Digital micrometer

For my sensing project I decided to make a Digital Micrometer. I use analogue micrometers quite often in design technology but I always find it a long and time consuming process to read off the scale and find the reading that the micrometer gives. I am planning to make the micrometer accurate to microns as all micrometers should be, however this will require a great deal to calibrating and will require highly accurate test equipment. The project will measure distances using an accurate linear potentiometer. Therefore in short my project is to calibrate a linear potentiometer so you can reliably measure changes as small as a micron.

Plan:

In order to set up my micrometer I will need the linear potentiometer which the physics department already has. This potentiometer is mounted on a stand with the measuring arm sticking straight out into a large screw thread with a low pitch. With this setup I will be able to push the potentiometer in with the screw thread, therefore giving a simple yet reliable way of getting precise positions on the potentiometer. With these precise known distances (which will become thicknesses) I can take a reading through the potentiometer which will be proportional to the position of it. To take the readings I will have to connect up the potentiometer in a circuit. Because it is a potentiometer there are three terminals. With these terminals voltage is fed into one terminal at 5V and 0V into another. The third terminal is the output and will be connected to the 0V rail through a voltmeter which will give the readings required. The circuit will be set up as follows:

With this circuit the voltage flowing through the voltmeter will vary from 0-5V depending on how far in the linear potentiometer is pushed therefore the system can be easily tested to see what voltages the different thicknesses give. The Voltmeter needs to be both accurate and reliable in order to calibrate the project properly. The system will be set up using a 5V regulated power supply a multimeter and four 4mm banana plugs. This simplification in the design will hopefully reduce any errors, and make problems easy to spot.

The results taken at regular intervals of 1mm can then be analysed and using statistical formulae the equation of the graph can be calculated along with the mean square error. The equation gained from the results and calibration can then be used to work out the thickness of the test sample in mm from a voltage readout. Once the micrometer has been constructed and calibrated it can be tested using slip gauges which are highly accurate thicknesses of metal which you slip together to make different thicknesses.

Practical:

When it came to construction it became apparent that getting 1mm thicknesses was going to be very difficult as there was an absence of larger slip gauges. The sets only went up to . 6mm and were rather rusty, therefore a better way of changing the thickness was needed. The screw thread was screwed in until it met the potentiometer and then screwed in 2 full turns to create a safe starting point. The screw handle has a large cross painted on the end of it separating the head into quarters. This cross was aligned with the thickest line pointing upwards and then the plan was to screw it in one full turn at a time, each turn would then have the voltage produced recorded and plotted onto a graph.

It also became obvious that the voltmeter was not accurate enough to measure a micron as the scale which suited the readings the best only showed two decimal places. To attempt to overcome this problem the data logging was set up on the computer to record voltages. A voltage sensor which ranged from 0-15V was found and plugged into an Easy Sense box. After setting up, it became apparent that the sensor was only sensitive to 1 decimal place and to increase the sensitivity a different sensor was needed which we did not have. It was soon realised that if the results were spread over 15V rather than 5V the results would be measured three times more sensitively.

The multimeter was not giving reliable results as the battery would wear down slowly and affect the readings, however the data logging was being highly reliable and wasn't flickering or changing at all. At this point an Op-Amp was found and set up as an amplifier to give the results a larger scale. The multimeter measured up to 20V and the data logging to 15V so the results needed to be amplified by 300% in order to fill the range of the sensor.

The op amp was set up successfully however it was quickly getting saturated with the higher voltages and making the graph appear less accurate. The results were higher at the end than the beginning producing a curve rather than a straight line. Therefore to save time the op amp was scrapped and a better idea used.

The quickest and simplest way that could be thought of increasing the range by 300% was to change the 5V power supply for one three times more powerful, a 16V one. This immediately changed the results and the range just as expected and gave a much larger range of results. In order to increase accuracy even more the frequency of each result was also increased to one reading for each quarter of a turn, giving readings once every 0. 255mm.

Due to the nature of a linear potentiometer it was expected that when plotted on a graph the results would give a straight. The Mean square error of the results (how far they are away from the curve) would show up any of the inaccuracies. All random error would become apparent from the graph, but any systematic error caused by poor setting of the home point would be harder to track down however, the graph should cross at 0, 0 so if it does not, then systematic error should have caused that.

When the experiment was carried out the following results were noted down, the first sheet is from the original 5V system and the second set from the more complex 15V data logged set, the third sheet shows the results obtained using the multimeter, which gives a higher number of decimal places and is more sensitive, but it is less accurate and less reliable.

Analysis of results:

The original calibration table was small, inaccurate and unreliable with only 11 readings each accurate to 0. 01V with this data plotted on a graph an equation could be found but it would not be as reliable as the second set of results which were taken using the data logging software thus making them extremely reliable but just not very sensitive as the steps in voltage are too large. However this sensitivity problem can be easily solved when the data is plotted onto a graph, as the stepping and rounding of values should not effect the equation which the computer gives too much. The mean square error will be higher but the data should still be good and useful because it is reliable. The last table of results was the simplest to measure, but may not be the most reliable due to too many factors which could have affected the results. E. g. Battery level, difference in different voltmeters and display flicking between values when the system is stationary.

The next step was to find out the equation which was needed to get the appropriate distance from the voltage which has been measured. In order to do this, the data from the voltmeter 0-15V experiment was used. This data was fed into software titled graphical analysis and then different curves were calculated by the computer to give an equation and a mean square error.

It appears from the data that a polynomial curve fits the data much better than a linear curve, which goes strongly against the original predictions. Therefore the equations of each graph were used and the data from the experiment fed into them, to see which gave to most accurate results. When the linear result was fed in, the result was very close to the result from the original experiment. However the polynomial gave an answer much higher and further out than the linear curve. From this it was decided that the polynomial curve was obviously really close for some results yet much further away for others. On average this gives a much lower mean square error, but the linear curve will have had more similar errors thus making it much more reliable across the range of results. The 36 results of the data logged experiment gave a straight line graph which is included at the end as a full page landscape graph.

This graph gives the equation of the line to be: y = 1. 5331 x + 0. 5474. This gives the formula in the wrong form as we need to know the x value by putting in the y value. Therefore the inverse of the graph is required which is: x = (y - 0. 5474)/1. 5331 the axis of the graph are as follows: x= Distance (mm) and y= Voltage (V) Therefore the basic formula which can be used to calculate the thicknesses put into the gauge but putting in the voltage readout is:

This formula can now be used to test the micrometer with the slip gauge set which was collected at the beginning of the project, however before this experiment started it was important to clean the slip gauges first as they had built up a large amount of rust and corrosion due to being stored incorrectly, this makes this an unfair test. The results are expected to be slightly high due to the rust making the slip gauges slightly thicker but in order to compensate this, one slip gauge was measured and then the system was calibrated by moving the zero point using the screw thread. The stock was screwed in approximately 1/16 of a turn in order to get the reading to be as it should.

The thickness printed on the slip gauge was out into the first formula and the voltage required was reached by adjusting the stock. This enables the micrometer to have a tare function like on digital scales and will also allow the gauge to be calibrated after the calibration period in a company to see if it has slipped or if it is still accurate. The main problem was that this equation was gained from the data logging which was less sensitive, however to get the thickness accurate to 20 microns a voltmeter was needed set to measure very small changes in voltage. However this makes the reading less accurate due to the problem of volt meters and lack of uniformity in voltage measuring.