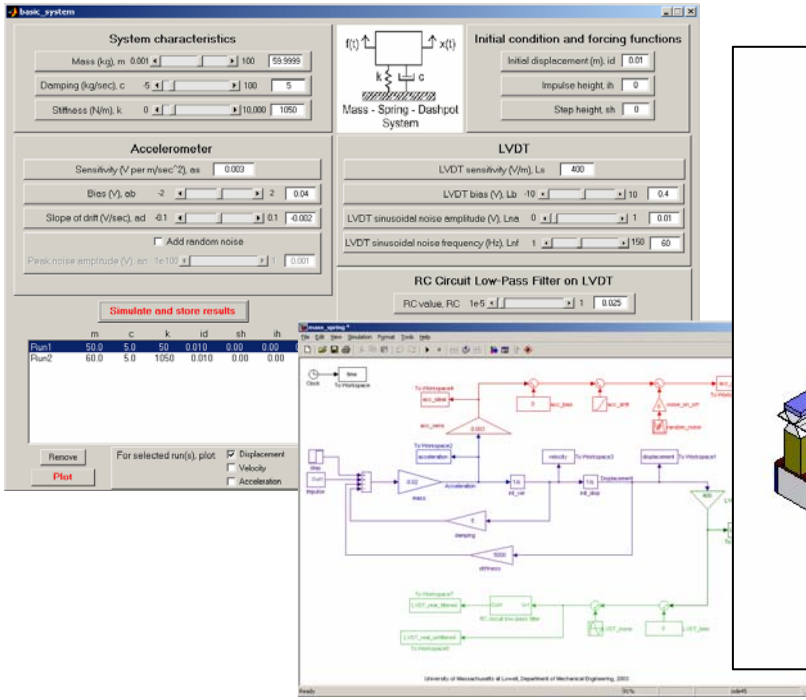
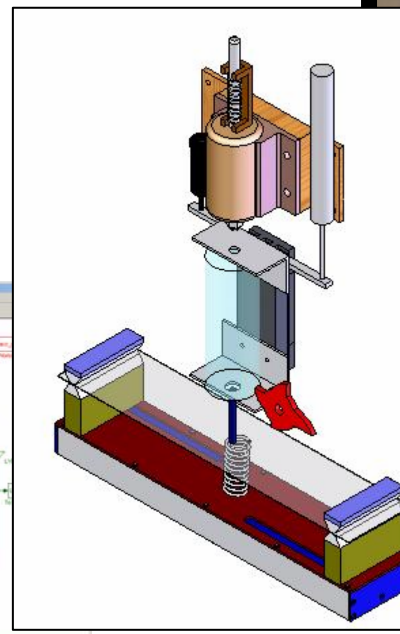
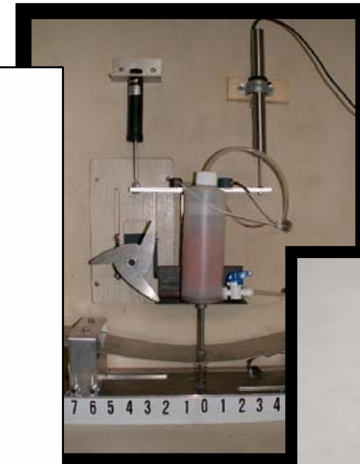
Second Order Online Acquisition System - RUBE







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Jeff Hodgkins, Nels Wirkkala
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University of Massachusetts Lowell

The Problem

Most of the student's educational exposure is to well behaved, deterministic problems with known results.

Most courses expose students to

- material in modules in book chapters

- with exercises/problems at end of the chapter

- majority of the material found in chapter/book

The Problem

Laboratory is the perfect place for students to become exposed to real world problems and solutions to those problems.

Laboratory is the perfect place to put student's knowledge of basic STEM material to the test.

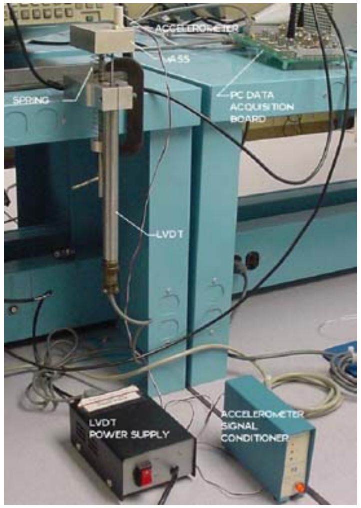
The Problem

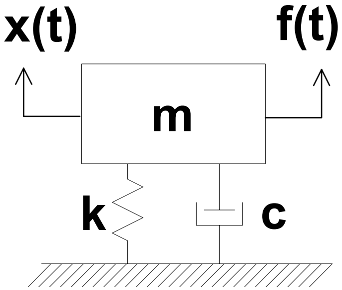
However, many times the real world measurement is much more complicated than the textbook.

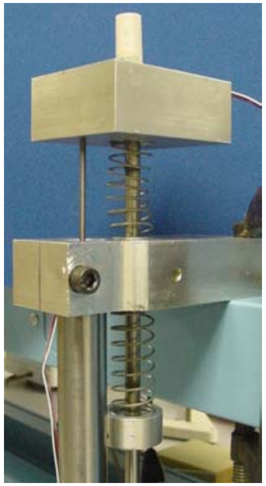
Students often struggle with methods and procedures to solve a real measurement problem (with no answer at the back of the book)

A Typical MCK Measurement System

A simple mass, spring, dashpot system is used to measure displacement and acceleration







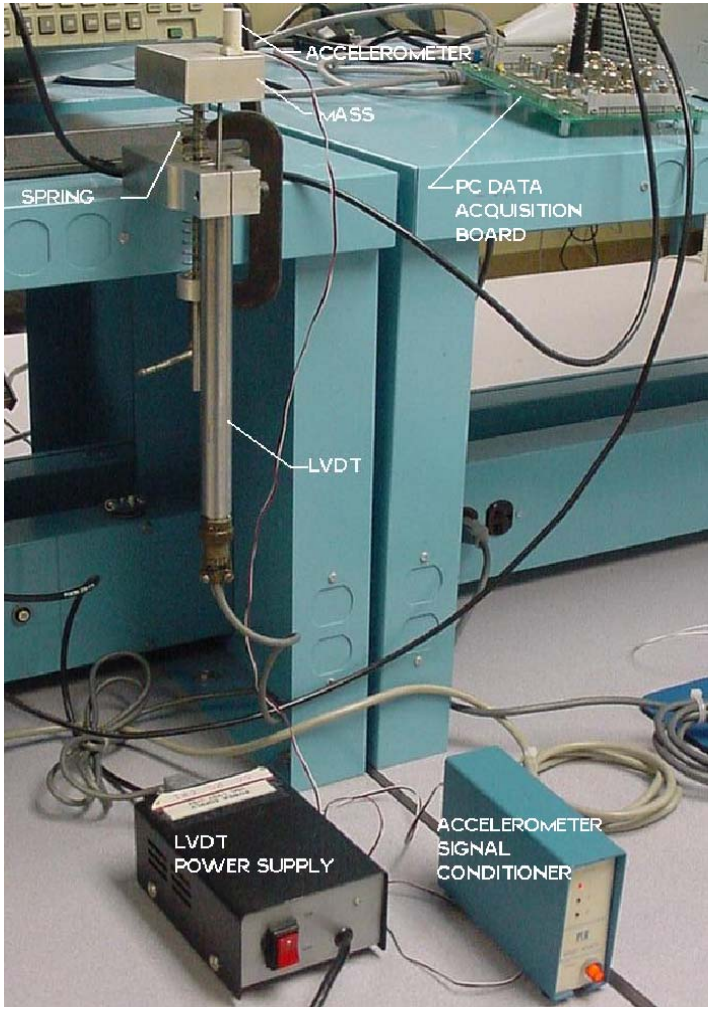
Numerical processing of integration/differential needed to process data

MCK Measurement System

Requires extensive use of a wide variety of different analytical tools.

Significant numerical data manipulation needed.

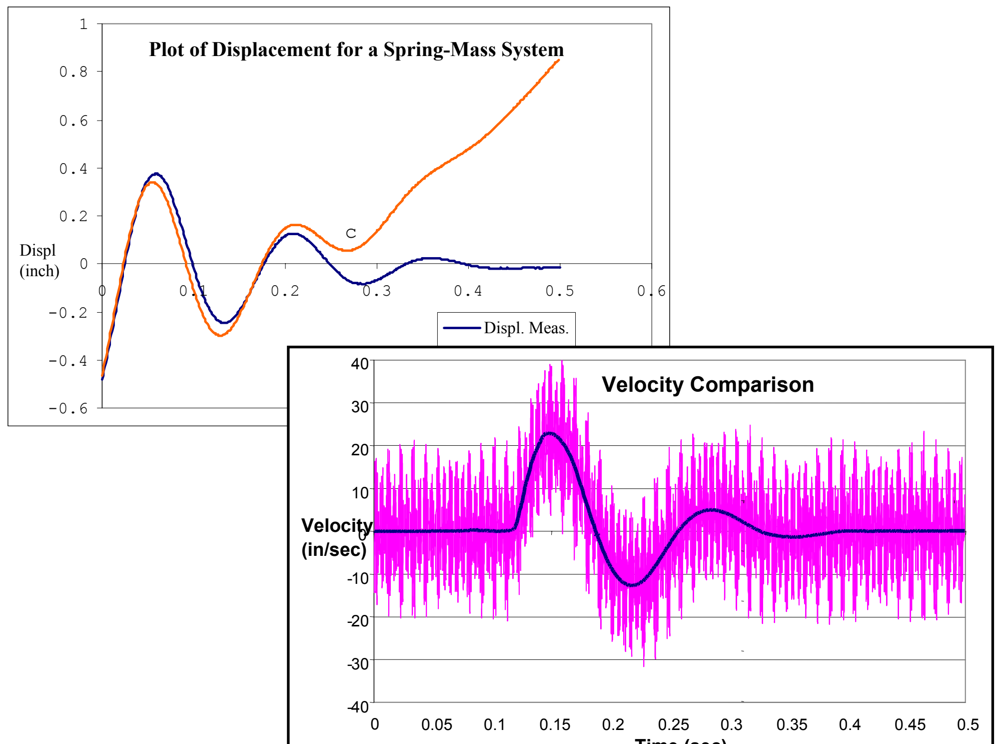
- Regression Analysis
- Data Cleansing
- Integration
- Differentiation



MCK Measurement System

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



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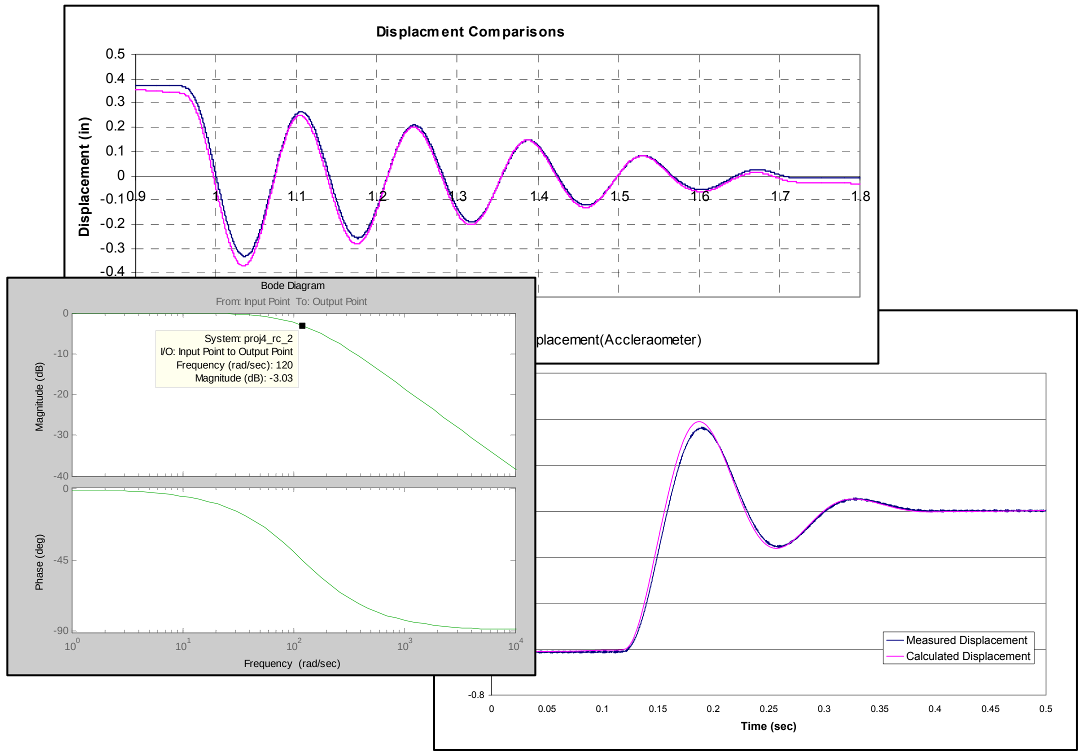
MCK Measurement System

The students are forced to integrate key STEM material and concepts to solve this problem

- Numerical processing
- Filtering
- Thinking is required !!!



Virtual Measurement vs RUBE

The paper is broken down into two basic parts.

The Virtual Measurement System which "prepares" the student with a simulation system where all the "contaminants" can be added to the system in a very controlled fashion to see the effects.

vs.

The RUBE (Response Under Basic Excitation) where the actual measurements (whatever they may be) are acquired via an online measurement system

The Virtual Measurement System

The Virtual Measurement System

The real test configuration has many problems that all simultaneously plague the measurement.

Many times students are frustrated with the significant open-ended aspects of this exercise.

This is due to the large number of items that simultaneously plague the measurement.

The Virtual Measurement System

In order to assist the student in understanding all of the individual effects, a virtual measurement system was developed.

This enables the student to add individual effects and see the result on the measurement made.

The pieces of the Virtual Measurement System are described in the following sections.

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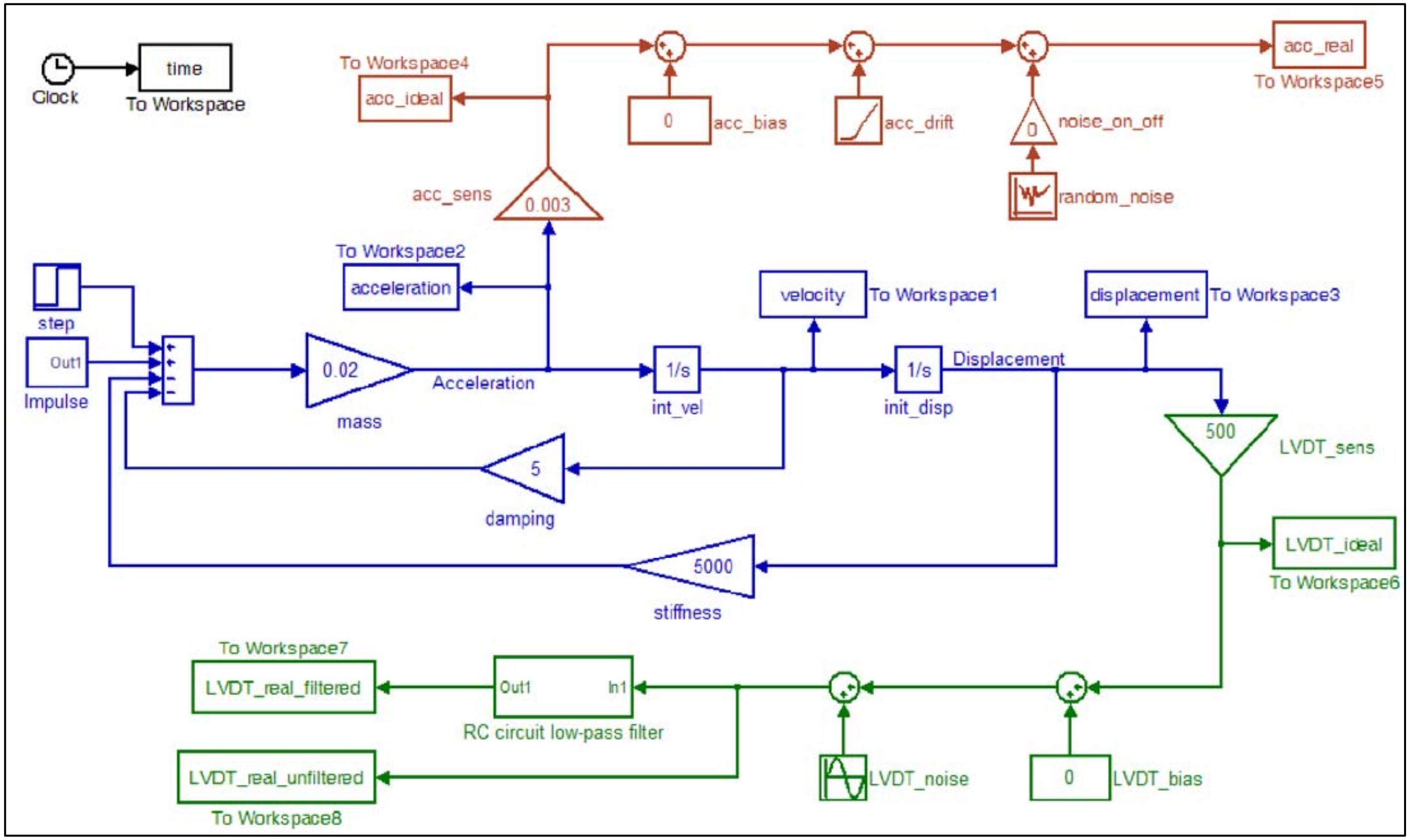
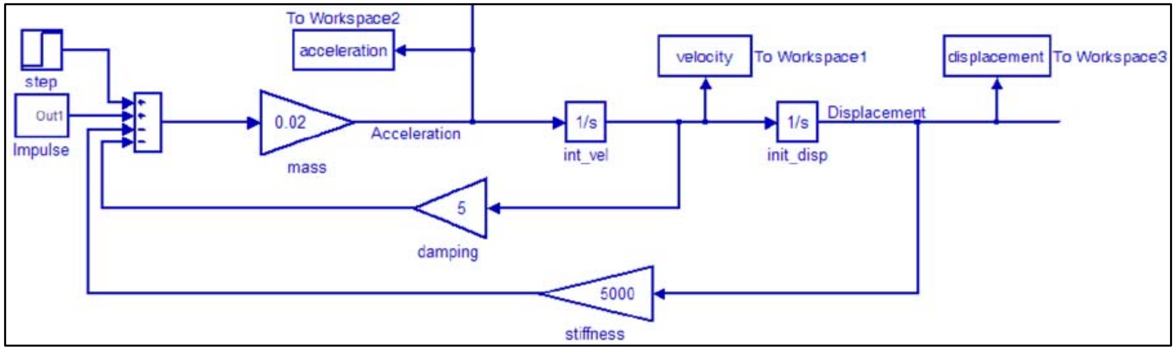
The entire Simulink model

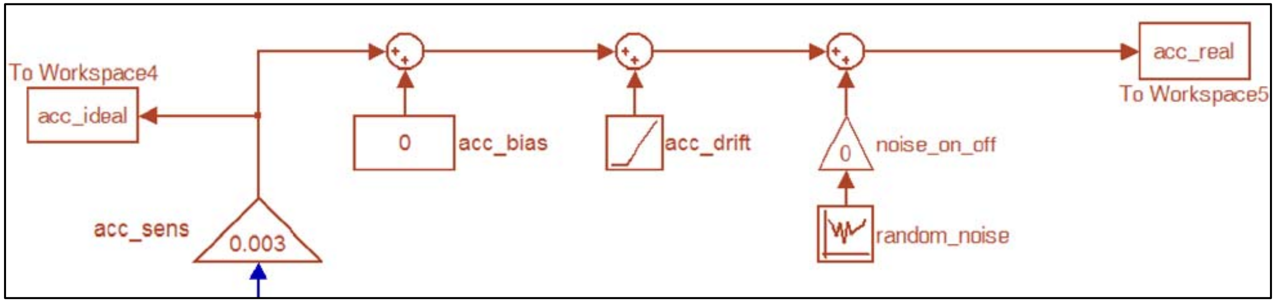


The SDOF system portion

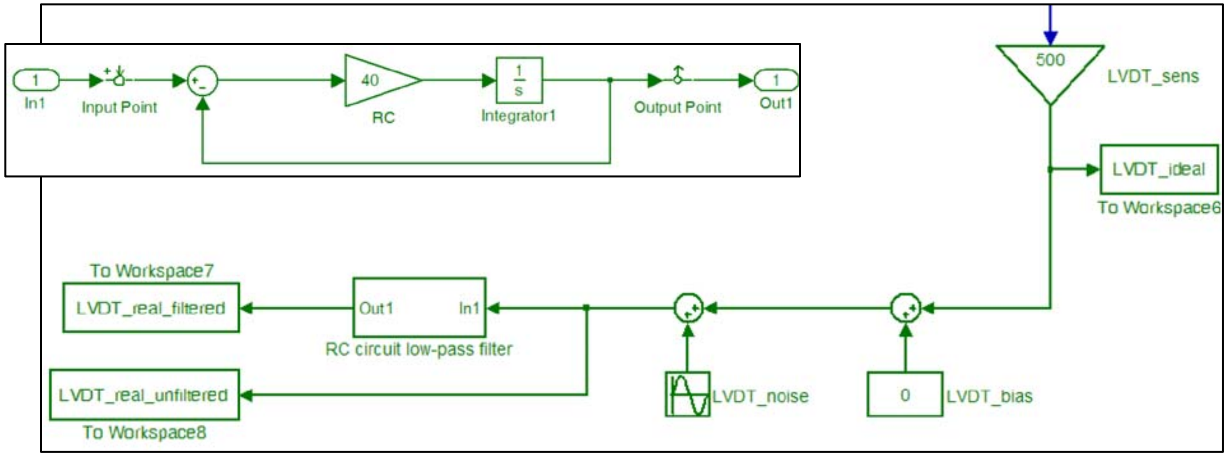


The Virtual Measurement System

The accelerometer measurement portion



The LVDT & RC filter measurement portion



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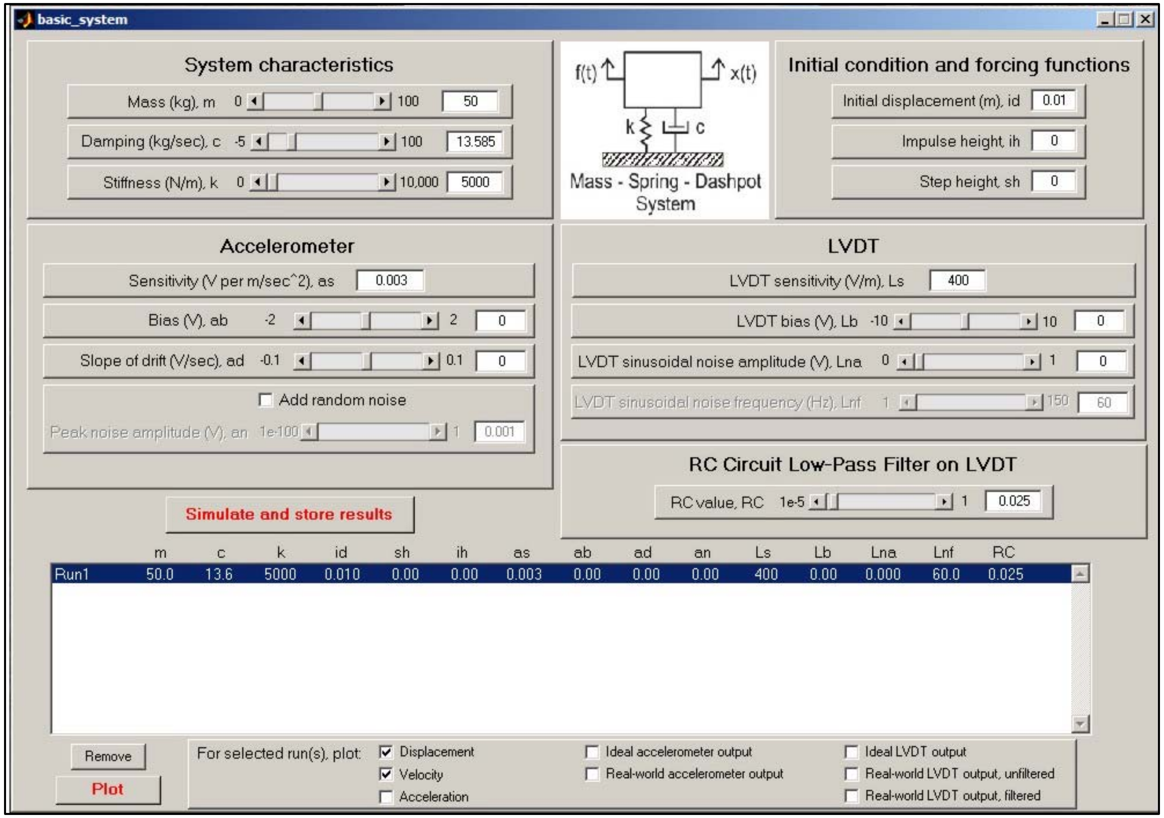
The Virtual Measurement System

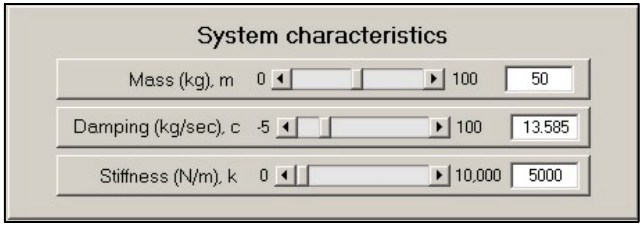
The entire GUI Interface



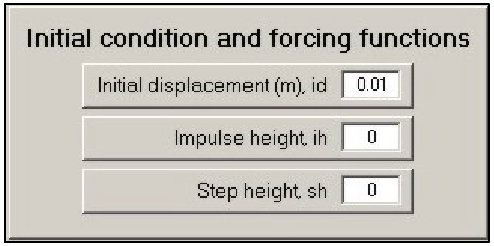
The Virtual Measurement System

The system characteristic definition of

mass,
damping and
stiffness



along with IC
and forcing function



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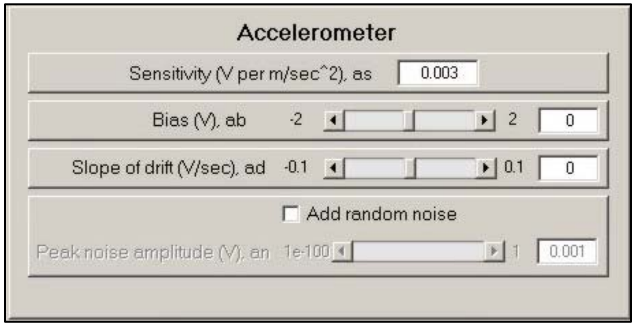
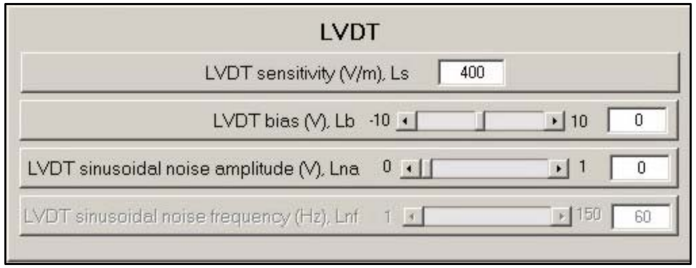
The Virtual Measurement System

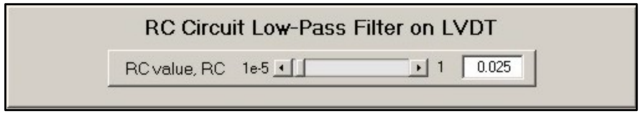
The accelerometer parameters can be entered



along with the LVDT



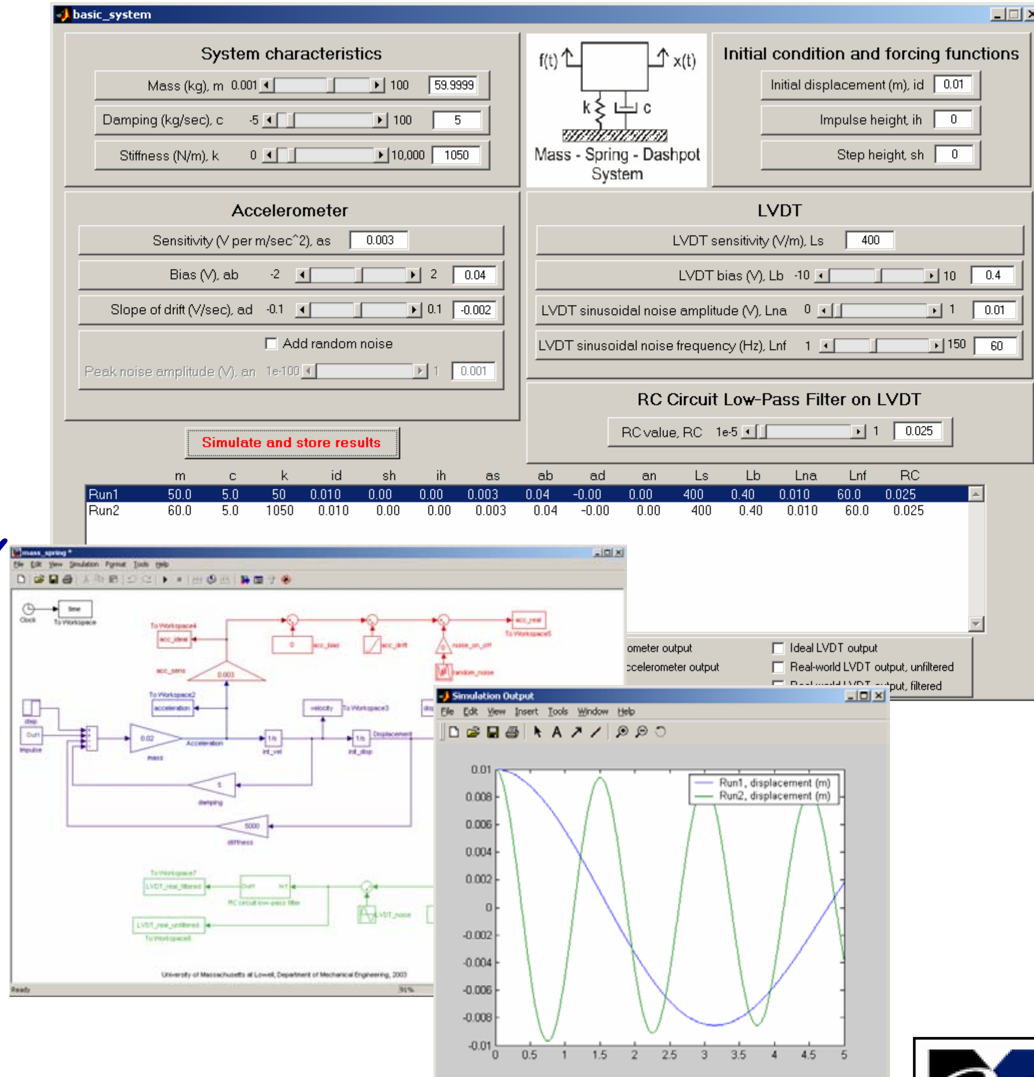
and RC filter setting



Virtual Measurement System GUI

User enters M, C, K system. User enters the amount of experimental distortion on the accel. (sensitivity, bias, drift) and displacement LVDT (sensitivity, bias, noise) and the low pass filter characteristics to virtually "simulate" the measurement environment.

Data can be exported with ability to select which outputs and what effects are included on the measurement.



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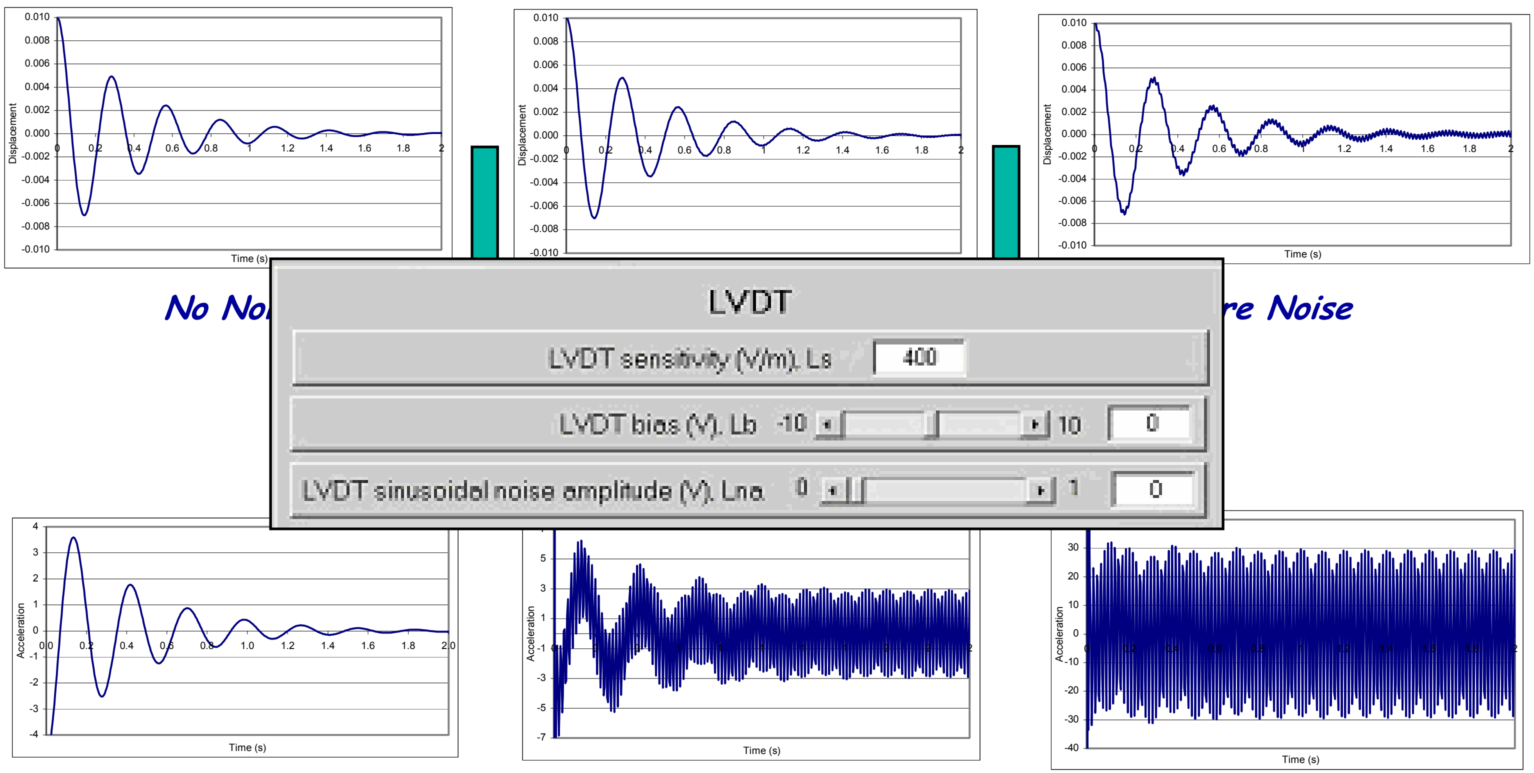
Virtual Measurement Simulation

The student can quickly study the measurement issues associated with drift, bias and offset.

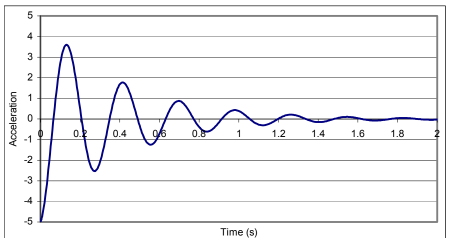
These effects are significant when numerically processing the data to perform differentiation and integration.

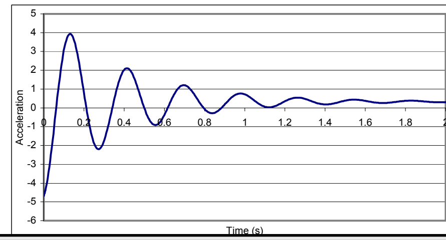
Several cases are shown to illustrate the usefulness of the Virtual Measurement System.

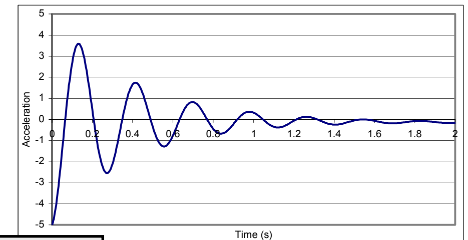
Differentiation of LVDT measurement and noise



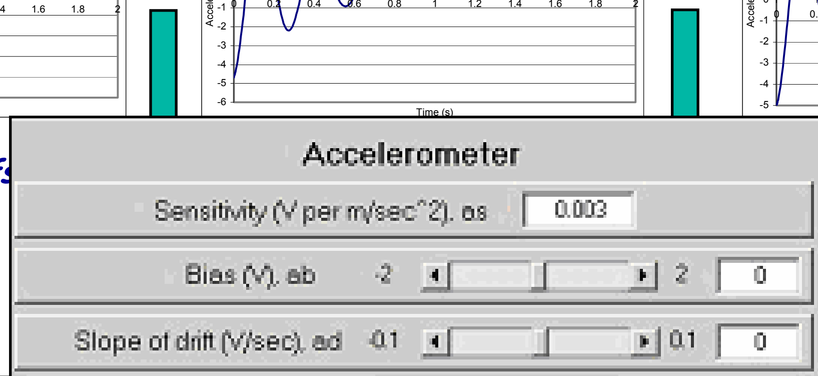
Integration of the accelerometer measurement



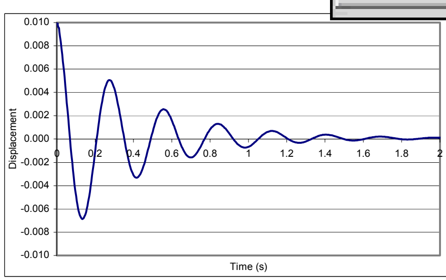


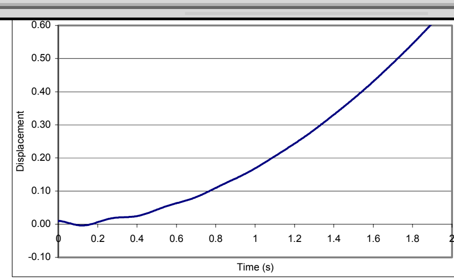


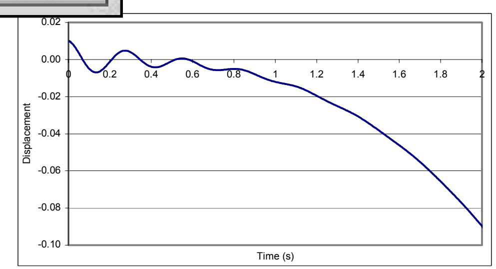
No Drift or Offs



Negative Drift







RUBE

Response Under Basic Excitation

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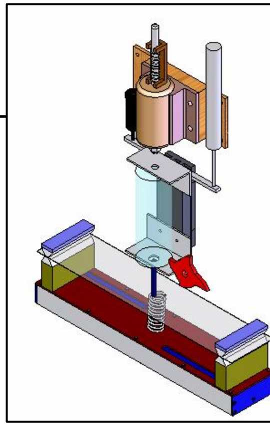
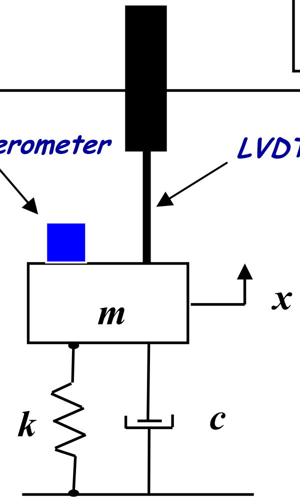
Online Measurement System

RUBE

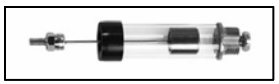
Response Under Basic Excitation





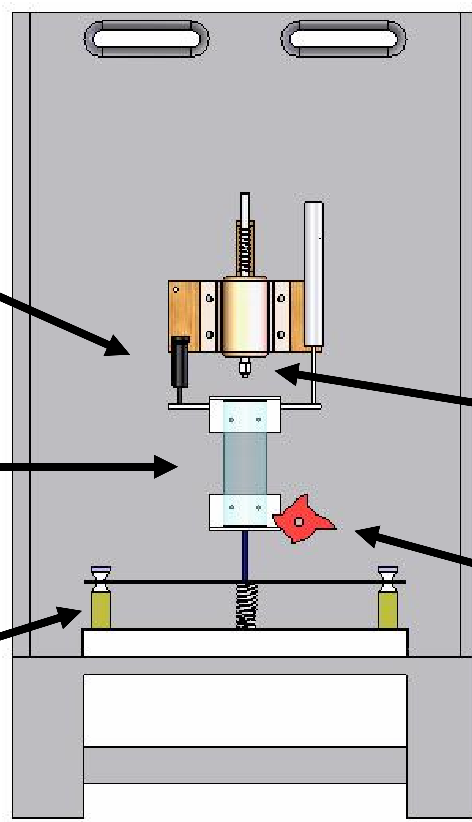
Measurement Devices

Variable Damping

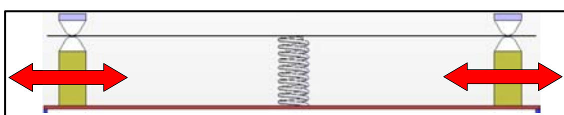


Variable Mass

System Characteristics

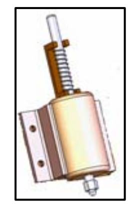


Variable Stiffness

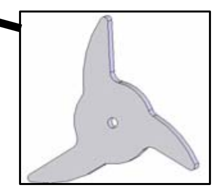


$$k_{EQ} = k_{LEAF} + k_{COIL}$$

Excitation



Impact Force



Initial Displacement

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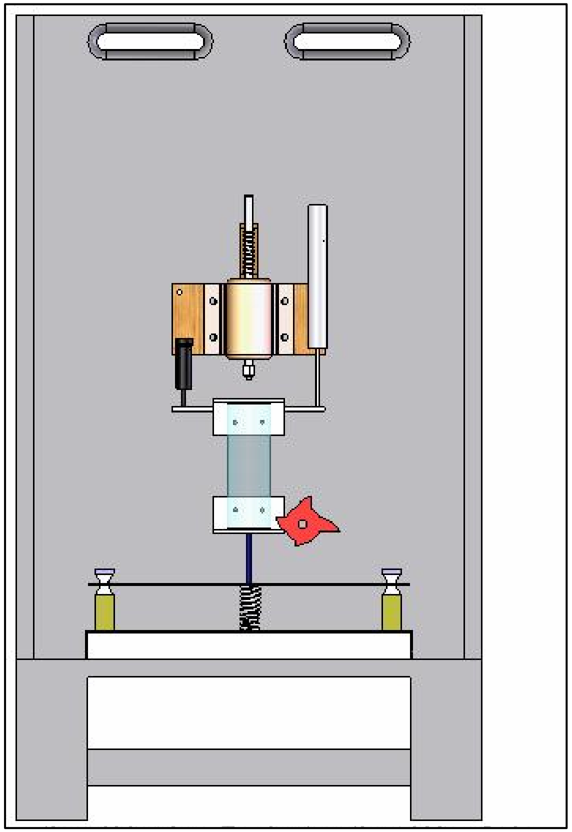
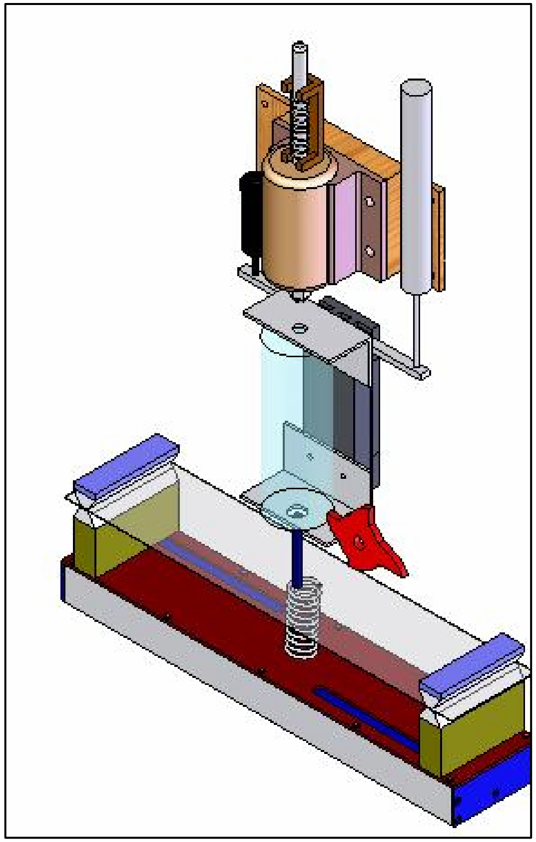
RUBE

Response Under Basic Excitation





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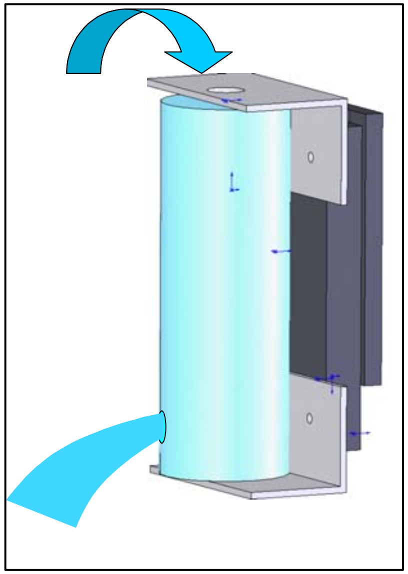
RUBE

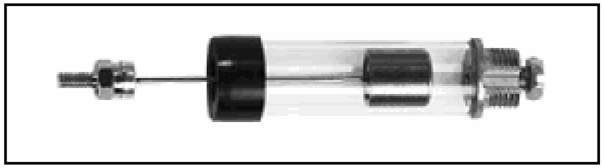
The variable mass is achieved by using a water reservoir to provide a constantly changing mass of the system.

This variable mass allows the total mass of the system to vary by approximately 15%.

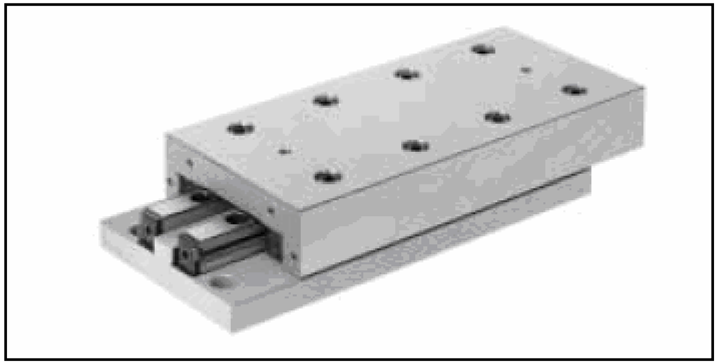


RUBE

The damping results from an adjustable airpot damper



There is also damping effect from the bearing support system

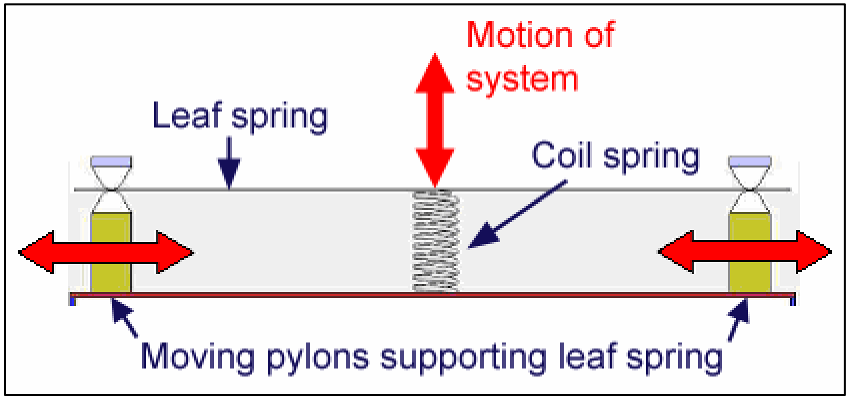


RUBE

A variable spring is achieved with a variable length leaf spring supported with a coil spring.

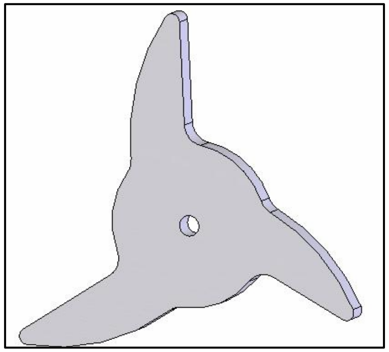
The variable spring stiffness allows the total spring stiffness to vary by approximately 20%.

Leaf spring length is adjusted by a rack and pinion

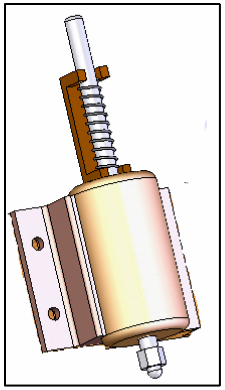


RUBE

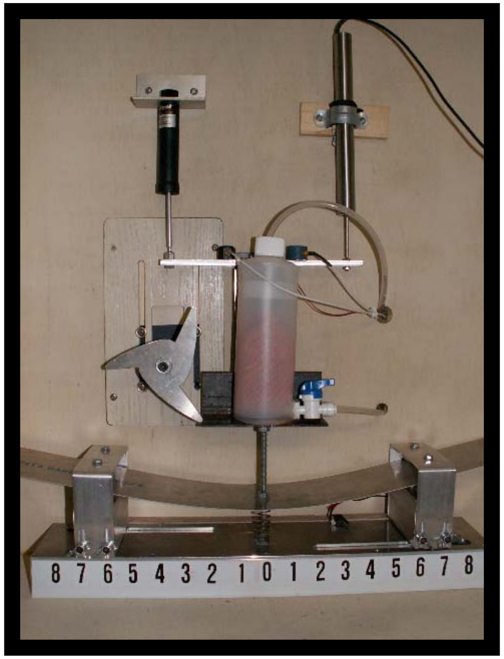
Initial displacement is provided with a three probed cam with different lengths



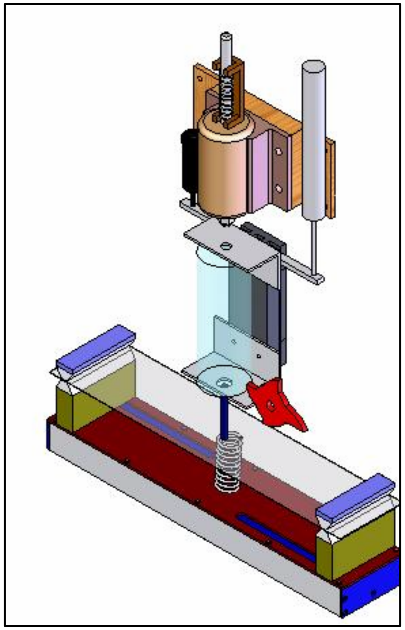
Impact excitation is provided with a solenoid



Online Measurement System



RUBE I



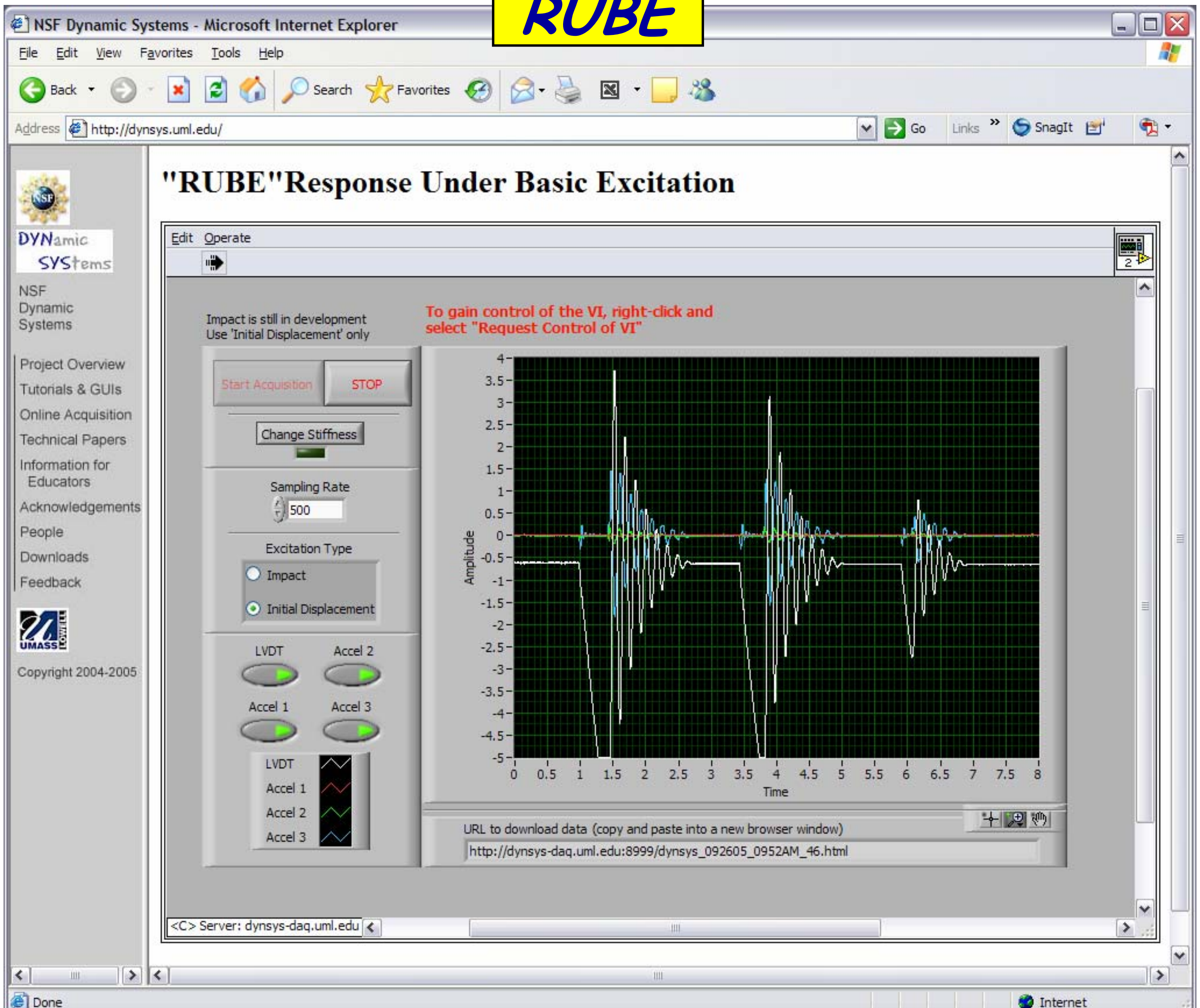
RUBE

Response Under Basic Excitation

RUBE II

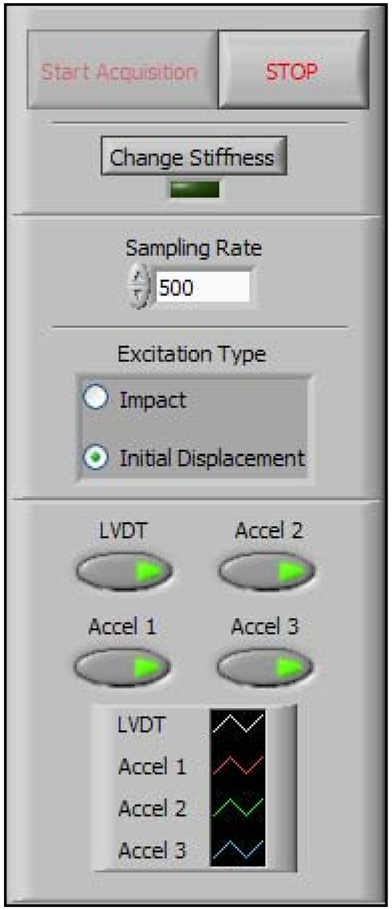
Online Measurement System

RUBE



Online Measurement System

RUBE



System can be remotely run

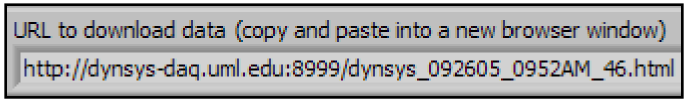
Stiffness is changed for each run

Sampling rate can be set

Impact is available
Initial displacements – three inputs

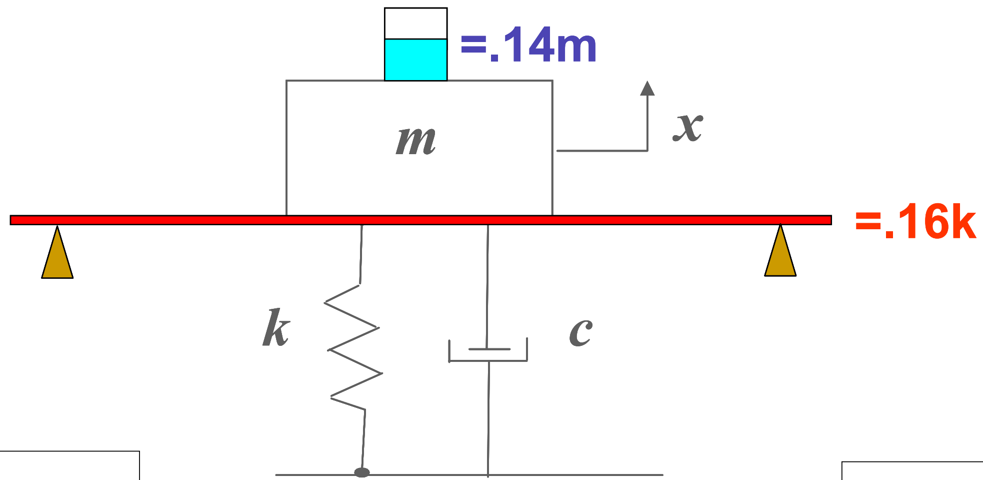
LVDT and accelerometers can be turned on and off as desired

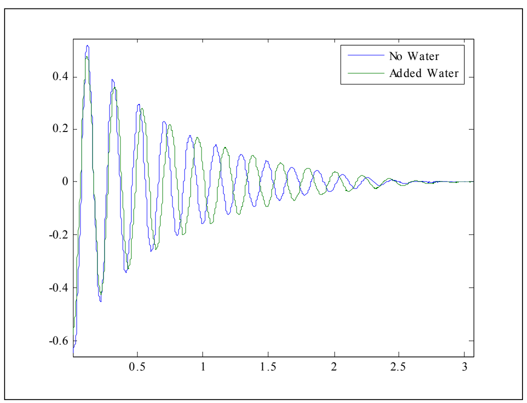
Data saved and captured to browser

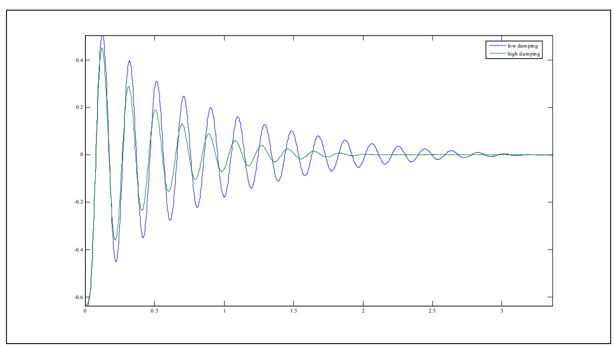


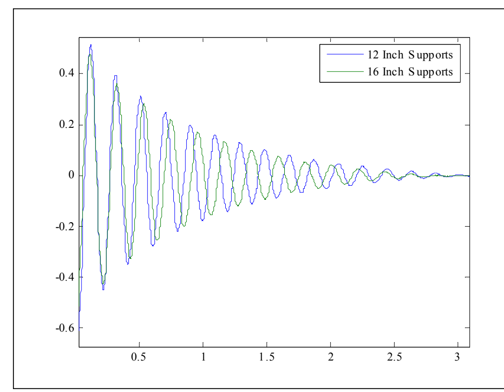
Online Measurement System Variation

$$4.5Hz < f_n < 5.7Hz$$









Online Measurement System Output

```
LabVIEW Measurement
Writer_Version   0.92
Reader_Version   1
SeparatorTab
Multi_Headings   Yes
X_ColumnsOne
Time_PrefAbsolute
Operator Administrator
Date      2005/07/27
Time      14:56:34.531125
***End_of_Header***

Channels 4
Samples  4000     4000     4000     4000
Date      2005/07/27      2005/07/27      2005/07/27
Time      14:56:42.52899914:56:42.52899914:56:42.5
Y_Unit_Label     Volts    Volts    Volts    Volts
X_Dimension      Time     Time     Time     Time
X0        0.0000000000000000E+0  0.000000000000000
  0.0000000000000000E+0
Delta_X   0.002000        0.002000        0.002000
***End_of_Header***
X_Value  LVDT     Accel  1 Accel  2 Accel  3 Comment
0.000000 -1.672363       0.002441        0.000000        0.0
0.002000 -1.667480       0.002441        0.000000        0.0
0.004000 -1.672363       0.002441        0.000000        0.002441
0.006000 -1.669922       0.000000        0.000000        0.002441

                                   •
                                   •
                                   •

7.980000 -5.000000       0.000000        0.034180        0.168457
7.982000 -5.000000       -0.002441       0.039062        0.178223
7.984000 -5.000000       -0.004883       0.070801        0.185547
7.986000 -5.000000       -0.007324       0.095215        0.195312
7.988000 -5.000000       -0.004883       0.095215        0.209961
7.990000 -5.000000       -0.012207       0.087891        0.236816
7.992000 -5.000000       -0.007324       0.041504        0.275879
7.994000 -5.000000       -0.007324       0.024414        0.334473
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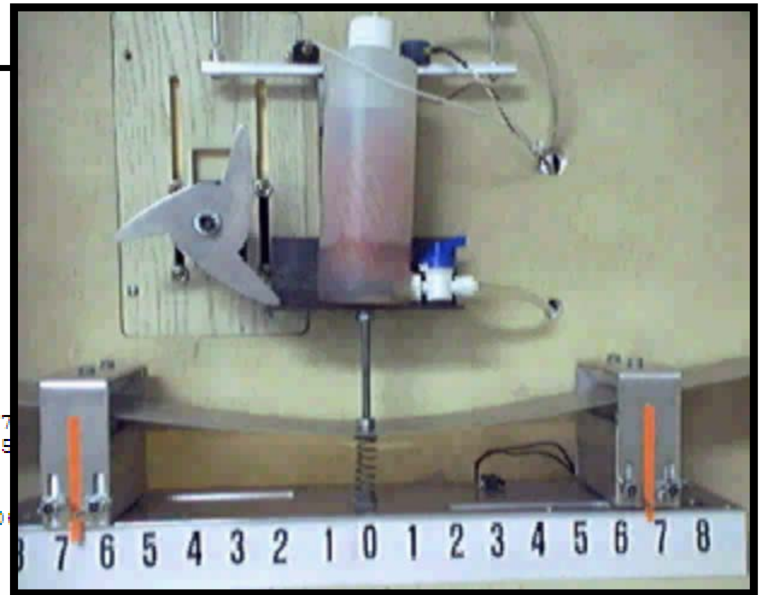
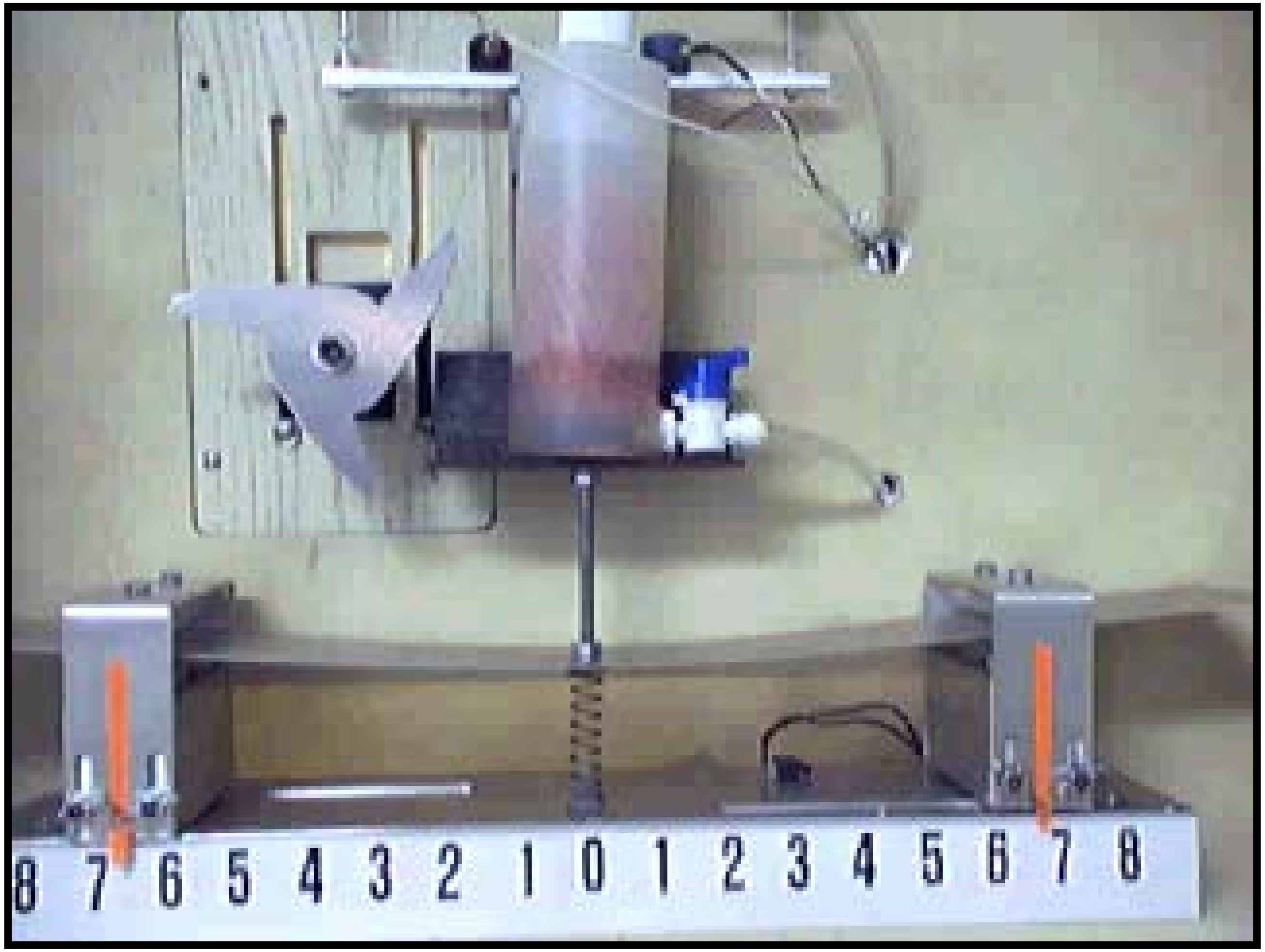


dynsys_072705_0301PM_49.avi

Online Measurement System Output



Webpage --- dynsys.uml.edu

Project Overview

Technical Papers

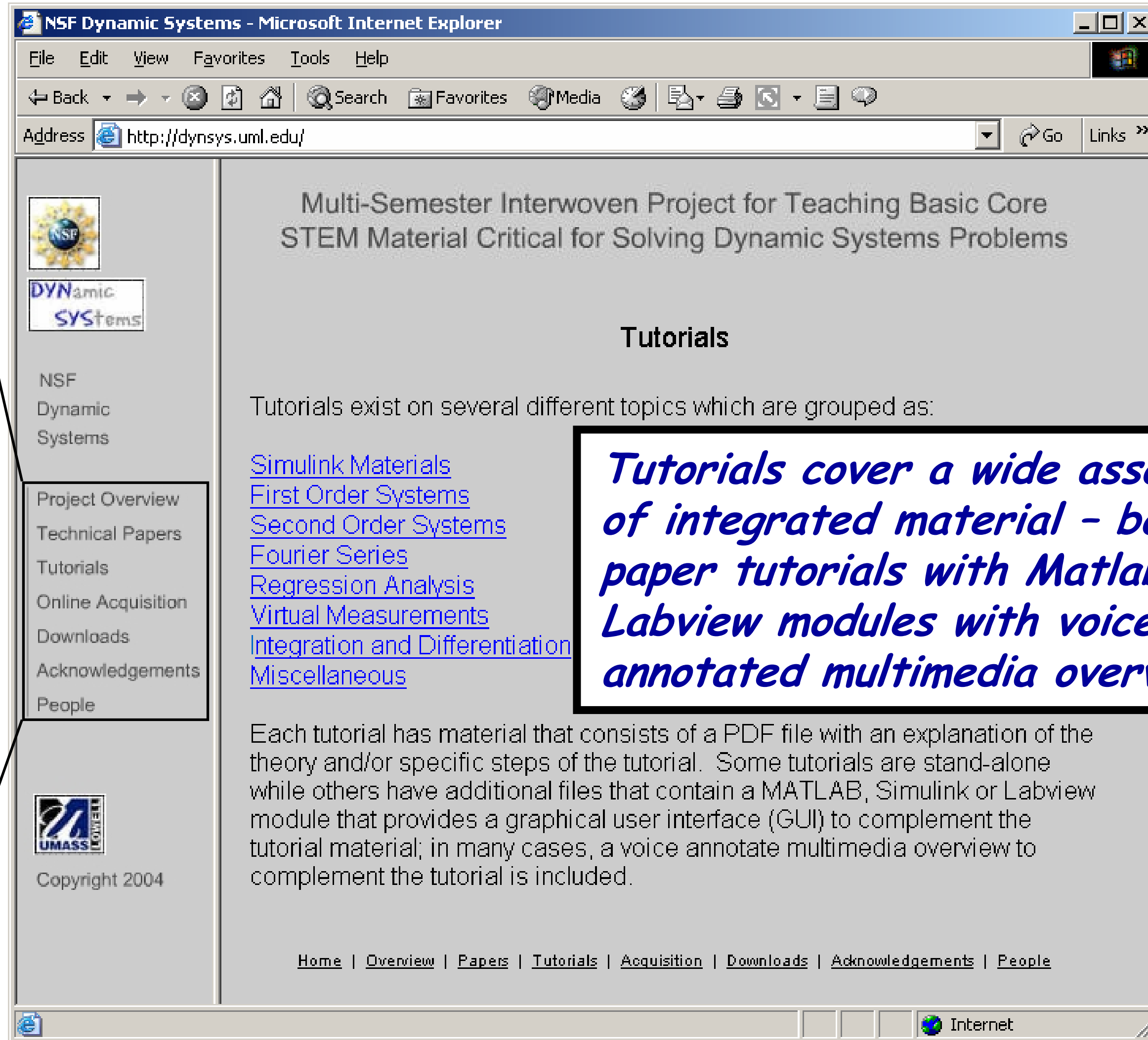
Tutorials

Online Acquisition

Downloads

Acknowledgements

People



Tutorials cover a wide assortment of integrated material – both paper tutorials with Matlab and Labview modules with voice annotated multimedia overviews

Student Reactions & Comments

Student A

- Useful to be forced to use earlier material
- Laboratory helped show these problems not easy
- Assumptions may not be correct
- Homework is easy; reality is not as easy at all

Student Reactions & Comments

Student B

- I learn better when I do it (not being instructed)

- Project forced me to understand the material (not just complete an assignment)

- Relevant hands-on experience is much more effective than theory by itself

Student C

- Approach to material is unlike any previous class

- Theory and class materials are driven home during project preparation

- Forced me to think “outside the box”

Student Reactions & Comments

Student D

- ***Admittedly, this course required more work and time than many other courses taken before***
- ***Hands-on approach and struggling through the projects is exactly the process by which the information was absorbed***
  – by not only learning, but really understanding

Student Reactions & Comments

Student D (cont.)

- *Very few engineering courses are successful at integrating information from previous semesters into a logical path to a problem solution*

--This one did a great job at that--

Student Reactions & Comments

Student E

- Important concepts from earlier courses usually don’t click” in the same semester as the course
- Usually the concepts “click” later always leaving me feeling a semester behind
- The Dynamic Systems course was different

Dr. Peter Avitabile, Associate Professor
Mechanical Engineering Department

Student Reactions & Comments

Student F

- Projects reinforced the material ... and forced us to think beyond the stated objectives
- The projects did not have simple solutions

Dr. Peter Avitabile, Associate Professor
Mechanical Engineering Department

Student G

- Involved interpretation of data, application of concepts discussed in lecture, and understanding of the physical system in the lab

- ...struggled through each project but had a much firmer understanding of the overall system

Summary

DYNamic SYStems

Student comprehension of basic STEM material for dynamic systems applications needs to be reinforced through active experiences

Response Under Basic Excitation (RUBE) is a second order mechanical system which is available as an online experiment

Virtual Measurement System (VMS) is a preview of most of the inherent problems associated with real-world data taken with RUBE (prepares the student)

Summary

Overall the students have clearly indicated that the problem presented has helped them to better understand the basic material needed to solve the problems encountered in the measurement system

The measurement system has definitely helped the students to comprehend solutions to problems where clearly defined parameters are not available (as is the case in most real-world situations)

Acknowledgements

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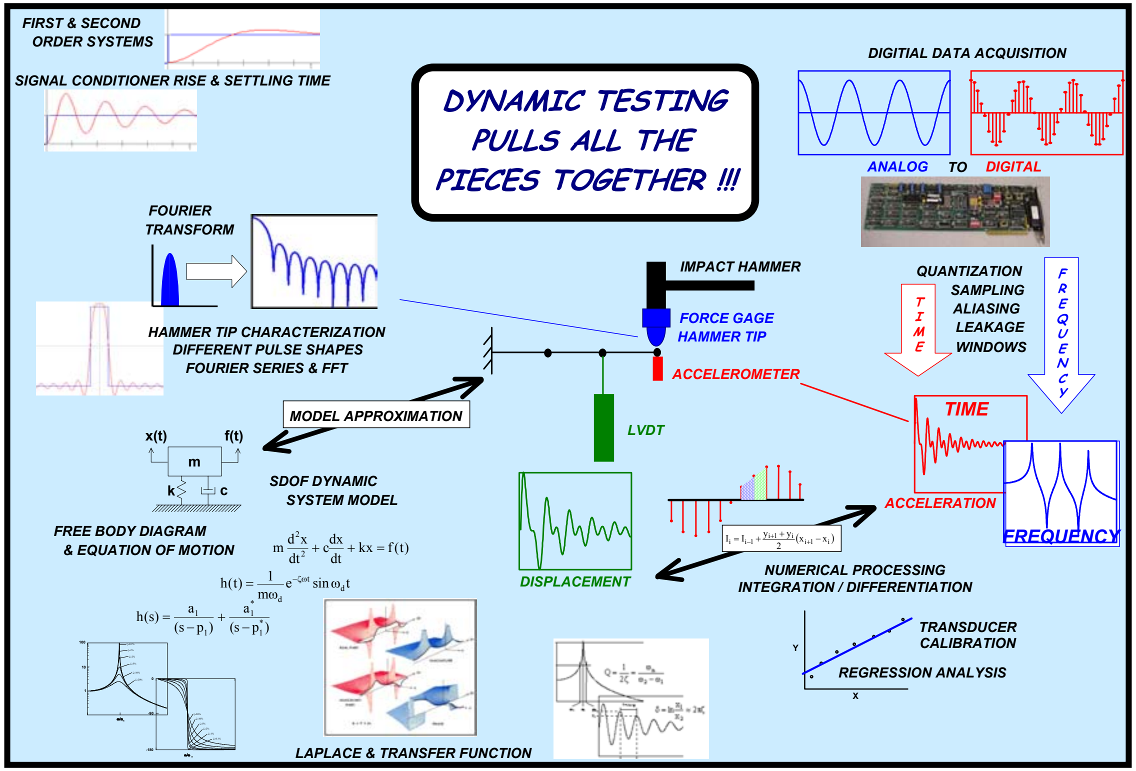
NSF Engineering Education Division Grant EEC-0314875

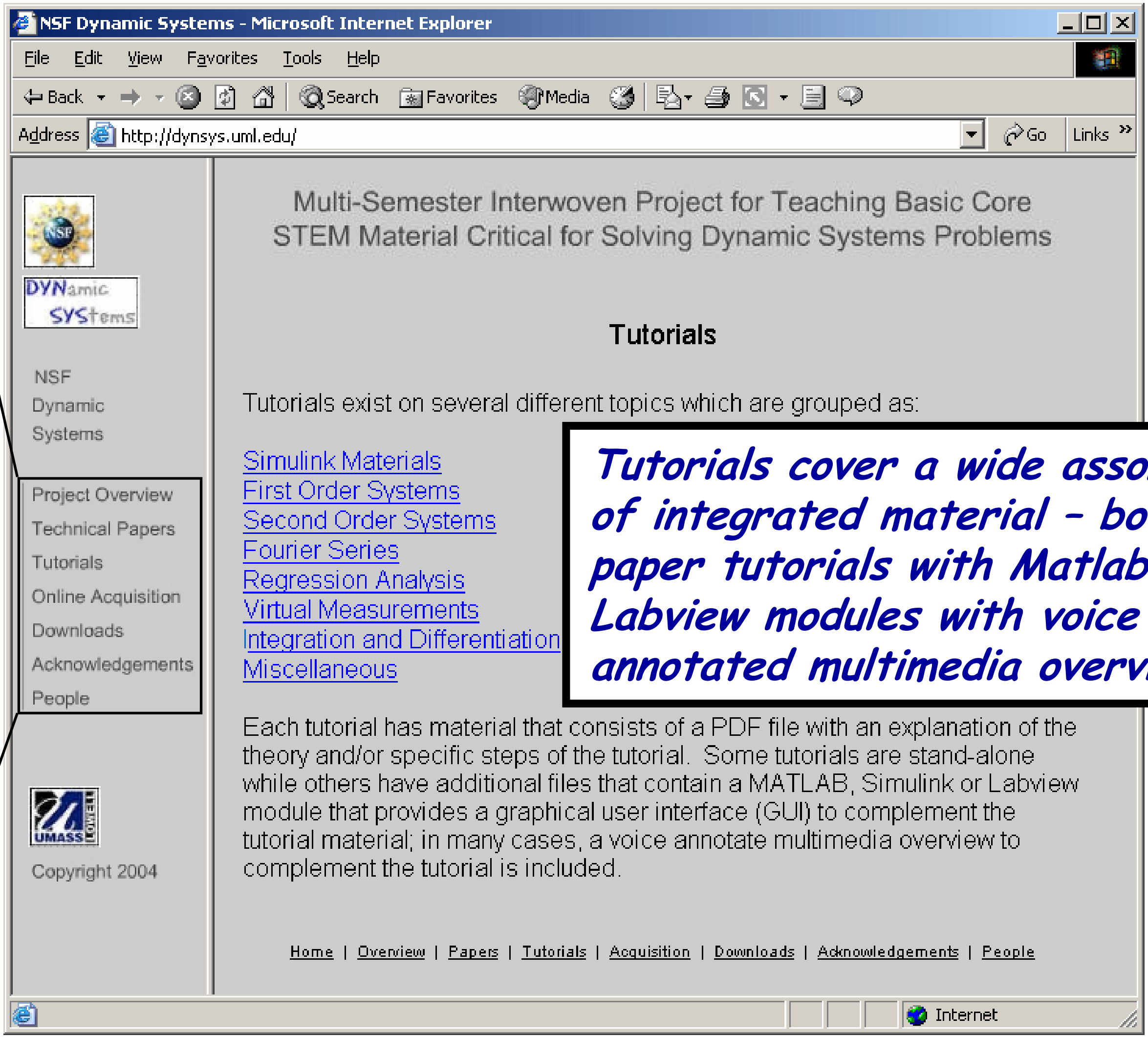
Multi-Semester Interwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems



Peter Avitabile, Tracy Van Zandt, Jeff Hodgkins, Nels Wirkkala

Webpage --- dynsys.uml.edu

DYNamic SYStems



Project Overview
Technical Papers
Tutorials
Online Acquisition
Downloads
Acknowledgements
People

Tutorials cover a wide assortment of integrated material – both paper tutorials with Matlab and Labview modules with voice annotated multimedia overviews

Acknowledgements

A special thanks to the students who have really been the driving force in making all this happen

Tracy Van Zandt, Nels Wirkkala,
Wes Goodman and Jeffrey Hodgkins
Mechanical Engineering Department
University of Massachusetts Lowell

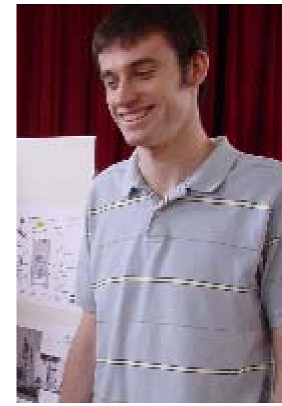
I could not have done any of this without their dedication and devotion to making this all happen

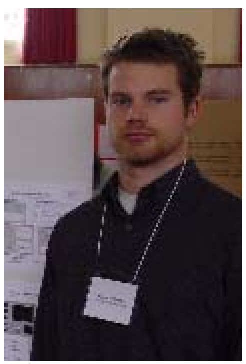
I have the pleasure of working with them and having them contribute to this effort

Acknowledgements

And to the undergraduate students who have also participated

Adam Butland, Dana Nicgorski,
Aaron Williams, Chris Chipman
Mechanical Engineering Department
University of Massachusetts Lowell

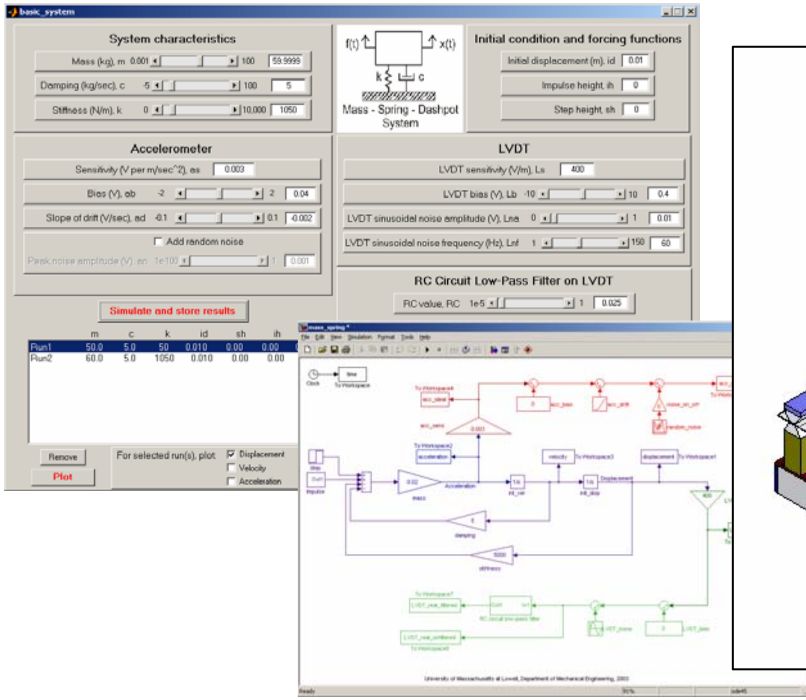


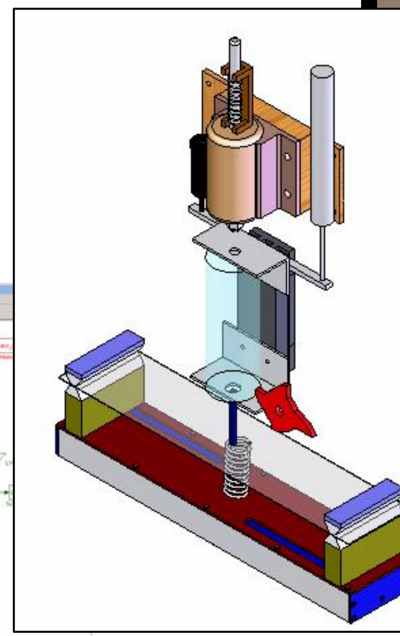


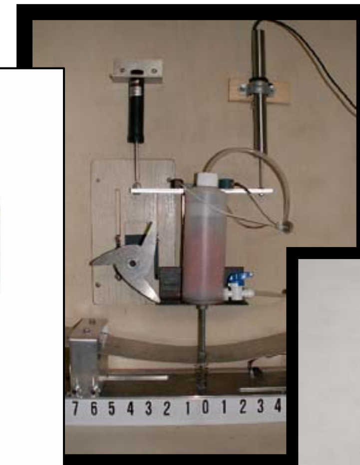
This past year they have also made significant contributions to the overall project

I am very happy for their continued support and dedication

Second Order Online Acquisition System - RUBE







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