ELR 4202C PROJECT

THE HAND TREMOR DISPLAY MODULE

OVERVIEW:
This project will use a piezoelectric transducer to create an electrical signal that indicates the position of the hand during cyclic movement, such as tremor and activity. This signal will be processed to produce a display of that movement on a 10-LED bar graph. Each team will design and fabricate a module, submit a written technical report and make a Powerpoint presentation and movie with a demonstration of its operation in addition to a live demonstration during the presentation.

There are three aspects of this project to be divided among your team members:

- **Report on the clinical aspects of different tremor types**
- **Create a mechanical interface between the subject and the transducer**
- **Design, fabricate and test the electronic module**

A. Clinical Research
Search the literature to determine the types of hand tremor, being especially aware of pathological vs benign conditions. Determine the appropriate frequency ranges to be covered. Also be aware of the conditions of the subject that may modify the signals. These conditions may include whether the subject is looking at the hand, whether the hand is holding an object or hanging free and whether the subject is relaxed or focused. Additionally gather information about actigraphy and its uses. The same transducer should have the ability to measure both types of signals and your project is to create a dual use device.

B. Fabricate a Patient Interface
Consider a geometry allowing an appropriate joint to generate the motion (e.g. wrist vs finger). Take into consideration information regarding the conditions of the subject while being measured. Design the transducer interface so it can be worn by the paitient.

C. Design and Test The Electronic Module
The attached information will help in carrying out this task. The following sections give details of the electronics, arranged in the suggested order for building them.

D. The Technical Report
This must contain a summary of the clinical aspects of tremor and actigraphy and show aspects to decide clinical conditions. The design of the patient interface must be described with respect to facilitating to show the patient parameters. The electronic module design must be described with design equations and test results included.

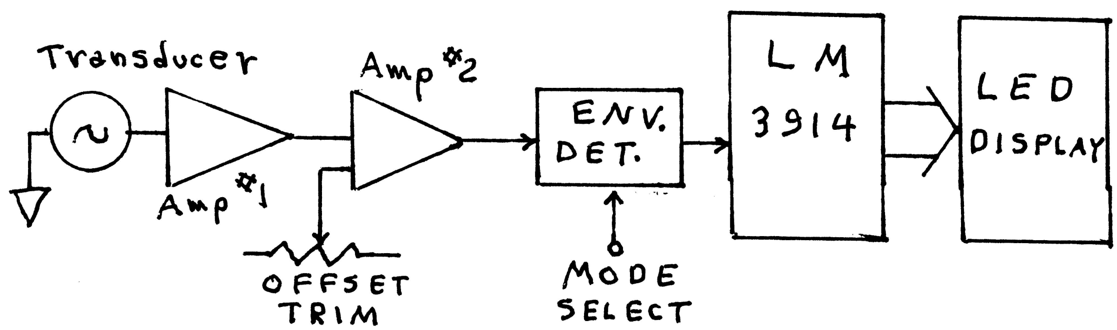
5.

F. Presentation
Summarize briefly the clinical aspects, the interface design and the electronic module. Then demonstrate the module with a human subject an the date assigned to your team.

THE ELECTRONIC MODULE

BLOCK DIAGRAM

The figure below shows a block diagram for an electronic system that implement the required functions.



Basic descriptions of the blocks:

The transducer consists of a piezoelectric plastic film that responds to the tremor/motion of the hand of the subject.

The input amplifier creates a high-pass frequency response based on the capacitance of the sensor combined with the amplifier's input resistance.

The second amplifier has a low-pass response and it sums the output of the first amplifier stage with a DC offset voltage from a potentiometer. This will be adjusted to optimize the DC level of the signal to the LM 3914 and "zero" the display.

The envelope detector processes the signal to condition it for the display with a switch to select between the two modes of display.

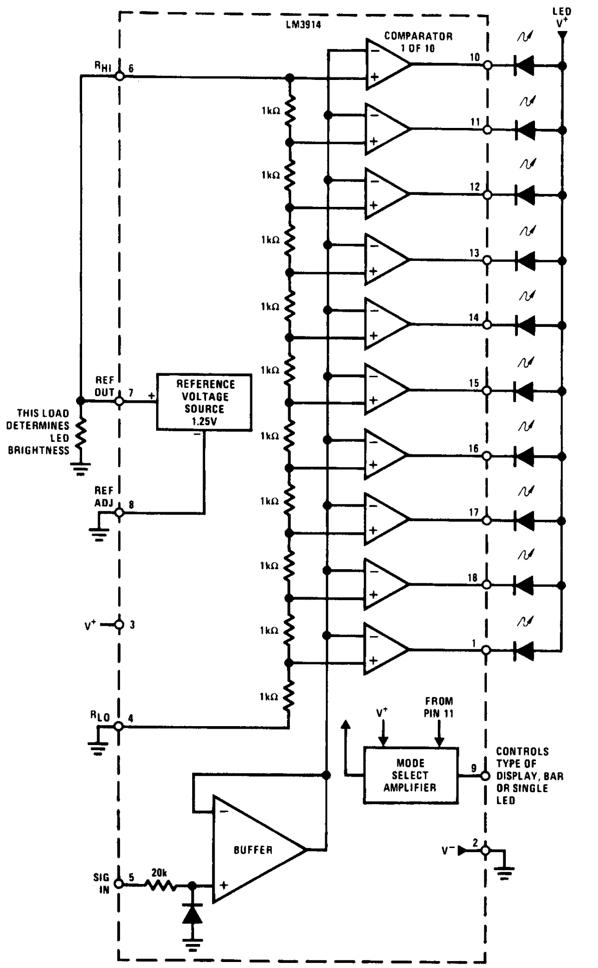
The LM 3914 with the 10-segment LED array implements a bar graph display.

HARDWARE TO BE USED

Fabricate the electronics on a "proto-board" and use ± 3 volts for the power source. You may use the lab power supplies for development but a battery pack will be substituted for the final demonstration. You will use the LM 3914 IC, a 10-segment LED bar graph and the TLC 2274 quad op amp. Build the circuitry with carbon film resistors rated for 1/4 watt with 5% tolerance and capacitors such as polyester film or metallized film with a tolerance of 5% and a voltage rating of 50 volts. All of these components are available from the BME lab and must be returned at the end of the semester.

THE DISPLAY ASSEMBLY

This section of the project implements the 10-segment bar graph display with a switch to select its display mode. The display is created by combining an LM 3914 (or equivalent) integrated circuit, a 10-segment LED and resistors. A typical circuit diagram is shown below, as taken from the reference listed below.



Reference: … **ERS; 2nd Ed; Franco; 1997;**

ADDITIONAL NOTES:

The power connections are slightly different than shown above. Apply the +3 volts to pin 3 of the IC and to the common anode of the LED's. Apply the -3 volts to pin 2 of the IC. The "ground", the midpoint of the batteries, is applied to pins 4 and 8.

The resistor between pins 7 and 8 determines the brightness of the LED's and its value should be normally 1000 ohms or more with higher resistance causing less brightness. Of course, the life of the batteries is better with less brightness (see the reference).

TESTING THE DISPLAY

The input signal is applied to pin 5 of the IC. The voltage levels on pins 6 and 4 establish the upper and lower voltage limits that will be displayed. With the circuit shown, those limits are +1.25 volts and ground.

Test the circuit by applying a sinusoidal voltage to pin 5, after first confirming the voltage on the oscilloscope. Use a sinusoid of 1 Hz with a peak voltage of ±1.25 volt. This should cause the display to sweep to full scale and back to dark and then remain dark for ½ second. Slowly reduce the amplitude and observe that the number of lit segments is reduced. When the amplitude drops to approximately 0.125 volt, only a single segment should light up. Document these events in your report.

ADDING THE ENVELOPE DETECTOR

Fabricate the envelope detector using a precision rectifier (op-amp configuration) and a RC averager. This circuit's output connects to pin 5 of the LM 3914. When configured in the precision rectifier mode, its output consists of the positive half-cycles of the input signal. When a capacitor(C) is added across the load resistor(R), the envelope detector output holds the peak amplitude of the input signal. In this mode it must have a decay time constant suitable for the tremor frequency. It is recommended to use a capacitor value of 1.0 microfarad and set the decay time constant to approximately 0.5 second.

TESTING:

Construct the circuit on the proto-board but do not yet connect it to the LM 3914 input. Connect the oscilloscope to the output and apply a sinusoid with peak amplitude of 1 volt at a frequency of 3 Hz to the input. Sketch the output waveforms in both modes by inserting and removing the capacitor. After confirming correct operation, connect the circuit output to pin 5 of the LM 3914.

Test the complete display section by applying sinusoidal input signals with amplitudes of 0.125 V to 1.25 V, peak at frequencies of 1, 3 and 10 Hertz. Confirm that the display responds properly in both modes of operation by removing and replacing the capacitor. Document these results in your report.

AMPLIFIER & FILTER SECTION

OVERVIEW:

This circuit amplifies the electrical signal received from the input stage (see below) and provides a low pass filter that attenuates noise signals. In addition, a summing function is included to allow correction of the DC offset voltage error. The specifications of this section are:

- Provide a voltage gain of ±10 volts/volt for frequencies below 10 Hz
- Create a low pass filter function that has a pole frequency of 10 Hz
- Use a 10 Kilohm potentiometer connected to the supply voltages for a DC input
- Allow an adjustment range of ±0.3 volts for the output DC level

ADDITIONAL NOTES

TESTING:

Construct your circuit but do not connect it to the envelope detector. Connect the oscilloscope to observe the output signal. With the input terminal grounded, the DC level is adjusted by moving the wiper of the potentiometer. Confirm that the adjustment range satisfies the specification above. If necessary, change the value of the resistor from the wiper of the potentiometer. Connect a sinusoidal voltage of 0.1 volt, peak at a frequency of 3 Hz to the input terminal. Observe that the amplitude of the output voltage is 1.0 volt, peak and that its DC level moves as the potentiometer is adjusted.

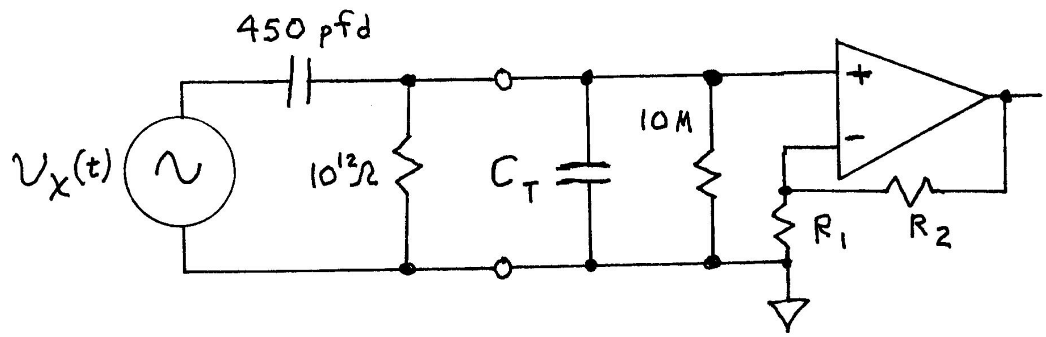
Vary the frequency of the input signal from1.0 Hz. To 100 Hz and record the output signal amplitudes at numerous frequencies. Construct a Bode plot of the results and confirm that your circuit satisfies the specifications.

Connect the output of this section to the input of the display circuit. With the signal input grounded, the display should be completely dark. Adjust the potentiometer so the voltage on the amplifier output (applied to pin 5 of the LM 3914) is zero.

Set the signal generator for 3 hertz sinusoidal with a peak amplitude of 125 millivolts. Connect the signal generator to the signal input of your total circuit and you should observe the full scale fluctuations in the display. Slowly increase the frequency to 60 Hz and observe the reduction in the display response. Test both modes of the circuit.

SENSOR AND INPUT AMPLIFIER

For the last part of the laboratory, the input amplifier stage will be added that is designed to match the characteristics of the transducer while satisfying the specifications for frequency response. The equivalent circuit for the transducer was presented in a class lecture and it is shown in the figure below. The specifications from the manufacturer indicate that the typical capacitance for this transducer is 450 pfd (remember that pico is 10^{-12}). The parasitic resistance of the film is very large (around 10^{12} ohms) and it can be neglected since it is parallel with 10 megohm input resistor. The Thevenin equivalent circuit for the transducer combined with the capacitor C_T was described in the lecture. This is used to calculate the value of C_T required to establish the specified high pass pole and it is used to calculate the voltage gain for this circuit.



TESTING:

Construct the input amplifier stage using R1 = 10 kilohms and R2 = 100 kilohms. Connect the signal generator **through the transducer** (it is being used as a capacitance) for this initial testing). Observe the output signal with the oscilloscope when the signal generator is set for 1.0 volt peak at a frequency of 3 Hz. Confirm that the results agree with the calculations for this Thevenin source and these resistor values.
Document these results in your notebook and include them in your report!
Connect the output of this stage to the remainder of your circuit. Vary the amplitude and frequency of the input signal from the generator and confirm that it delivers the frequency response expected. **Include these observations in your report!**

CONNECT TO THE SENSOR ASSEMBLY

The transducer with the patient interface apparatus will now be connected to the input terminals. With no displacement of the transducer, confirm that the DC voltage at the input to the envelope detector is at ground potential. If necessary, adjust the potentiometer to adjust this voltage to zero.

The nominal voltage gain values in these laboratory instructions will probably implement a level of sensitivity that is too high. Simulate a very slight tremor by the patient and measure the voltage on pin 5 while observing the display. Reduce the voltage gain by lowering the value of resistor R2 in the input stage until the display shows only one segment lit. Test the complete system with tremor amplitudes that simulate normal and pathological values. Use your own judgement and rely on information from the clinical references.

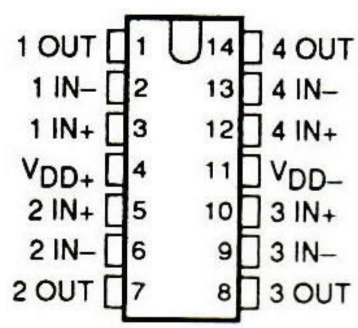
As an option, you can enhance your system by adding a sensitivity switch. The normal screening mode (as per the specifications) would be used to distinguish between normal and Parkinson subjects. The second mode would be applied to subjects with significant tremors to further classify them as moderate or severe.

APPENDIX 1: PIN-OUT FOR OP AMP

TLC2274, TLC2274A, TLC2274Y
Advanced LinCMOS™ RAIL-TO-RAIL
QUAD OPERATIONAL AMPLIFIERS

SLOS106B–D4001, MARCH 1992–REVISED OCTOBER 1992

D, J, N, OR PW PACKAGE
(TOP VIEW)



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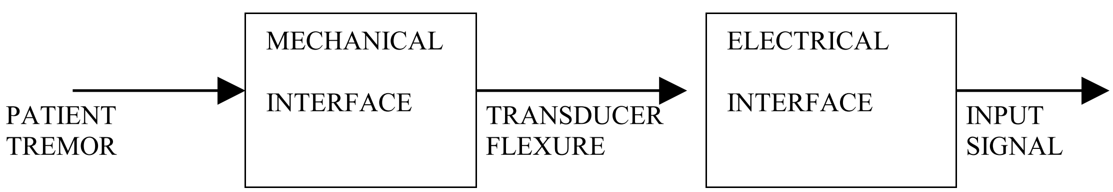
PROJECT EXERCISE #1

M. HEIMER

The transducer that is being used in the project is required to create a signal on the input terminals of the amplifier that is proportional to the amplitude of the tremor. This patient interface system may be represented by the diagram shown below.



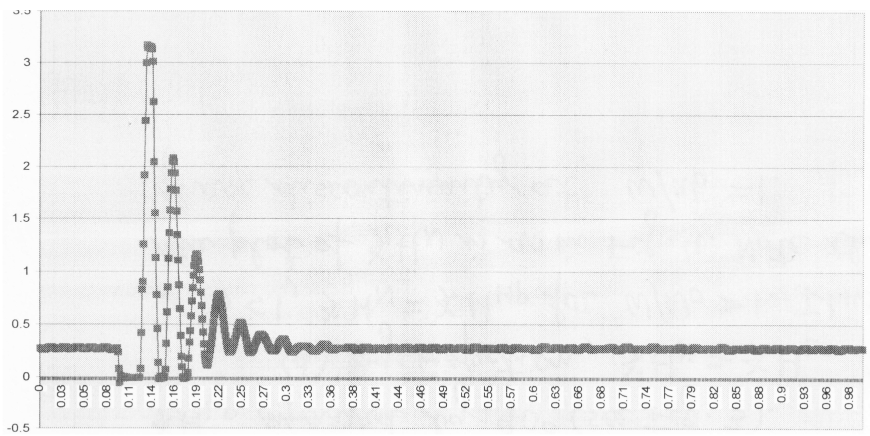
The analysis of the electrical interface will be carried out later in the course as the design of the input amplifier stage is completed. At this point in the project, the parameters of the mechanical interface will be analyzed for use in the design of the patient interface.

There are two versions of the transducer supplied and different approaches to the patient interface may be taken based on the selection of which transducer to use. The version with an attached mass acts as an accelerometer and its use allows a more simple design for the patient interface. The purpose of this exercise is to analyze its parameters and to use those results to make a decision on whether or not to use it in this project.

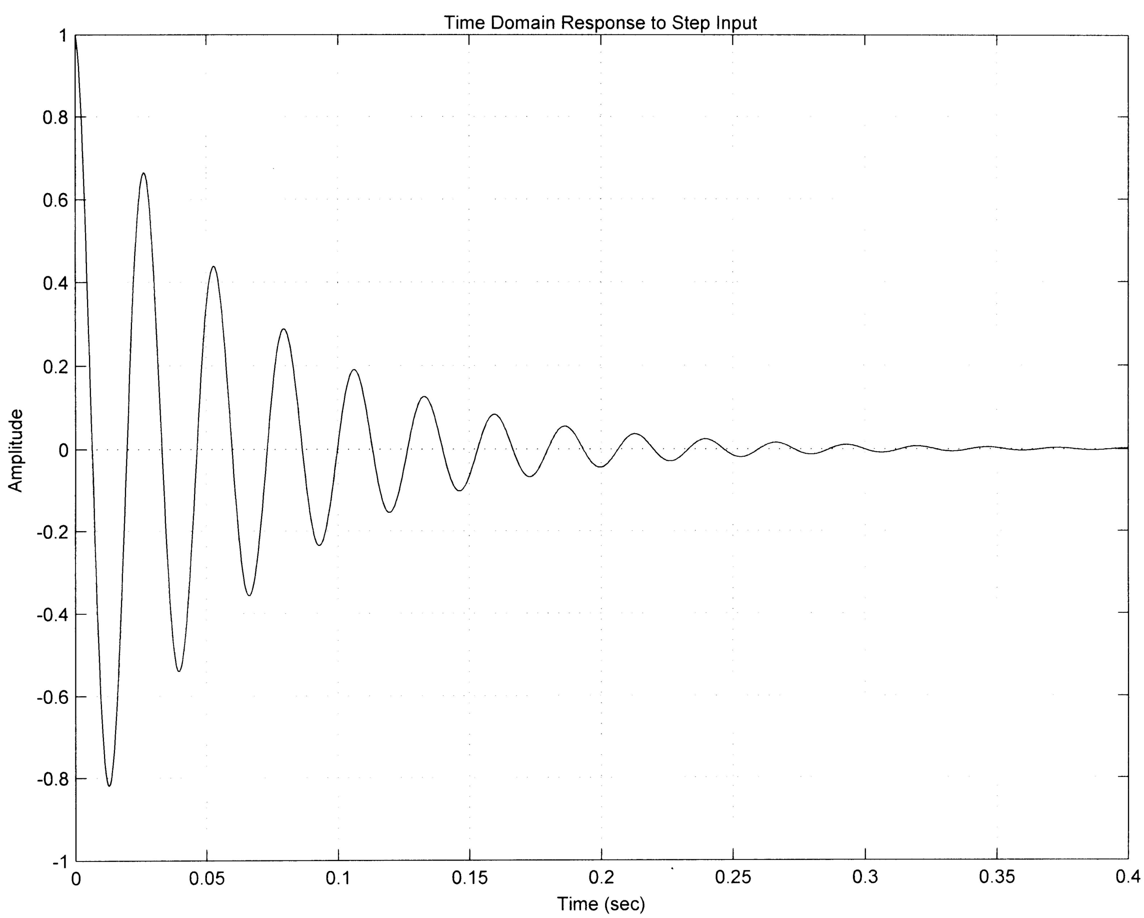
This transducer comprises a mass on the end of an elastic film. Its system response has as an input the movement of the electrode-end of the plastic film and as an output the flexure of the film. This mechanical response is a 2^{nd} order high pass function as was discussed in the class lectures (see section 1.10 in the text).

There are three elements that determine the mechanical response: the mass, the spring constant of the plastic film and the friction due to both the air resistance and the viscosity of the plastic film. Using these values, it would be possible to calculate directly the two response parameters: the resonant frequency, ω and the damping factor, ξ (see the text).

The response parameters can be determined experimentally by analyzing the impulse response of the transducer. This was done by mounting a transducer on the end of a rod and then striking that rod against a hard surface. The signal from the transducer was recorded by a digitizer and the results are shown below.



The waveform was "cleaned up" and translated into the MATLAB plot shown below. This waveform can be subjected to graphical analysis to calculate the values of resonant frequency and damping ratio (see text, section 1.10).



<u>PROJECT EXERCISE #1 INSTRUCTIONS</u>

Use the formulas from Section 1.10 of the text together with other references. You are investigating the use of the transducer as an accelerometer. Do a graphical analysis of the waveform plotted above to calculate the resonant frequency and the damping factor for this transducer. You may simplify the calculation by assuming that ω_d is the same as ω_n.

Sketch a Bode plot for the frequency response of this configuration. Recall that the plot will be the mirror image of figure 1.7d. The resonant frequency is found from the analysis of the impulse response plotted above. The amplitude of the peak in the response at resonance is the ratio $(1/2\xi)$ but this must be converted to dB by taking the $\log_{10}$ and multiplying by 20.

Based on your clinical research, compare the frequency range of the tremors with this Bode plot. Will the mechanical response of this transducer provide uniform amplitude response over this tremor frequency range? If not, how much reduction of signal will occur in the region of interest? On the sketch of the Bode plot, mark where the tremor frequency range falls and calculate the sensitivity variations that would be expected between the minimum and maximum tremor frequencies.

Consider the possibility of adding mass to this transducer to make its frequency response suitable for this application. Given that the original mass is 0.75 gram, how much mass would have to be added to make the resonant frequency suitable for tremor detection? Assuming that the added mass has negligible air resistance so it does not increase the damping, calculate the new value for ξ. Sketch the new Bode plot for this modified transducer. Consider the response of this modified transducer (in the time domain) to a single "jerk" of the hand of the subject(actigraph response)? (Refer to Figure 1.7c). What effect might this have on using this modified transducer to monitor tremors? Would it be practical to further modify this transducer to increase the damping factor while keeping the resonant frequency at this value?

The results of this exercise will be handed in (one copy per team) and the results will also be included in the project report. In the project report, it will comprise a feasibility study by the team to determine which version of the transducer to use in the patient interface.

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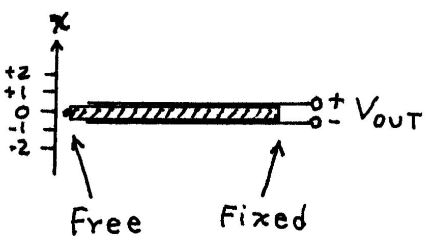
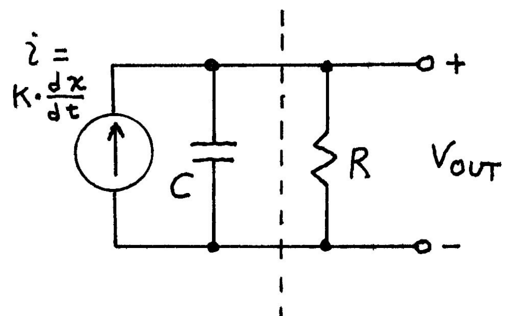
MEDICAL INSTRUMENTATION

PROJECT EXERCISE #2:

The sensor/transducer that is used in this project is modeled below.



Geometry



Circuit Model

The sensor is fabricated by placing flexible conductive layers on both surfaces of a piezoelectric plastic film. When the film is flexed, a voltage signal is generated across the two terminals connected to the conductors. Fixing the terminal end of the device and allowing the free end to move will generate a voltage proportional to its displacement, x. This is a configuration for the transducer as a vibration sensor. For the project, this sensor can be applied to detect the hand tremor of the subject.

Based on figure 2.10b in the text, the equivalent circuit for the sensor/transducer includes a current source proportional to the velocity dX/dt, as shown above. For this project, the parameter that will be displayed is the displacement, X which is proportional to the voltage on the capacitor. When the transducer is connected to the input terminals of an op amp circuit, the R shown above is reduced by being in parallel with the R_{IN} of the circuit. Since R is very large (around 10^{12} ohms), the effective value is just R_{IN}. The frequency range for the transducer is determined by the pole frequency $\frac{1}{2\pi * C * R_{IN}}$.

The frequency response is a high pass filter function. For tremor rates above the pole frequency, the output signal is the displacement, X. For tremors below that frequency, the signal becomes the velocity of the tremor.

Carry out an analysis of the pole frequency using the known C value and the lower limit of the tremor rate that must be displayed. Recall that it is necessary to include a resistor between the + input terminal of the op amp and ground in order to absorb I_{BIAS}.

Show that the required value of R_{IN} is much larger than the available values for resistors. There are a few options for overcoming this problem besides the one described below:

- **Use a "bootstrap" circuit with positive feedback to increase R_{IN}**
- **Use a switched-capacitor circuit to simulate a very large resistor**
- **Use an integrator to convert the velocity signal into displacement**

The recommended solution for this problem is to use the largest available resistor (e.g. 10 Megohms) for R_{IN} and use a Thevenin equivalent to increase the value of C. To apply this method, first transform the equivalent circuit above to a Thevenin equivalent (replace the current source with a voltage source in series with the capacitor). Then place an additional capacitor across the output terminals and convert this combined circuit into a new Thevenin equivalent circuit. Calculate the new value of C as the sum of the C of the transducer and the added capacitor. Also, calculate the new Thevenin voltage from the original Thevenin voltage and the values of the capacitors. Based on the required pole frequency and the value of R_{IN}, calculate the required value for the Thevenin capacitance. Then calculate the value of the capacitor that must be added to the transducer terminals. Also calculate the ratio by which the signal amplitude will be reduced so this voltage gain can be implemented in the input amplifier stage.

To complete this assignment, hand in the calculations you carried out and the resulting circuit schematic that your team intends to use for your input stage. These results will also be included in your laboratory report.

The group has to make a decision which transducer configuration will be used and state their logic in making the design decision.