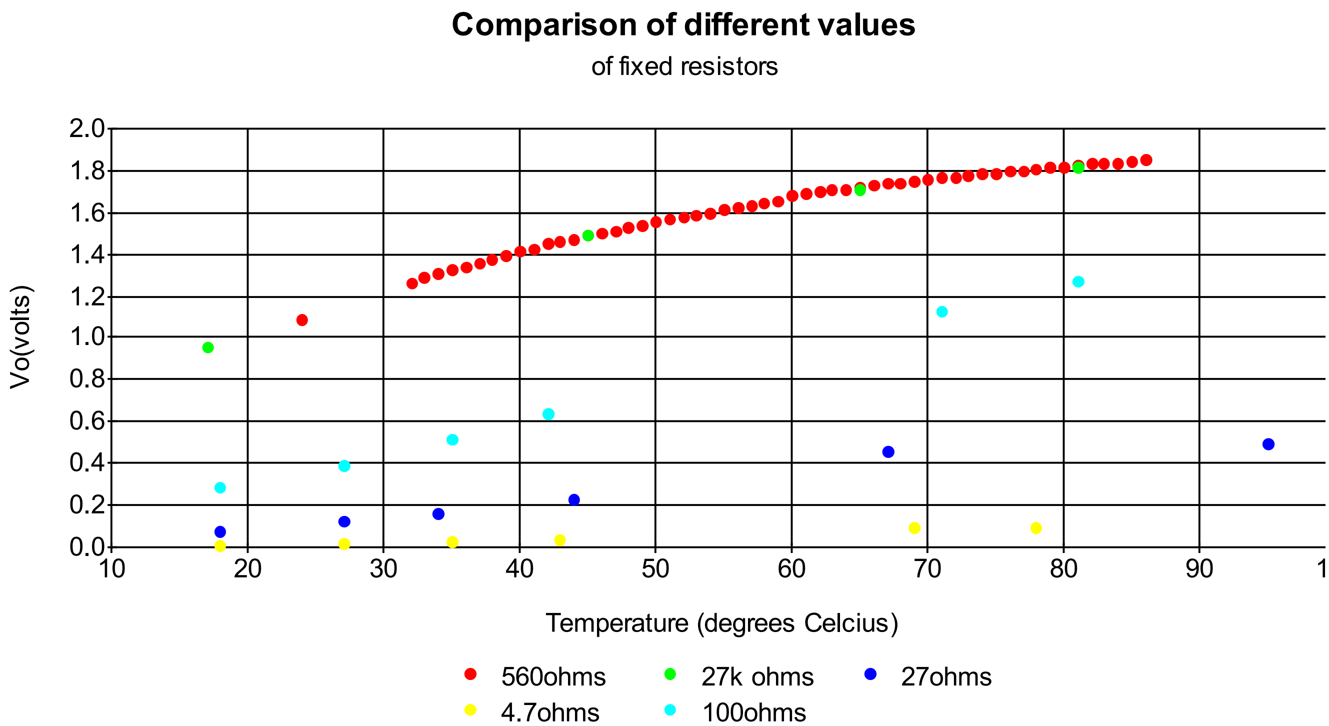
Vo(volts) set 1	Vo(volts) set 2	Average Vo	Temp. (degrees Celsius)
1.86	1.86	1.86	86
1.85	1.85	1.85	85
1.83	1.85	1.84	84
1.84	1.84	1.84	83
1.83	1.85	1.84	82
1.83	1.83	1.83	81
1.82	1.82	1.82	80
1.82	1.82	1.82	79
1.8	1.82	1.81	78
1.8	1.8	1.8	77
1.8	1.8	1.8	76
1.79	1.79	1.79	75
1.79	1.74(void)	1.79	74
1.77	1.79	1.78	73
1.77	1.77	1.77	72
1.77	1.77	1.77	71
1.75	1.77	1.76	70
1.75	1.75	1.75	69
1.73	1.75	1.74	68
1.74	1.74	1.74	67
1.73	1.73	1.73	66
1.71	1.73	1.72	65
1.7	1.72	1.71	64
1.71	1.71	1.71	63
1.7	1.7	1.7	62
1.7	1.68	1.69	61
1.68	1.68	1.68	60
1	1.66	1.66	59
1.65	1.65	1.65	58
1.65	1.63	1.64	57
1.63	1.63	1.63	56
1.62	1.62	1.62	55
1.59	1.61	1.6	54
1.59	1.59	1.59	53
1.58	1.58	1.58	52
1.57	1.57	1.57	51
1.56	1.56	1.56	50
1.54	1.54	1.54	49
1.53	1.53	1.53	48
1.51	1.51	1.51	47
1.5	1.5	1.5	46

1.5	1.48	1.49	45
1.47	1.47	1.47	44
1.46	1.46	1.46	43
1.45	1.45	1.45	42
1.43	1.43	1.43	41
1.42	1.42	1.42	40
1.41	1.39	1.4	39
1.38	1.38	1.38	38
1.36	1.36	1.36	37
1.34	1.34	1.34	36
1.33	1.33	1.33	35
1.31	1.31	1.31	34
1.29	1.29	1.29	33
1.26	1.26	1.26	32
1.09	1.09	1.09	24

When doing the second set of results the tape holding the thermistor in the water came undone on 74 degrees, causing the resistance to decrease as it tried to adjust to room temperature, so I thought it best to disregard this result and take the value of from the first set.

Also, before taking the results I realized that to obtain accurate and reliable results that I must stir the water, so that the temperature stays constant throughout the beaker. I also saw it necessary to clamp the thermometer so it could be positioned at the same height to the thermistor, as I thought that although the mixture was being methodically stirred, temperature might vary at different depths of the beaker.

After performing the first experiment, I thought that as well as using 25ohms suggested by my algebra, I would do experiments with 5 and 105ohms (shown to be the extremes on a RS data sheet (that can be found in the appendix). I was also curious if, as suggested by this data sheet (done of logarithmic scales), there was little difference between fixed resistors of high value, so I also tested one of 25k ohms. However due to the fact that I didn't have a great deal of time left, I only took one set of results for these experiments (the results above also suggest little need to take two sets of data, as the two sets are extremely similar). I turned these, along with the results above into a graph (the raw data can be seen in the appendix):



This graph shows some very interesting results. For a start, there appears to be very little difference between the values of V_o for 560ohms, and 27k ohms, as suggested by the RS data sheet. I then considered adding error bars, however, for temperature I would only add + or - 0.5 degrees, and the inherent uncertainties of the digital voltmeter is only + or - 0.01 volts. Due to the minimal changes I opted to leave out error bars, but still think the results are sufficient to conclude that there is little difference between the 560ohm and the 27k ohm fixed resistors.

Although my algebra suggested that the 27ohm resistor would perform most sensitively (measured by the gradients), I found it to perform consistently (shown by the fairly steady slope), but by no means was it most sensitive. I was also under the impression from the RS data sheet that the 5 and 105 ohm resistors would perform most sensitively at the extremes, which appears correct, however I have no idea as to why the gradient of the 100 ohm resistor is steepest at high temperatures and not low temperatures suggested by the data sheet. The 5 ohm resistor appears not very sensitive as the slope is not very steep. Although relatively, it appears to be most sensitive at low temperatures, opposite to that of the 100 ohm resistor, which

I still did not expect. To try and justify my results, I went back to my equation

$\triangle V_o = V_s R[1/ R+R_{Th\ t2} - 1/ R+R_{Th\ t1}]$

However I manipulated it to give me the specific value of R_{Th}, not a range of values:

$\triangle V_o = V_s R[1/ R+R_{Th}]$

I proceeded to plot these graphs on Excel:

I was then faced with the problem of converting 'resistance of R_{th}' into temperature, and at first thought that the best way to do this was to was by finding the equation of the line of the calibration graph provided by RS. However, I faced with the problem of logarithmic scales, and due to the large jump in numbers, thought that the equation I produced would not be accurate enough. However, from the 5 ohm graph is clear that DV_o increases rapidly with low values of resistance, which still contradicts the calibration graph. The graph of the 100ohm resistor is harder to tell which for which values gives a sharp increase in DV_o, as the curve is quite steady. Therefore I am none the wiser as to why my results given do not indictate that 100ohms is more sensitive to low temperatures, and 5ohms is more sensitive to high temperatures.

Unfortunately I ran out of time with this project, however I would have liked to have taken more readings, and a second set of results for the experiments above. However, I do think that they were sufficient to conclude that the thermistor has good repeatability, and also that there was little difference between using the 560ohm and 27k ohm fixed resistors. Also, from the fixed resistors I evaluated, 100ohms appears to be the most sensitive.