

## Homework #2: Hands-on Lab Exercise I (Due 9/29)

### (Frequency Response Function, Phase Angle, Undamped Natural Frequency and Damping Factor)

#### Learning Objectives

- 1) Conduct a sweep sine test to obtain the FRF and phase angle plots of a structure
- 2) Determine undamped natural frequency, and damping factor from the bode plot (FRF+Phase Angle)

#### 1. Test Structure (One Story Shear Building Structure)

The test structure is made of two aluminum plates and two acrylic plates. On the top acrylic plate, two fixtures for sensors are attached. In this test, we are going to use an accelerometer installed underneath the top plate. The shape of the structure and its physical properties are given in Figure 1.

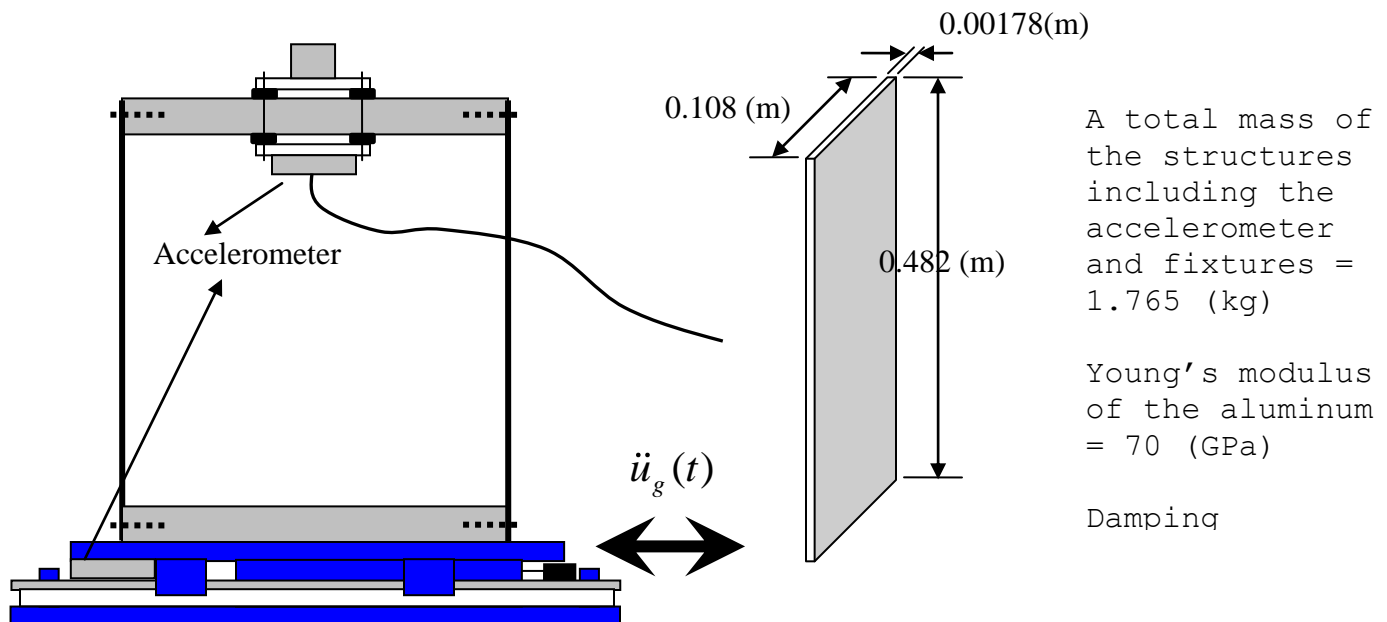


Figure 1 Test Structure Installed on the Shake Table and Its Physical Properties

#### 2. The Instructional Shake Table and Its Capabilities

The instructional shake table to be used in this hands-on lab exercise has been recognized as a versatile tool for learning basics of structural dynamics and earthquake engineering. The University Consortium on Instructional Shake Table (USCIST: <http://mase.wustl.edu/wusceel/ucist/default.htm>) had led the development

of various hands-on experiments and teaching modules for both undergraduate and graduate level courses.

The shake table can be run by real-time control software RTX/WinCon which is compiled and linked by MATLAB real-time workshop, MS Visual Studio NET and Simulink libraries. The system hardware consists of a shake table, a desktop PC with a data acquisition board, a Q8 terminal board, a universal power module, accelerometers attached to the test structure as shown in Figure 2.

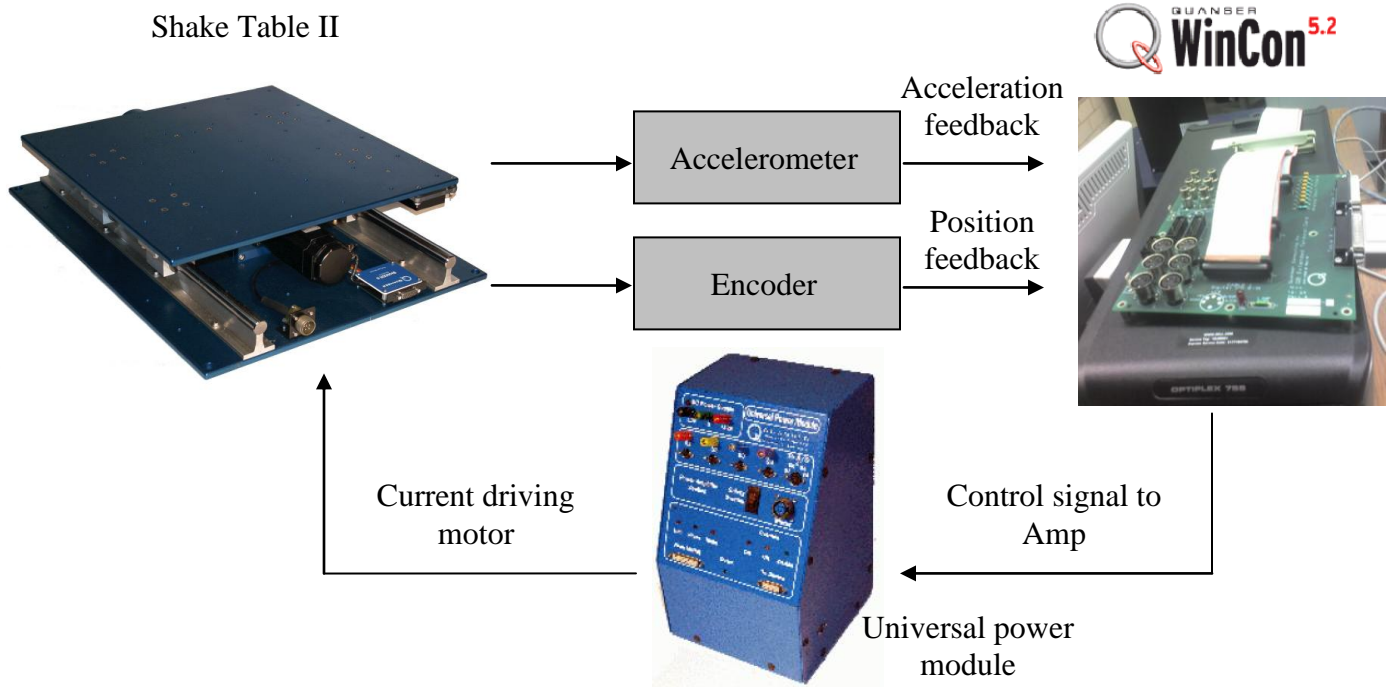


Figure 2 Overview of Major System Components

Table 1 Shake Table Specification

Parameter descriptions	SI Value	Units	US customary Value	Units
Preload mass	7.74	kg	17.1	Lb
Max. total load mass	15.0	kg	33.0	lb
Mass of Shake Table	27.2	kg	60.0	lb
Dimension of top	0.46 x 0.46	m <sup>2</sup>	18.0 x 18.0	in <sup>2</sup>
Dimension of bottom	0.61 x 0.46	m <sup>2</sup>	24.0 x 18.0	in <sup>2</sup>
Max stroke position	76.2	mm	3.0	in
Max linear velocity of stage	664.9	mm/sec	26.18	in/sec
Max linear force of stage	708.7	N	159.3	lb
Max linear acceleration of stage for 0 kg load	24.5	m/sec <sup>2</sup>		

### 3. Experimental Testing Procedures

For the sake of safety, the experiment must be conducted only with the attendance of the instructor and designated TA. The test structure has been already installed on the shake table.

#### 3.1 Sweep Sine Test

Test will be conducted with detail explanations during instructional time. Start and end frequencies are 1 Hz and 15 Hz, respectively.

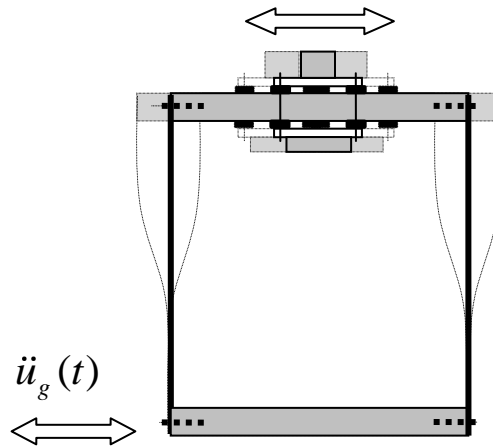


Figure 3 Sweep Sine Test (1 Hz ~ 15 Hz)

### 4 Problem Statements

#### 4.1 Damping Factor and Undamped Natural Frequency

After testing, the input and output signals will be provided.

Q1) Draw plots of FRF and Phase Angle using 'xfunc' matlab code.

Q2) Determine undamped natural frequency and damping factor using half-power method.

#### 4.2 Modeling of Structure

As shown in **Error! Reference source not found.**, model (idealize) the test structure using the given physical properties. Damping factor ( $\zeta$ ) should be determined first. Consider fixed and fixed boundary conditions at the top of each aluminum plate. The lumped mass should be reasonably determined. Reasonably assume the mass as a portion of the total mass (1.765 kg) of the entire structure.

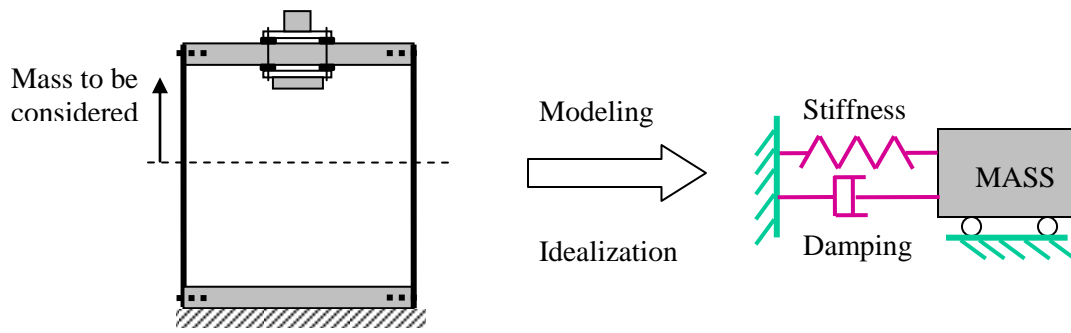


Figure 4 Modeling of the Test Structure

- Q3) Calculate stiffness using the given values.  
Q4) Derive analytical FRF and plot FRF comparing with the experimental FRF.