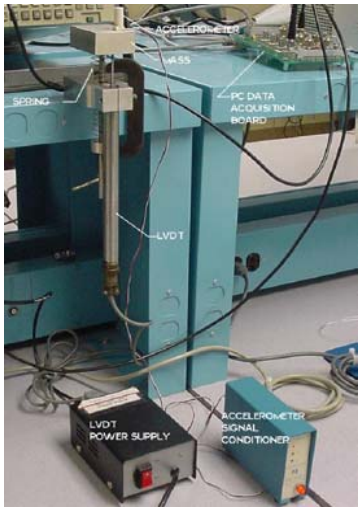
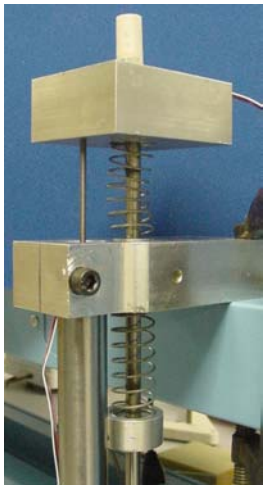
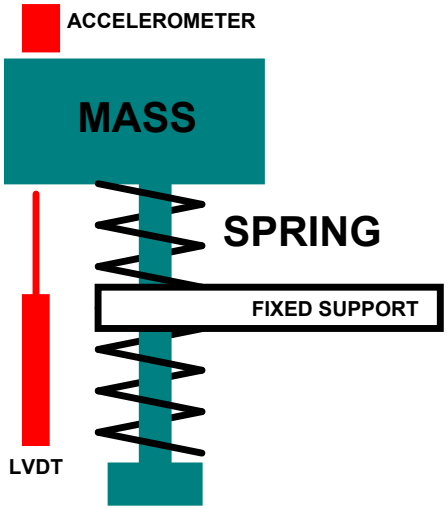
DYNamic SYStems

NUMERICAL EVALUATION OF DISPLACEMENT AND ACCELERATION FOR A MASS, SPRING, DASHPOT SYSTEM







Dr. Peter Avitabile, Jeffrey Hodgkins
Mechanical Engineering Department
University of Massachusetts Lowell

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At UMASS Lowell, the laboratory course is taught in a two semester sequence.

The first semester concentrates mainly on basic instrumentation, measuring techniques and processing of data.

The second semester begins with the same format as the first semester with more complicated labs and ends with a five week project on designing a measurement system

(A companion paper describes that project)

Mechanical Engineering Laboratory I

DYNamic SYStems

The first semester concentrates mainly on

- *basic measurement tools (oscilloscopes, multimeters, digital data acquisition, etc),*
- *measuring devices (flow meters, manometers, pressure transducers, pitot tubes, strain gages, thermocouples, accelerometers, LVDTs, etc)*
- *methods for data collection/reduction (regression analysis, curvefitting, numerical processing)*

Mechanical Engineering Laboratory I

DYNamic SYStems

One laboratory project requires measurements for the displacement and acceleration of a simple mass-spring-dashpot system.

Students acquire digital data using

an LVDT

and accelerometer

to obtain this displacement and acceleration data.

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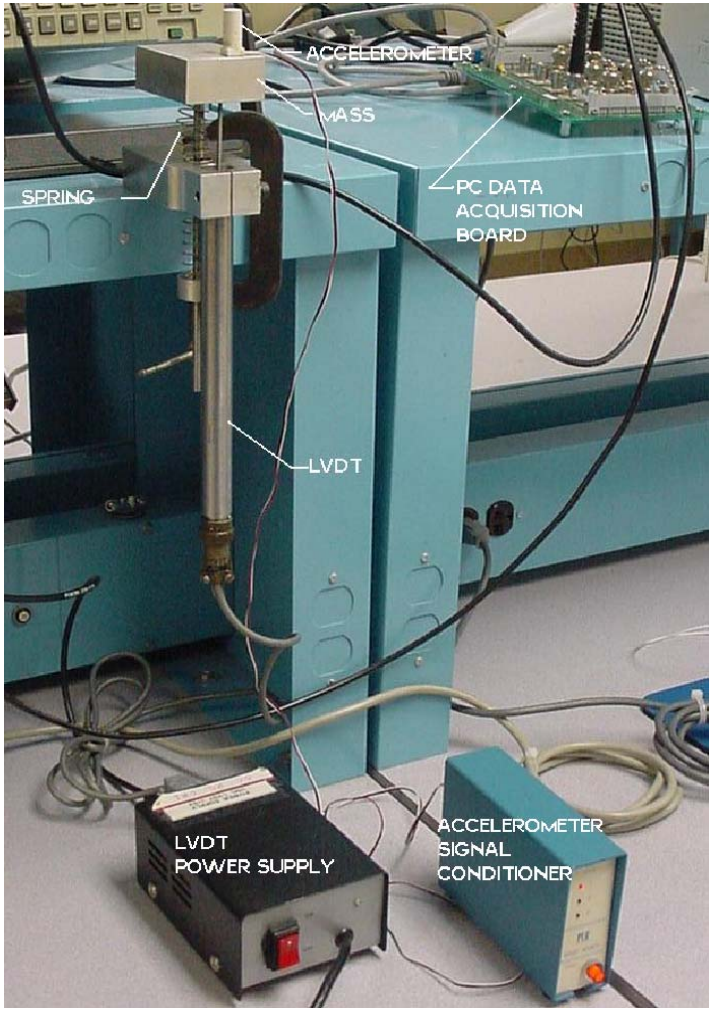
Mechanical Engineering Laboratory I

DYNamic SYStems

This final project requires extensive use of all material covered over the semester.

The project requires significant numerical manipulation of data.

- *Regression Analysis*
- *Data Cleansing*
- *Integration*
- *Differentiation*



Problem

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The data acquisition system and transducers are intentionally selected such that the majority of possible errors exist in the data

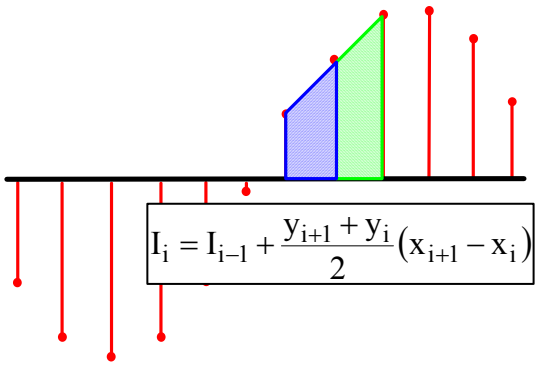
- *Drift*
- *Bias*
- *Offset*
- *Quantization*
- *Noise*

Problem

This data is integrated and differentiated to compare

- *displacement measurements to acceleration*
- *acceleration measurements to displacement*

The actual numerical processing of the measured data is performed via spreadsheet calculations.



$$I_i = I_{i-1} + \frac{y_{i+1} + y_i}{2}(x_{i+1} - x_i)$$

Problem

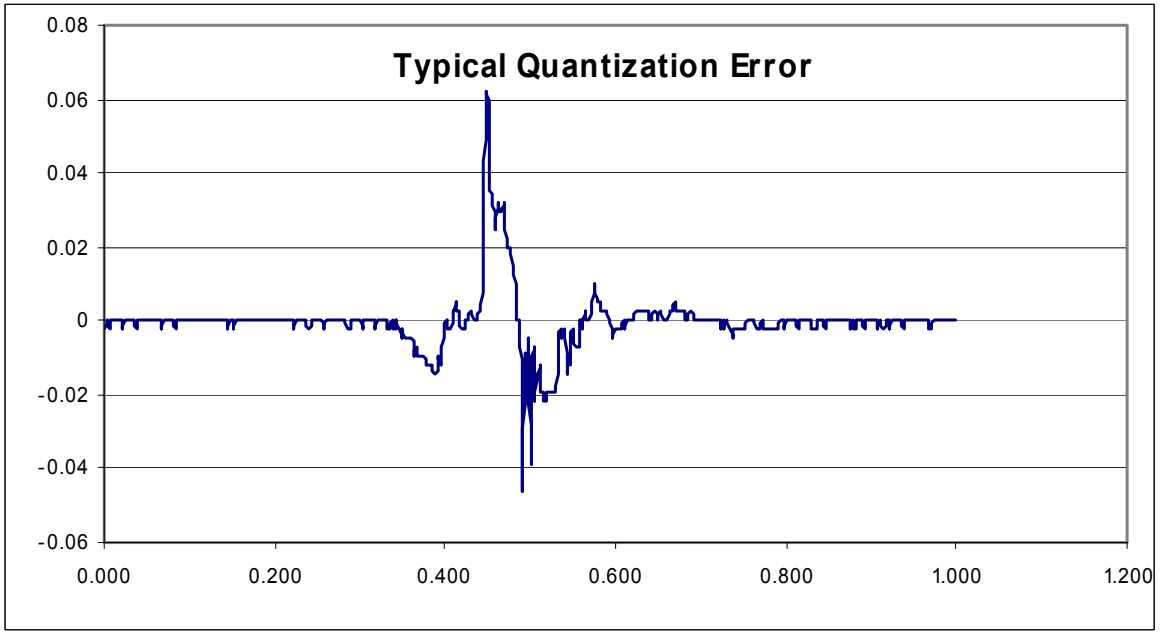
Students struggle with this "less than perfect" data to emphasize the importance of good measurements.

Students re-visit the project at the end of the semester with better instrumentation and understanding of the problem at hand.

A final report is then written covering all aspects of test/analysis and any recommendations to improve process.

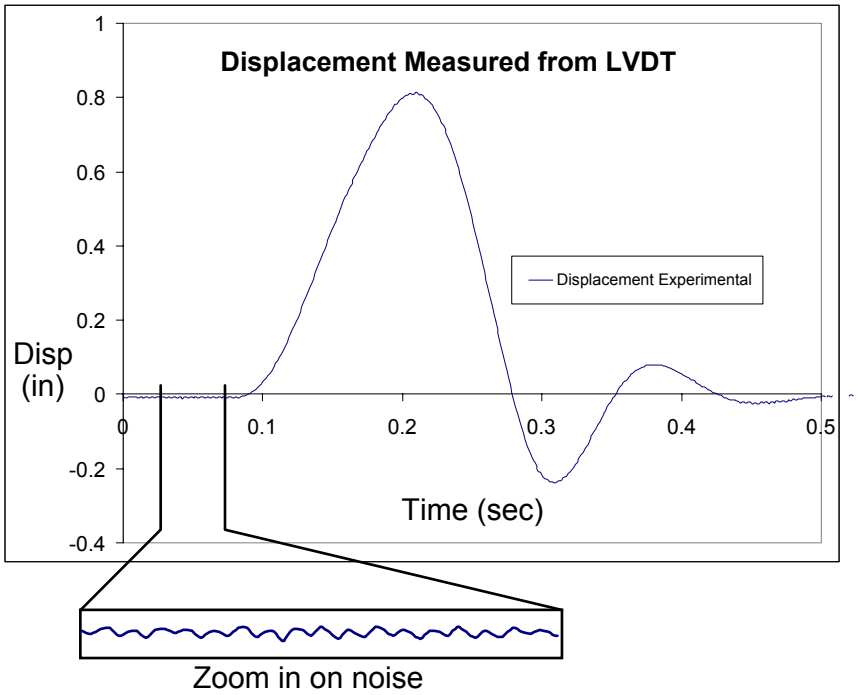
Quantization Errors

A 12 bit board with a 10 volt range and no AC coupling is used to measure an accelerometer that has approximately 30 mv peak signal



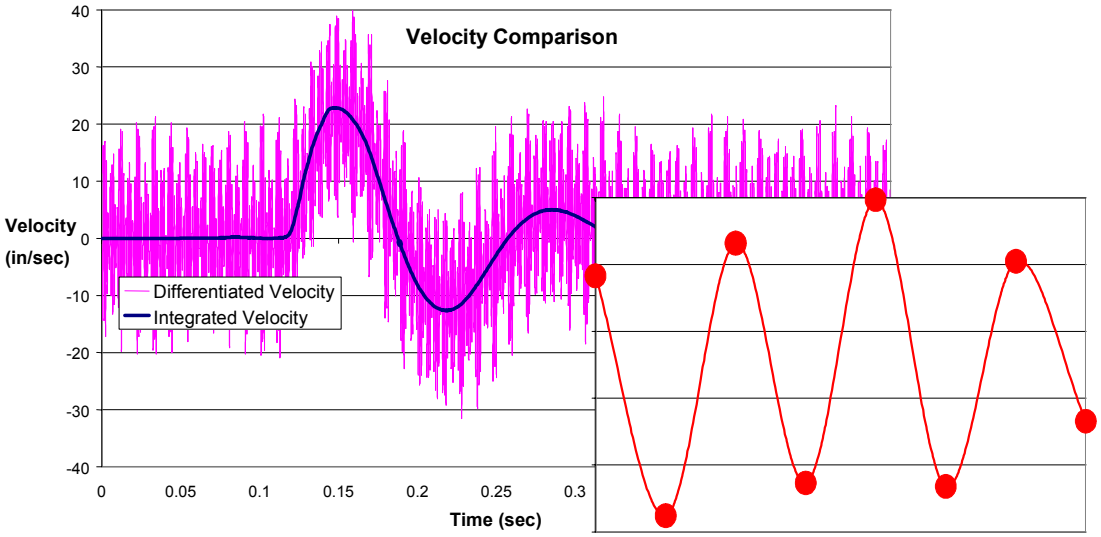
Noise Effects

The measured LVDT signal appears to be acceptable until a closer look is made – this has a pronounced effect on differentiation



Differentiation Effects with Noise

Differentiation amplifies any noise which confuses the students until they realize the effects.

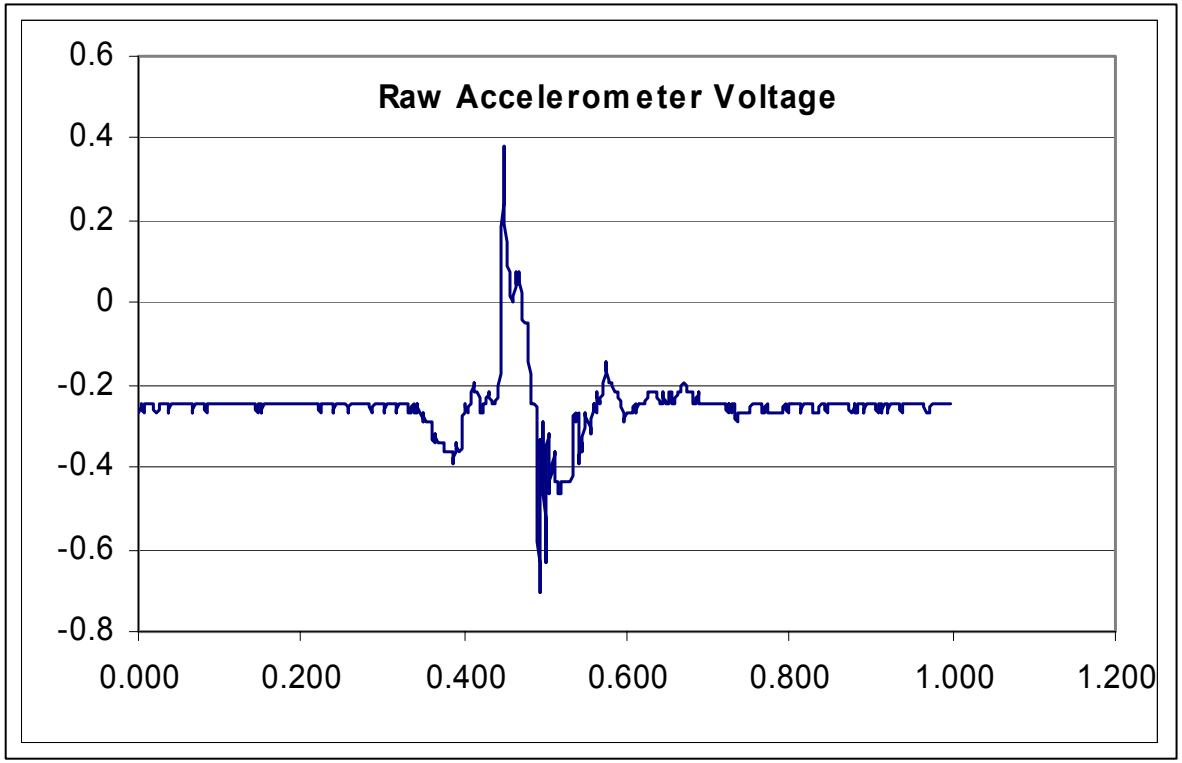


High Frequency Noise on Signal

After the second differentiation, acceleration trend is lost under amplified noise.

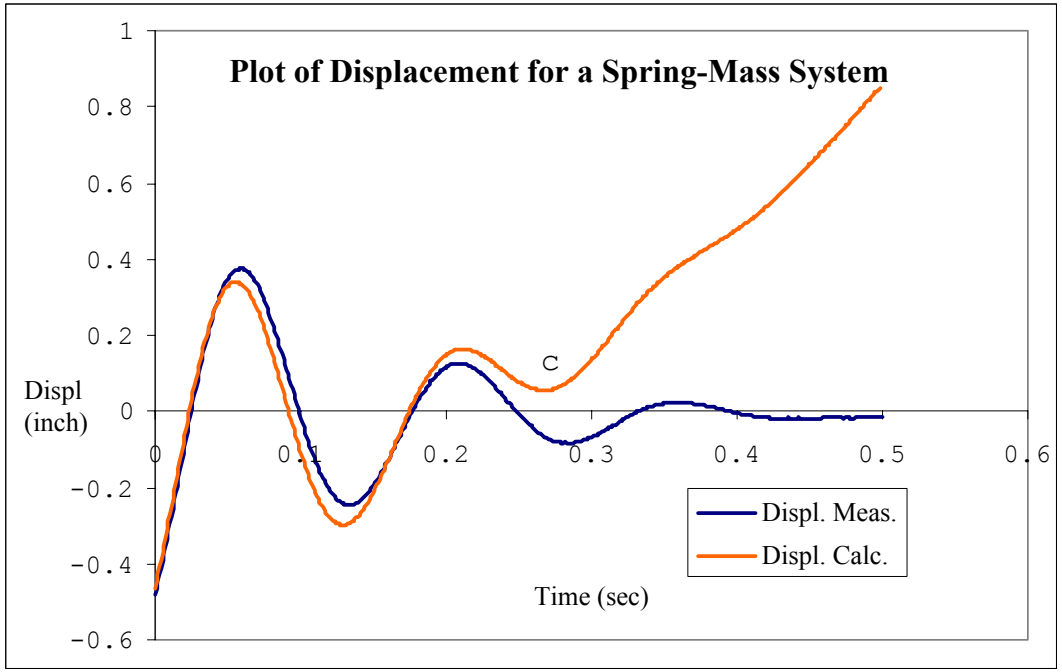
Offset Effects

The accelerometer signal conditioner has a DC offset that has a dramatic effect upon integrating the signal to obtain displacement



Integration Effect with Offset

Integration smooths any noise but the trend is confusing if any offsets exist.



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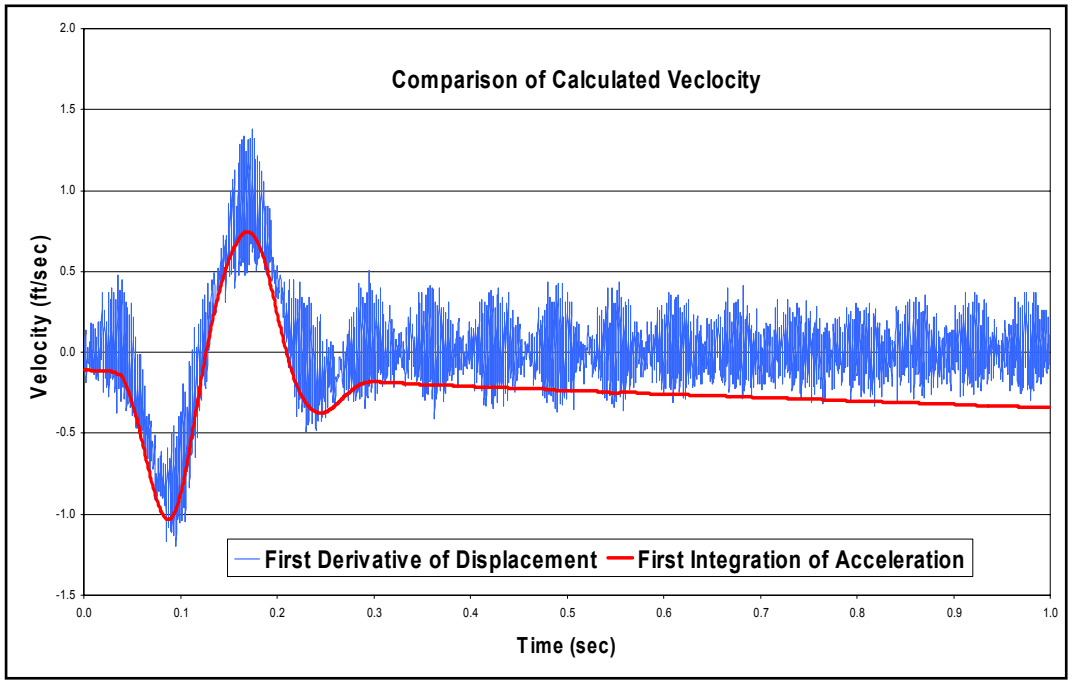

Some realize the velocity is more reasonable

Student Ownership of Problem

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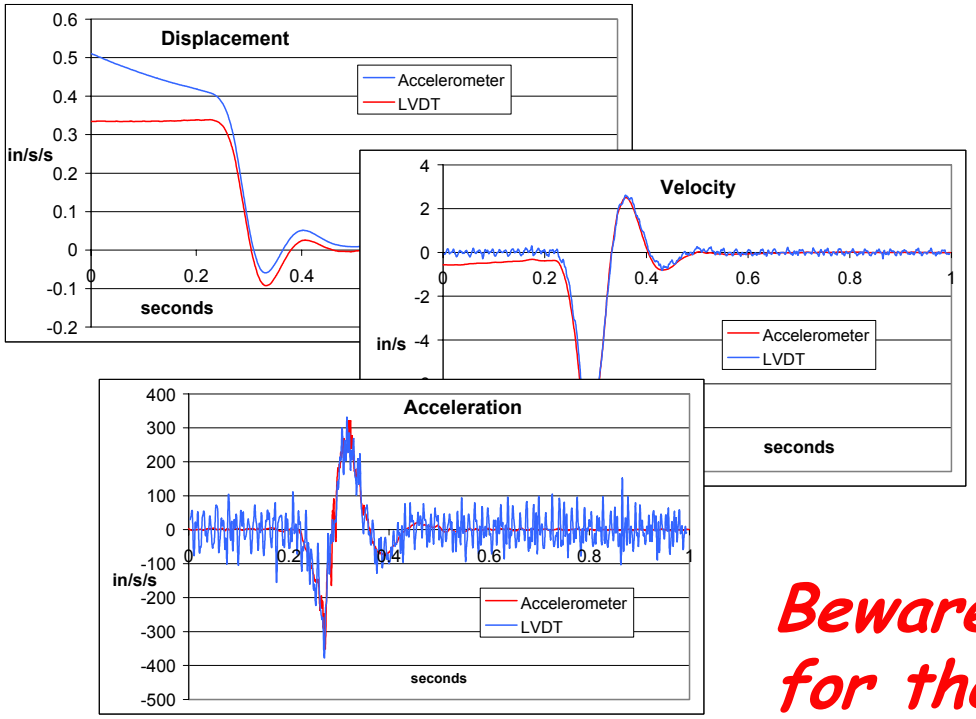
The students generally work hard to try to understand the problem and often do very well.

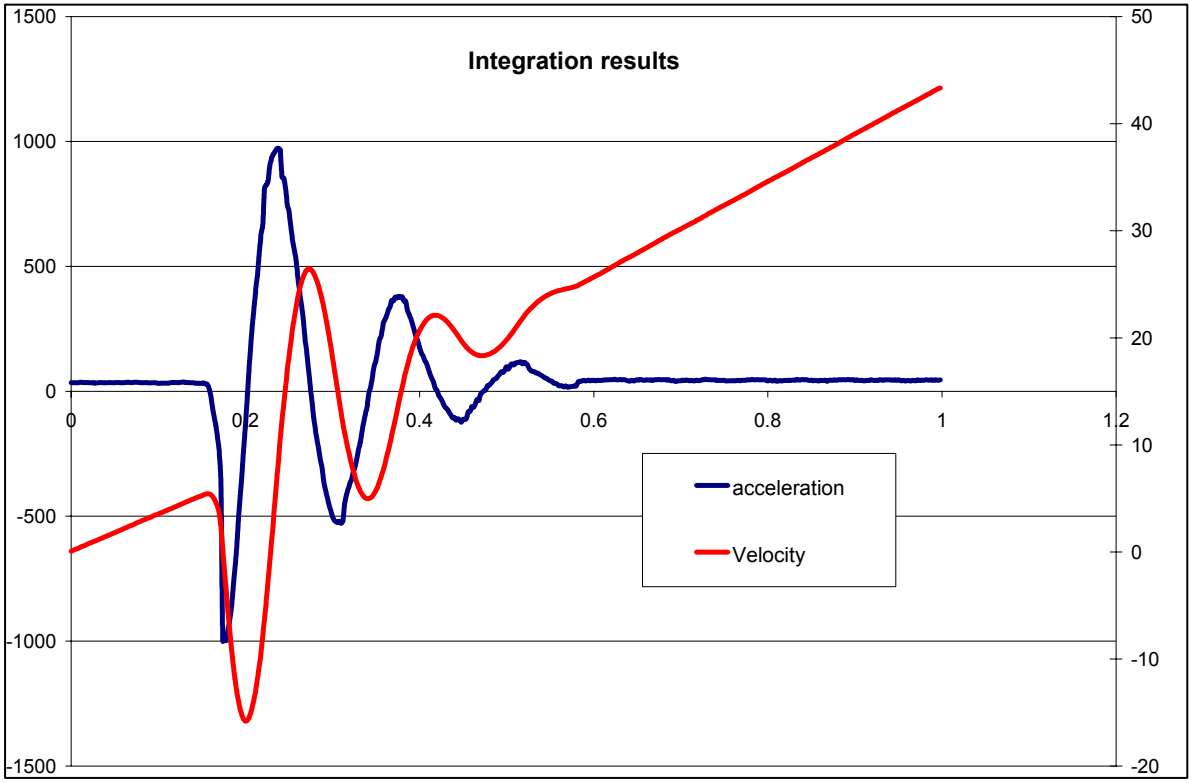


The professor is just a guide or mentor to help direct them in trying to solve this problem.

Beware…No answer guide for the Professor either!!

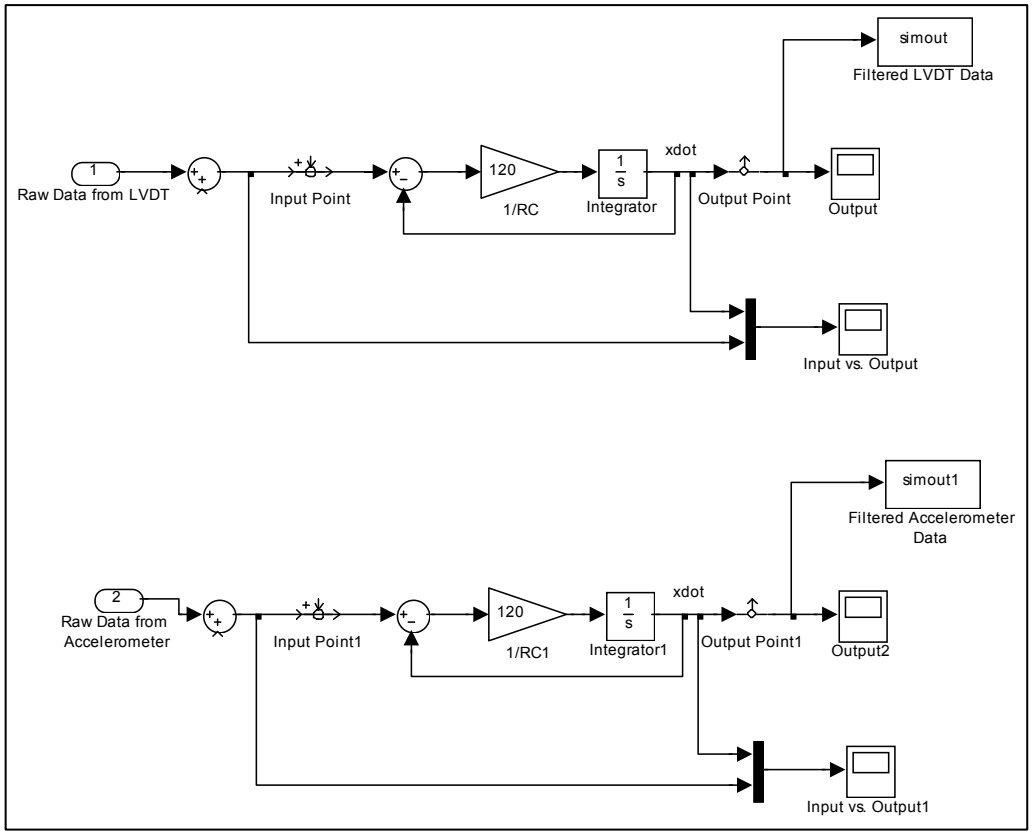
Student Ownership of Problem

Many times very novel and unique approaches result in an attempt to solve this problem.



Student Ownership of Problem

Several students have also resorted to building low pass RC filters in Simulink to remove noise



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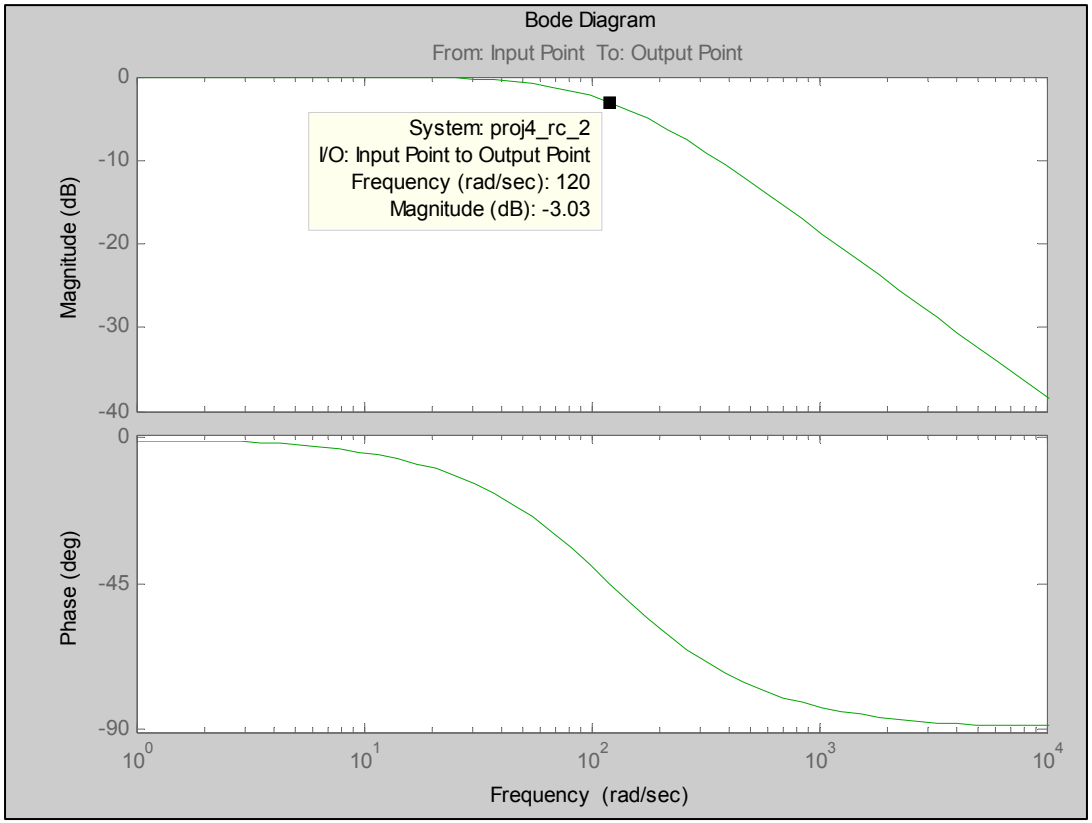
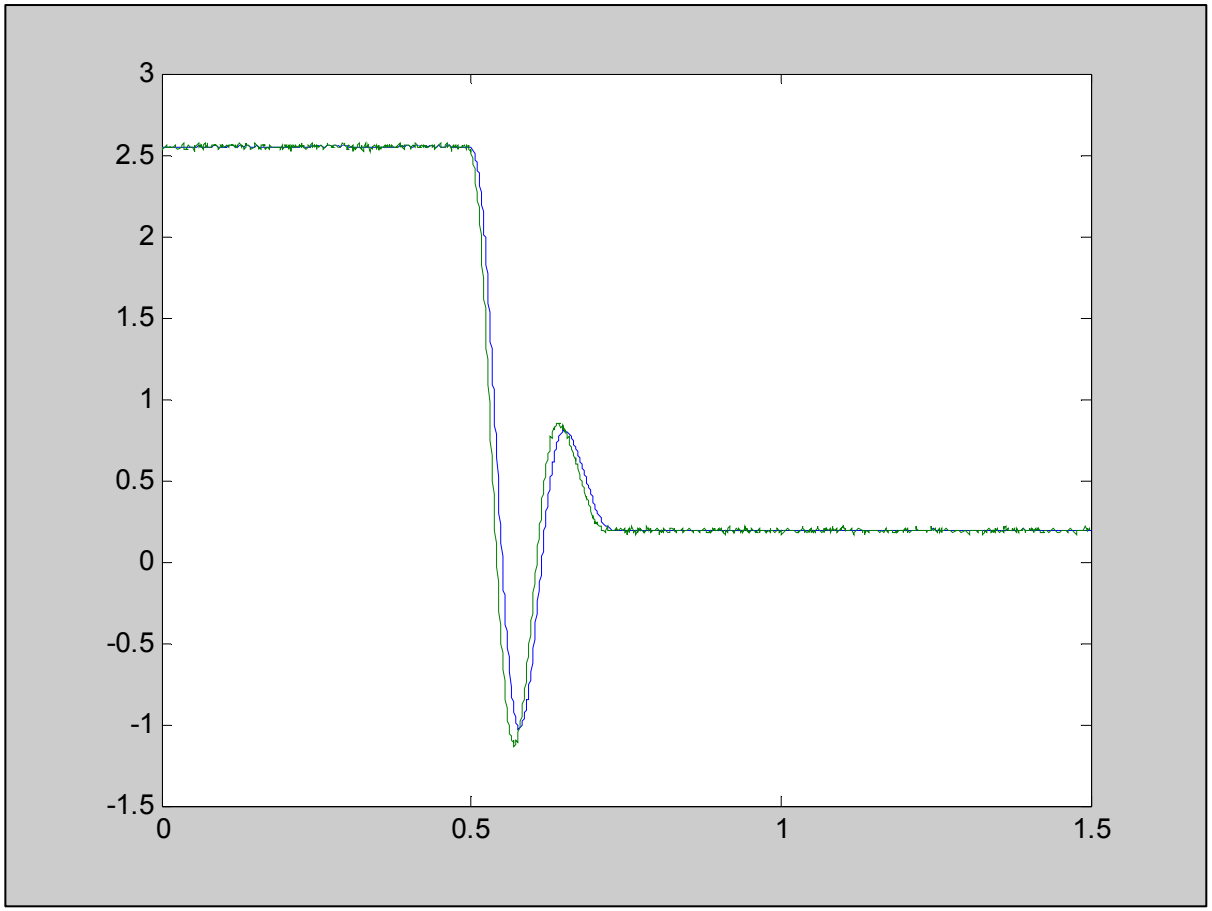


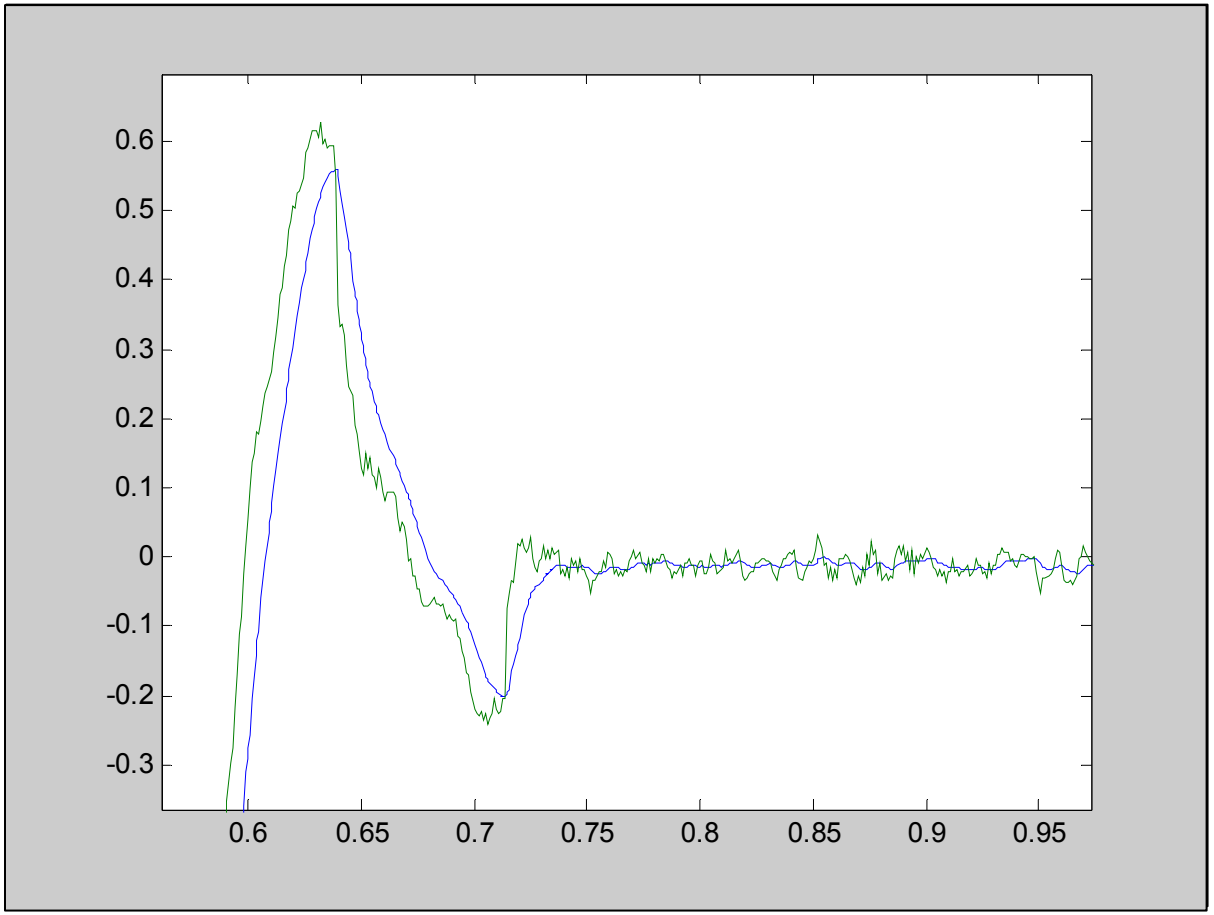
Student Ownership of Problem

LVDT noise filtered



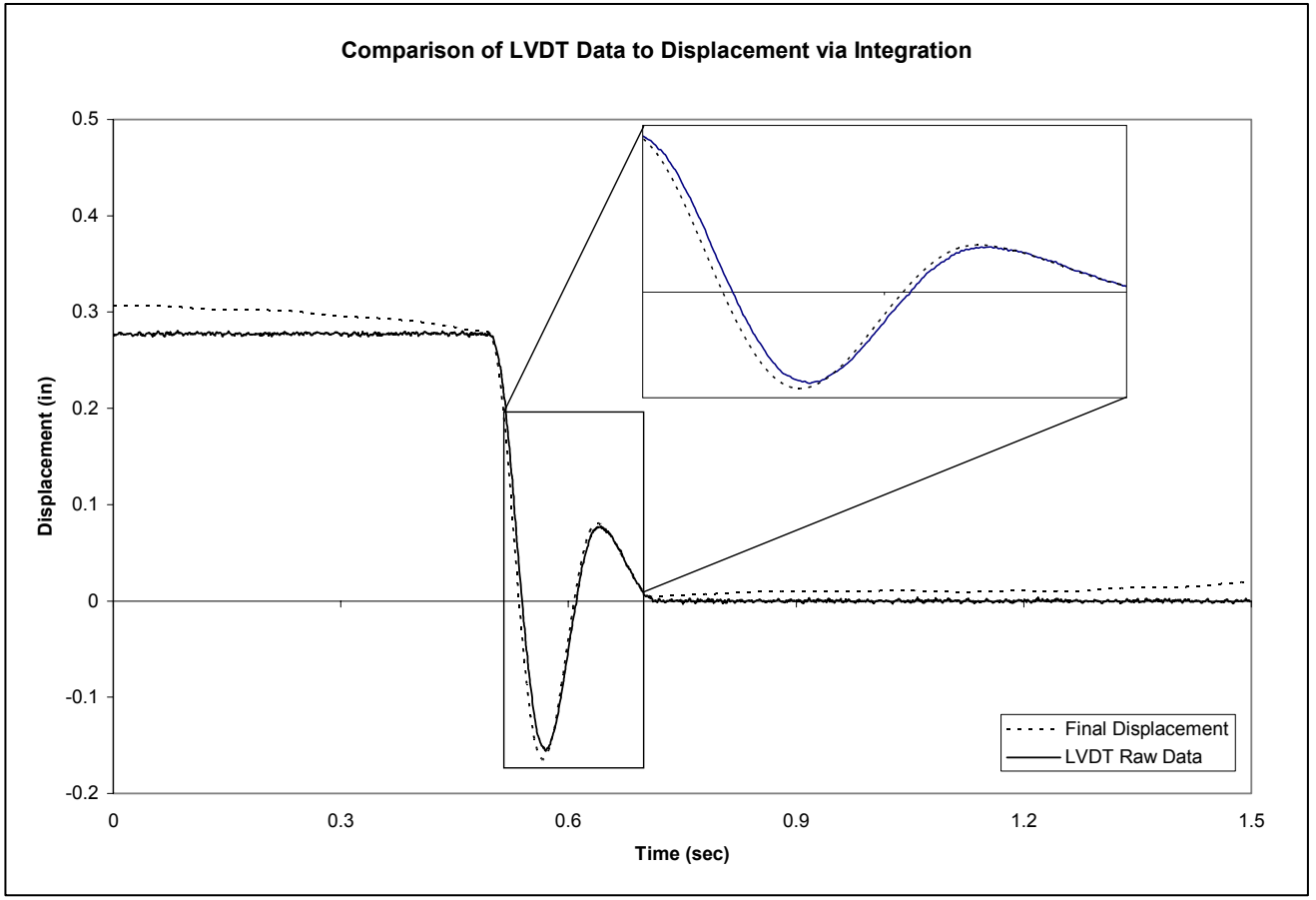
Student Ownership of Problem

Accelerometer noise filtered



Student Ownership of Problem

Comparison of integrated data after Simulink noise removal



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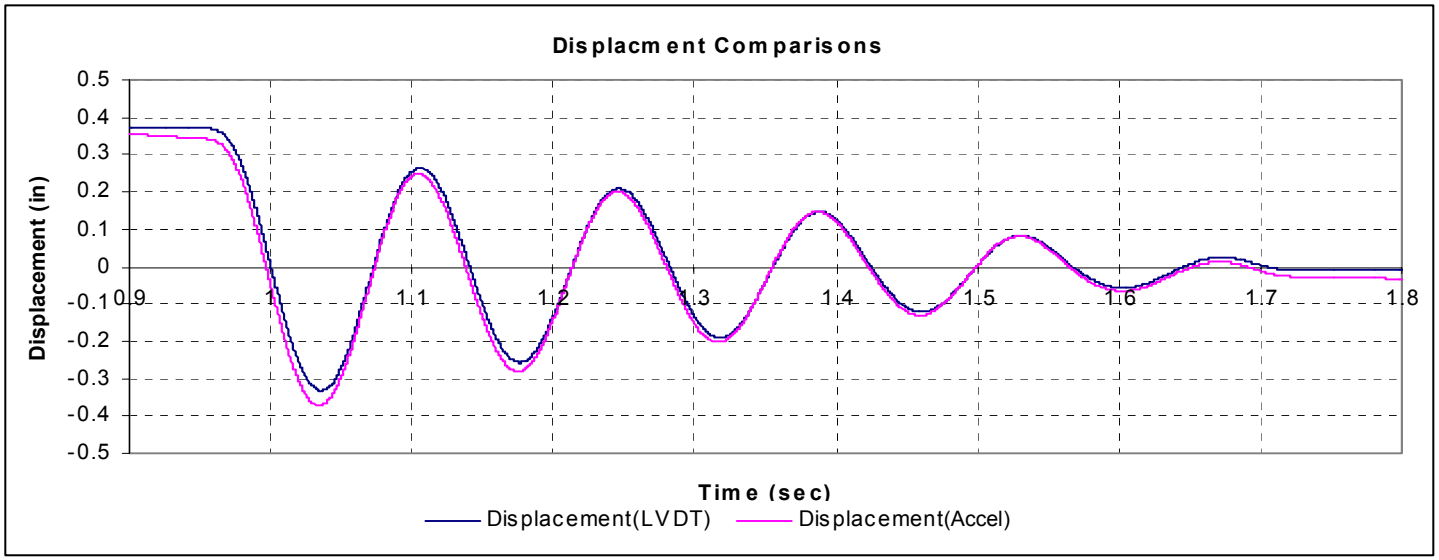
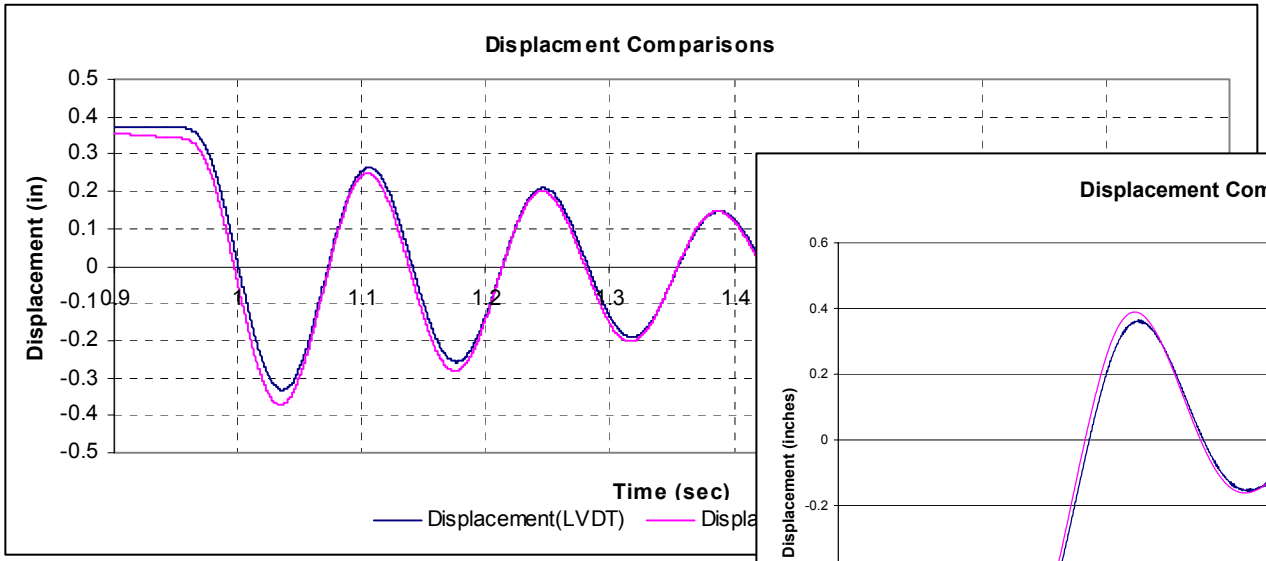
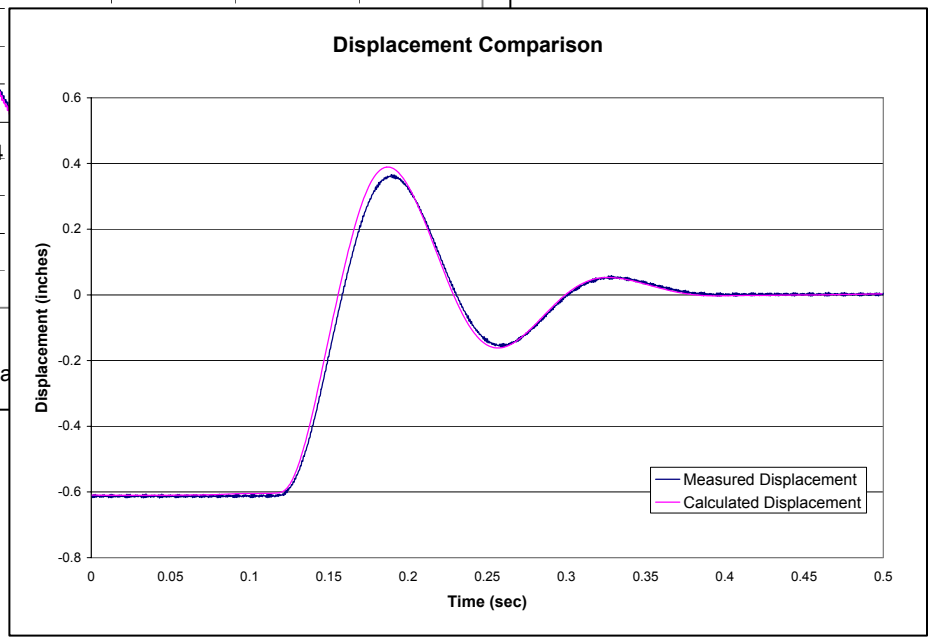


Student Ownership of Problem

And of course there are students that persist to the point of success !!!





Acknowledgements

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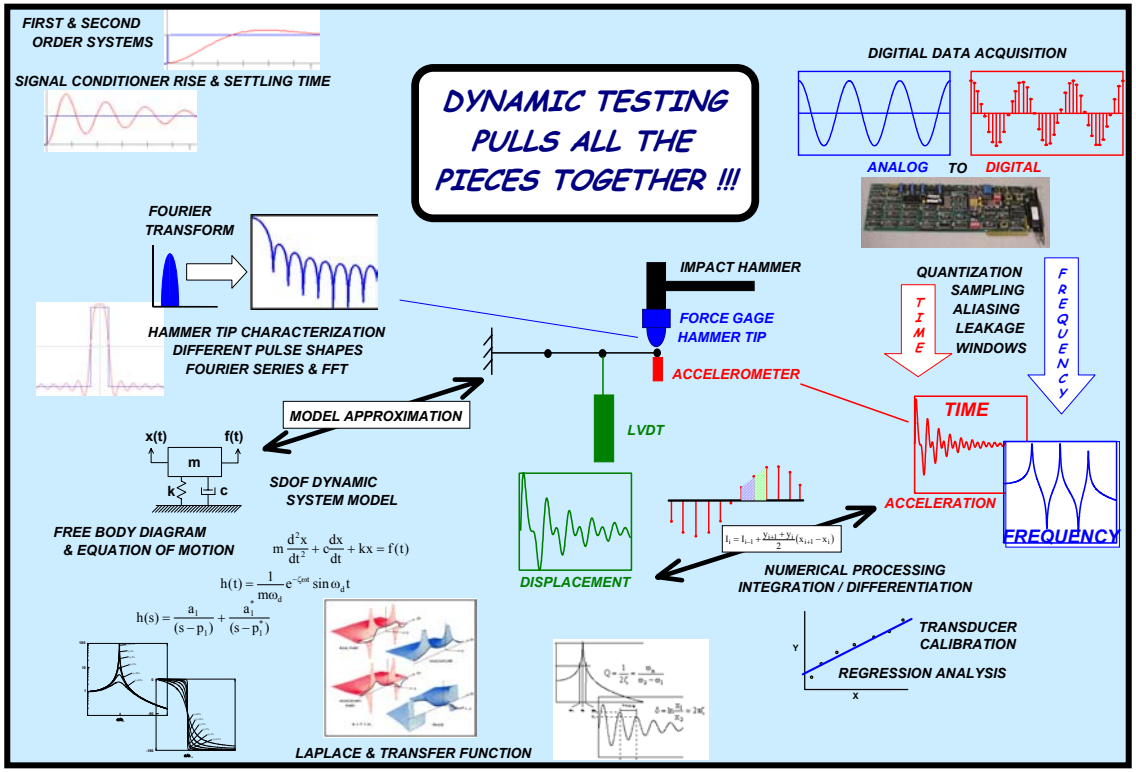
NSF Engineering Education Division Grant EEC-0314875

Multi-Semester Interwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems



Peter Avitabile, John White, Stephen Pennell

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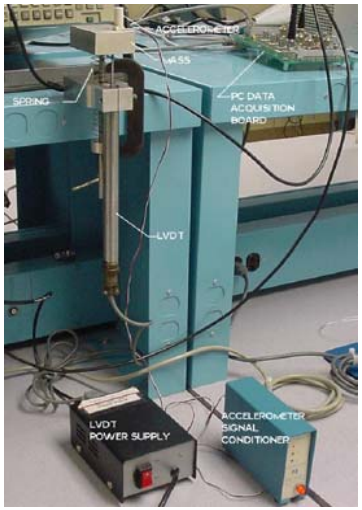

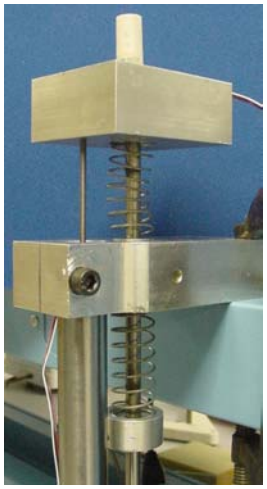

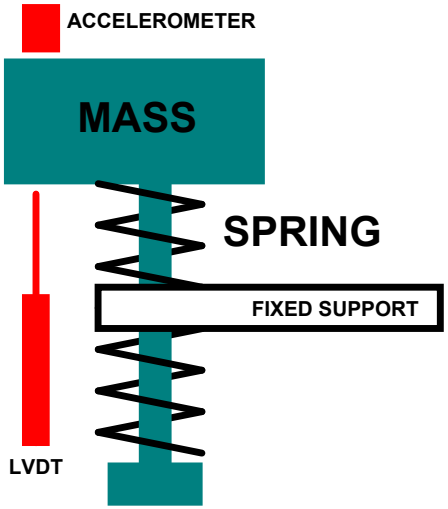

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